Switching the human-power back on:

Domesticating human-power to practice energy saving behaviour

By

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Abstract

This research took an exploration into particular products which use human-power as main power source. Against the problem of over consumption of energy, it views the ‘human-powered product’ (HPP) not merely as an object that simply generates ‘free energy’; but instead considers as an interactive artefact that people can make sense of, and as a tool to practice energy saving behaviour. Efforts to improve the knowledge on design aspect of HPP and its statistical benefit have been proved, but largely by scientifically driven approaches. No such theoretical framework has been discussed or explored in relation to how people use HPP in their daily practice. Therefore, current research undertook the work into substantive area of HPP study that is understanding the actual ‘use-phase’. It explored how design can help induce a better use of HPP, and how intended behaviour of generating human-power can be reproduced, maintained, and internalised.

An explorative investigation of actual HPP use was carried out through multiple-case studies, along with cross-disciplinary literature review which contributed in building an explanatory conceptual framework. The framework serves as guideline to explain, the abstract, prediction about phenomenon of HPP use; formulating questions to further study; and developing a ‘HPP Internalisation Model’ which hypothesised the suggestive design strategy for prolonging the HPP use. The hypo-theoretical state of ‘HPP Internalisation Model’ was empirically iterated and final recommendations was integrated into a research artefact. Through final case study, this artefact was utilised to produce knowledge and understanding for constructing a theory. The result of study described the relationship, process, and influences between phenomena that account the explanatory concept for each dimensions of ‘HPP Internalisation Model’.

As a final result, the model suggests a three dimensional (Empowerment, Feedback, and Motivation), and interdependent to each other, constituent elements in HPP design for bringing internalisation of human-power use. This research has therefore contributed to current knowledge by bringing the social-psychological theories and strategies of ‘design for sustainable behaviour’ together to develop the theoretical model of ‘HPP Internalisation Model’.

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Publications

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Glossary

DFSB	Design for Sustainable Behaviour
EuP	Energy Using Products
HCI	Human Computer Interaction
HPP	Human-Powered Products
HUS	Home User Study
ICT	Information and Comunication Technology
IHD	In Home Display
REFS	Residential Energy Feedback System
WB	The ‘White Box’

Section 1: Background

Chapter 1 Introduction

1.1 Research Problem

Today, we live in a society where we interact with growing numbers of products that consume electricity. It is suspected that increasing ownership of electronics and inconspicuous habits of using these daily products contribute towards prolific energy consumption. To counteract an over-consumption of energy debate, most electronics have been evolving and developed over time to consume less electricity. Nevertheless, average total electricity consumption in the domestic sectors has remained static, or increased over past years, caused predominantly by the increase in the number of EuP (Energy Using Products) such as accessible electronic appliances and portable devices. In response, governments, agencies, and many other stakeholders are endeavouring to search for alternative energy supplies such as solar power or natural gas. According to Department of Energy and Climate Change (DECC, 2011b), the statistics show that total electricity supply has been incremental over past decades, including renewable energy sources, although it shows a slight decrease in year 2005, but it remained static since. As a solution, future industries will inevitably focus on the development of energy efficient technologies, such as eco-products, and its implication into everyday electrical products.

Since electricity is an essential part of each industrialised society and economy, it is unrealistic to deny its use overnight. Today, electricity consumption has become the norm of accomplishing everyday tasks through use of daily electrical products; however, they are mostly invisible during use. Despite dramatic issues of resource depletion, these electronic era aggravated the increase of over-consumption in the electrical (consumer electronics) energy sector (Owen, 2012). Increased dependency on a power supply for using consumer electronic devices, industrial production, and evolving living styles, places today’s society into more vulnerable situation, when faced against its interruptions such as ‘power blackouts’. Looking at recent blackout crises in the US which caused massive losses[1], it is recognised that increasing electrical power supply may not be the only option. Whilst creating energy-efficient technologies is the first necessary and important step towards sustainable energy consumption and to prevent such crisis, it is only a partial solution.

Many emphasis on the notion that perhaps future approaches should also take account of an understanding why and how people consume energy (electricity). An alternative approach has been suggested such as increasing the energy supply and the energy efficiency of EuP. However, it is evident that over-consumption of energy issue may not only be solved through an adoption of these products and technologies. However, this should not lead to a conclusion that those technological interventions are ineffective – it can and does achieve some impact towards energy reduction. On the other hand, a new approach may achieve stronger effects and benefits, where behavioural change can also have an impact. The question of how to make people more conscious and aware about their energy consumption is perhaps now more relevant than it has ever been, making ‘electricity’ visible and even tangible. It is hardly necessary to point out the dramatic changes in society that have resulted from the innovation of today’s everyday things. Of course, this is not to argue that designers hold entire responsibility, but rather it is more affected by governmental policies. However, Shove *et al*. (2007, p. 134) argues that ‘designers have an indirect but potentially decisive hand in the constitution of what people do’. The question still remains how ‘design’ can inform and influence new practices, which drive people into direction of sustainable energy consumption.

1.1.1 Observed problem

It was 2003, when the author first read the article about Trevor Baylis’ Free-play radio in the Design magazine. Ever since then, the author was fascinated by the work of sustainable design particularly in relation to designed objects that either stimulate or shift behaviour to bring energy reduction in everyday practice. This investigation evoked from a personal interest in observing electronic products and

1 The total impact on US workers, consumers, and taxpayers will be a loss of approximately $6.4 billion, due directly to the effects of the electric power blackout that hit the Northeast United States and portions of Canada on the afternoon of August 14, 2002 (Anderson and Geckil, 2003).

their relation to over-consumption of energy. However, it raises many questions; looking around daily routine of using these products, particularly in an environment filled with electronic devices.

(a) (b)

Figure 1.1 Drinking water fountain in S. Korea with auto sensor for dispensing (a), Tourist information map dispenser in Netherland (b)

The two images (Figure 1.1) were taken during my travels of South Korea and the Netherlands. This was soon after South Korea had experienced the nation's worst power outage in year 2011. Government officials had announced and blamed the miscalculation of power supply/demand including the backup energy and a lack of interagency communication for the cause of blackouts. Also, many claimed that it was due to unpredicted hot weather. However, walking around the subway and along the streets in Korea, it left the author with no doubt of suspecting that the cause was purely from 'using too much' rather than any miscalculation or unpredicted weather. Every 5 meters on a subway platform had flat TV screens showing marketing materials; a vast majority of people carrying smart phones; automated ticket widgets; air conditioning; automated sensors installed on water fountains, and so on. The automated doors between the subway coaches were bittersweet to see. But travelling in the Netherlands, it was obvious there was a different side of story. People ride bicycles, hardly see any electrical marketing banners on the platform, and people were reading books instead. At some points, the author stumbled across the map dispenser in the small town called Delft, see (b) in Figure 1.1. It had a big lever on the side of the kiosk as if guiding the user to pull it for dispensing a map. The moment when the lever was pulled with a bit of muscle force and a sound of rattle, it was realised that this kiosk has no electrical mechanism at all. A Human-Powered Product. A holding a paper map and having such experience gave a refreshing jolt.

Why are we dependent on electricity if there are ways we can deliver the needs? The solution may not be prolonged by blaming those who miscalculated power supply needs, or making another energy efficient TV. Perhaps, as designers, increasing awareness of energy usage and seeking for solution to decrease the energy demand may suggest as a more intrinsic approach to the problem. So far, designers and other stakeholders have managed their work against convincing people to consume more commodities (e.g. EuP) that they have designed. However, designers may also have capability to convince people to consume less, e.g. through design artefacts, to turn their desires in other directions. Thus, against the over-consumption of energy issue, this thesis discusses an alternative option that is using human-power as everyday power source to drive EuP. It is anticipated that this thesis shed new lights on the notion of using this traditional power source which has been widely used and always have been available in mankind history.

1.1.2 Why human-powered products?

Humans began to gradually less use their own muscle power since the invention of powerful motors and electricity became more common in use (Dean, 2008). Surely, the use of electricity, EuP, efficiency, and convenience gained by this resource has dramatically changed the way we live today. It enabled our industry to produce in mass, accelerated, and sometimes enabled us to travel in longer distance. However, while people pursuit for these novelties reflecting as convenience, humans may have self-consumed their own skills and those memories. It can be argued, over the years, people may have been indoctrinated into believing that products that have power plugs are better than those that do not have plugs. People may have built prejudice against those products that they are simply better than the others, making them more efficient to accomplish daily tasks within relatively short period of time. On the other hand, the EuP can be seen as ‘object of manipulated desire’ where the manipulation is undertaken by the production and distribution system of capitalism, and through consumption, in order to persuade the population that their needs are being met (Palmer and Dodson, 1996).

It is the author’s contention that, a ‘product’ without a motor may prove as ‘wise’ if it is convenient, efficient to use, and with an equitable performance. As recently as 150 years ago, human-powered products (HPP) were the norm in every nation, e.g. hand crank grinder, bicycle, pedal powered lathe and sewing machine. However, as the electro-mechanical motors developed and became more widespread, everyday ‘products’ have evolved significantly. Simultaneously, using human-power for powering such products has also gradually diminished (Dean, 2008). Technologies have been constantly evolving and through these advances, our life styles have become notably more efficient. The ever-increasing efficiency of products means that less and less effort is required to carry out a task. However, will it be possible to abandon these new accustomed efficiencies and use the human-power once again to power EuP and perhaps create new practice?

Most renewable energy comes from forces of nature (e.g. wind turbine or solar panel) or using nuclear power. But why couldn’t we use the calories that we consume everyday into renewable source of energy? In reality, humans emit energy from everyday behaviour. The Bicycle is a great example of a means of utilising relevant human-power that allows user to exercise, transport, and save consumption of conventional energy at same time. If, for example, we can design bicycles to become more ‘entertaining’, this may be an optimal method of encouraging new behaviour of using human-power, and hence reduce energy consumption in a transportation context. Nevertheless, it is unfortunate that human-power has not been appropriately treated for its befitted potential of being alternative solution.

There are vast amounts of on-going developments using natural resources such as solar power or wind turbine which provide more alternative energy supply into the grid. However, the downside of these renewable energies is the volatility. Both scarcity and oversupply may result in grid instabilities due to problems such as having lack of available storage capacity in case of insufficient demand (over charged). For this reason, it is worthwhile investigating micro-levels of energy consumption (at domestic level) instead of solely seeking for solutions around macro-level of supply (Industry).

In the past two decades, there has been an exponential increase in the number of consumer electronics and portable electronic devices providing increased mobility; and new applications of ICT[2] related devices (Bertoldi and Atanasiu, 2007). The increase in electricity consumption from using consumer electronics such as Televisions, home computing and other power supply units outstands as their energy usage are still at an incremental rate (DECC, 2011a). Human-powered products (HPP), as perceived in recent research literature as alternative power source for battery running electronic products (Jansen, 2011; Jansen and Stevels, 1999; Jia and Liu, 2009), is considered as one solution to reduce the environmental impact of products, including problems such as the over-consumption of energy (electricity) caused by increase of EuP[3]. In other words, users of HPP no longer rely solely on the use of electricity from the grid to drive the EuP in use. Some may argue that the amount of savings generated for being ‘off the grid’ may not give much impact. However, against this assumption, this research explored other form of potential benefits that every individual of HPP users may be able to contribute towards bringing alternative impacts.

Evidence supplied later in this thesis suggests that replacing existing EuP to HPP would not provide a significant cost reduction in electricity bills, although it may vary among different individuals. However, such enthusiasm of human-power inventors and its users emphasise on the particular notions of; empowerment, portability, and availability on demand.

> “No matter how small the output, it’s empowering to discover how much we can do without the utility company, or the noisy, smelly motor, or the plug” (Dean, 2008, p. 1)

[2] ICT refer to Information and Communication Technology
[3] Energy Using products

Against this context, research work for this thesis set a scenario based hypothesis that HPP can potentially be a viable solution in bringing about a reduction of energy consumption; using the human-power source as alternative to non-renewable energy that is generated and transported from power plant. The scope of this research investigation was focused on identifying the strategy to encourage use of HPP - as a means of de-routinising the current habitual energy consumption through new interactions of human-power generating, which can drive awareness, and promote sustainable energy consumption in everyday life. The definition of sustainable energy (electricity) consumption, in this research, means a conscious choice of using products and practicing ‘energy saving behaviour’ with the goal of reducing energy consumption. In the latter part of this thesis, it presents on the interesting findings from exploring people’s everyday practice of using HPP. The thesis argues that there are other notions to consider in wider design contexts for greater benefits beyond being off the grid. Moreover, it is anticipated to provoke new questions against current norm – for example the over reliance on new technologies with increased efficiency and greater supply or that still uses conventional power sources. It focused on investigating other empirically proved benefits that can be applied from a design strategy perspective, which helps to raise awareness of sustainable energy consumption. Beyond being reliant to technological interventions, the study aims to explore potential solutions dealing with the broad and diverse role of design through identifying more intrinsic approaches.

> “Using human-power, our exertion makes visceral what we take for granted from the grid. It raises our awareness.” (Dean, 2008)

1.1.3 Definition of Human-powered products

Throughout this thesis, the definition of human-powered products (HPP) is defined as ‘products which function using power generated by human muscular exertion’. Defining a clear meaning of human-powered products was very important as the first step for this thesis since there are three broad definitions found from relevant literature. First, Dean (2008) featured most of the examples of HPP from her book which incorporates rotary motion; in other words, HPP with mechanism such as pedal power or treadle. Whereas A. Jansen defines the concept as ‘electrical products powered by muscular work from the user' which focuses on the conversion of that work into electricity (Jansen, 2011, p. 2). Thus, Jansen additionally sub-defines between 'human-power' and 'energy system' in order to clarify that the power is generated by 'human muscular work' within a system of 'a technical artefact designed for converting the effects of human muscular work into electricity' (Jansen, 2011, p.3). The last definition is used by scholars (Jia and Liu, 2009; Paradiso and Starner, 2005; Starner, 1996) as 'parasitic harvesting' where using human body or its movement as power source to drive electronic devices (e.g. using body heat, breath, blood pressure and footsteps, etc). In this thesis, the definition of HPP remains as much broader scope compared to the other three mentioned above. This is due to this study spending significant amount of time exploring and classifying existing HPP from various different sources to help clarify the definitions. The examples of representative HPP and their images are discussed in Chapter 2.2. The detailed analysis and explanation of classifying processes using so called 'HPP Interaction Matrix' are presented in Chapter 4.2.

1.2 Research Questions

The core aim of the research is to investigate how the 'use of human-power' and designed interactions in HPP could lead to interventions for instigating the change of existing attitudes and behaviour in regards to energy use and consumption. In pursuit of this aim, a set of subsequent research questions were developed as research progressed, representing each stage of the research processes. They are:

- Q1: What are the current trends/developments of HPPs?
- Q2: What are the user benefits of using HPP?
- Q3: Is HPPs user-centred? If not, what are the factors driving this response?
- Q4: Can HPP influence users to practice energy saving behaviour?

1.3 Structure of thesis

Table 1-1 presents the structure of this thesis in matrix format, describing the (sub)research questions and methodologies used.

Research Question		**Methodology**
Question	**Sub-Question**	**Data Source and methods**
Q1: What are the current trend/development of HPP?	Q 1.1 What is the definition of HPP?	Literature Review
	Q 1.2 How can HPP be characterised?	HPP Interaction Matrix
	Q 1.3 What is public's perception about HPP?	Pilot Study
Q2: What are the user benefits of using HPP?	Q.2.1: What benefit has been discussed in the past research or publication?	Literature Review, LCA Study
	Q. 2.2: Can sustainable usage of HPPs reduce energy (electricity) consumption?	LCA Study
Q3: Is HPP user-centred?	Q 3.1: If not, What are the factors driving this response?	Literature Review, Conceptual Framework, HPP Analysis, Pilot Study, HUS stage 1
	Q 3.2: What motivates users to use the HPP?	HPP Interaction Matrix, HUS stage 1
	Q 3.3: What are the missing elements or barriers in design of HPP that prevent people from using it for longer-term or even short-term period?	Conceptual Framework, HPP Internalisation Model
Q4: Can HPP influence users to practice energy saving behaviour?	Q4.1: What strategies have been discussed in the past research about behavioural change?	Literature Review
	Q4.2: How can HPP be designed in a way that encourage its use in a longer-term?	HPP Internalisation Model
	Q4.3: How effective is the new model?	HUS Stage 2

Table 1-1 Thesis Structure Matrix

Chapter 2 Literature Review

2.1 Introduction

The literature review in this chapter includes analysis of published research work in the field of human-powered products; over-consumption of energy debate; theories of behavioural change; sustainable energy consumption and strategies to maintain sustainable behaviour and use. Each sub-chapters are presented with relevant research questions to be addressed. It demonstrates the exploratory process to understand status quo and to formulate further research enquiries.

2.2 Human-powered products (HPP)

The literature review on HPP and relevant academic works were performed with focusing on two main areas. The scope was based on retrieving the answers for the following research questions:

Q1: What are the current trend/development of HPPs?	Q 1.1 What is the definition of HPP?
	Q 1.2 How can HPP be characterised?

In this chapter, the first focus was conducting literature reviews of academic publications in relation to HPP. Secondly, it was the collection of information on currently available human-powered concepts/ideas/products. Although different types of HPP were collected through various different sources, the research faced boundless difficulties to identify indicators for configuring their classifications. This was due to hazy or varied definitions of HPP among the publications. Another difficulty was against the lack of relevant literature available in the field of HPP research. No book publications on HPP could be found except for Dean's 'Human-Powered Home' (2008). Arjen Jansen who has written the most number of research papers on the topic of HPP and its energy system, also acknowledges that there are limited publications presenting basic guidelines on the design of HPP. However, number of literature based on scientifically driven study of HPP, especially about harnessing power from human's daily activity (Jia and Liu, 2009; Paradiso and

Starner, 2005; Starner, 1996) are well reviewed in Jansen's PhD Thesis (Jansen, 2011). Particularly, when reviewing the history of HPP as consumer product, Jansen's thesis presented overview of HPP starting from the intermediate period (1998-2010)[4] and as early as introduction of Baylis' freeplay radio (Baylis, 1999), see Figure 2.8 on page 18, which was first introduced through publication by Chick (1997) in February 1996. Total 145 publications, including the popular media source such as magazines and newspapers, are presented in Jansen's doctoral thesis. Therefore, it can be seen as most comprehensive publication work insofar. The scope of following sub-chapters introduces representative HPP examples and their definitions described by above mentioned scholars.

2.2.1 HPP with mechanical output

The book, 'Human-Powered Home' (Dean, 2008), presents a historical overview of how the evolution of human-powered devices perceived over the past centuries and throughout industrial revolution. Further, the book presents some examples of currently available electrical HPP. Major part of this book particularly presents examples of HPP that can be used in different domestic environments such as the kitchen, lawn, garden and emergency preparedness. Interestingly, Dean challenges excessive technologies that parasitically harvest energy from human-power or from peoples' daily movement such as using piezoelectric systems. This is due to their 'exaggerated' impact where the actual amount of generated energy will not justify the expense in installation of these systems. Therefore, examples that Dean provides are mostly mechanical human-powered devices, without an electricity generator or storage unit, such as using pedal power or hand crank mechanism where human-power is transformed into velocity or rotational power. One of the example presented by Dean (2008) is the initiative of Maya Pedal, see Figure 2.1. It is a non-governmental organisation based in Guatemala's Mayan country, who accepts crates of cast-off bicycles from various organisations and transforms them into household appliances. Maya Pedal's Bicilicuadora is one of their bike-powered machine which transforms the pedal power into a rotational power for blender.

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4 Jansen (2011) mentions the earliest HPP - "Dyno-Torch" ('knijpkat' in Dutch 1946, produced by Philips) as well as the first human-powered quartz wristwatch also popularly known as the 'Seiko Kinetic" in 1998. However, since his main focus was oriented around user preference in cranking of HPP, not much detail on above two were found.

Figure 2.1 Maya Pedal's Bicilicuadora – Blender Bike (Anon., 2010)

Dean's notion of emphasising on the merit of mechanical HPP also draws upon the fact that transition from pedal power to electricity and gas-powered engines were conventional in westernised world. Whereas in developing countries, the traditional power source like pedal or treadle still serves as real alternatives to high priced and less available energy source such as fossil fuels or photovoltaic cells. Looking back at late 19th century, using human-power as power source for everyday tools was as norm as we use electricity today. However, we use such source in more inconspicuously way, meaning that they are mostly invisible to many users now days. Dean (2008) argues that this rapid transition from using human-power to electricity consumption has resulted in human-power being languished before realising its potential.

2.2.1.1 The History

The history and evolution of human-powered devices are also comprehensively reviewed by Dean (2008). Dean hypothesises that first ever known HPP is potter's wheel which was invented around 3,500 BC., and curiously this design changed little until the 19th century. It is believed that people began to use the rotary power at least from 8,000 BC, and the mechanism of rotary working machines have evolved drastically since then. For example, two person operating lathe was first recorded in Egyptian tomb drawing around 300 BC, and one of the most favoured mechanism of HPP, the hand crank, was first evidenced around AD 200.

Figure 2.2 Drais' Running Machine (Herlihy, 2004)

A bicycle is the most iconic example of HPP throughout the history. The early model of bicycle were designed as foot-powered vehicle. Figure 2.2 is the first human-powered land vehicle developed by Karl von Drais and patented in 1818 (Herlihy, 2004). This device is also known as 'Laufmaschine' (running machine in German) or 'Velocipede' (fast foot in Latin) or as 'Dandy Horse' which was originated from Drais' intention of building a 'mechanical horse'. Compared to pedestrian, the rider of this device purportedly travelled a distance with relatively less labour.

In 18th century, the term 'bicycle' was coined after the addition of pedal mechanism attached on a front wheel - making to run faster, easier to manoeuvre, and became more appealing to ride (Dean, 2008). The first pedal-powered bike was recorded in 1866 from a patent filed by Pierre Lalement, shown in Figure 2.3. However, the credit of this improvement to the front wheel of bicycle has historically been given to Pierre Michaux, a Paris blacksmith who later offered a variety of bicycle styles in 1860s.

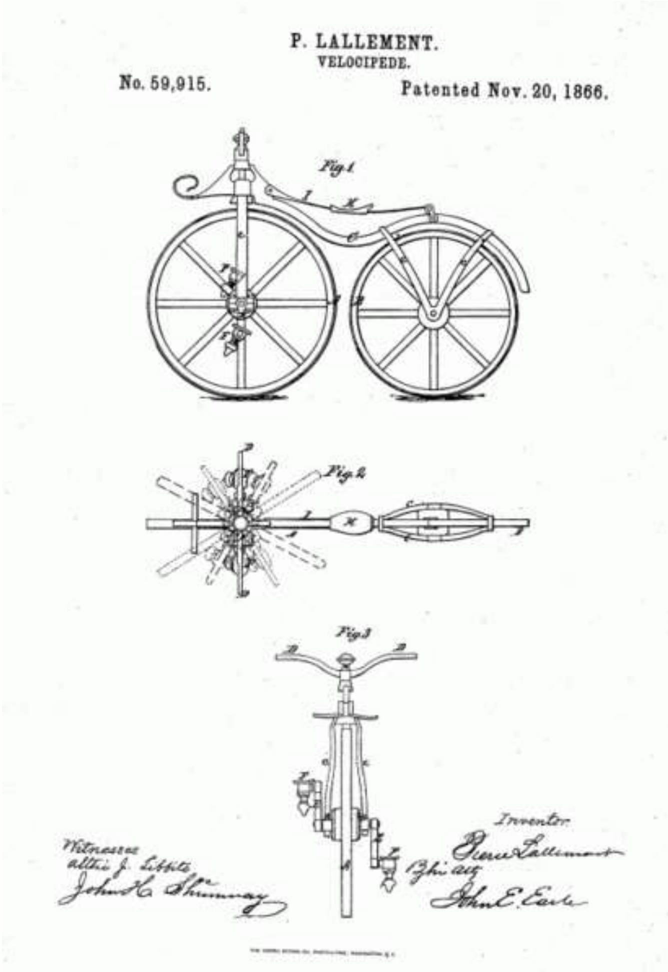

Figure 2.3 Lallement's original bicycle patent (Herlihy, 2004)

Beginning around 1969, the development of bicycle showed the tendency of increasing the speed through growing the size of front wheel. The pedals equalled one revolution of the front wheel. Therefore, the bigger the front wheel, the faster a bicycle could go. In 1871, British inventor James Starley and William Hillman patented the Ariel, a bicycle with 48 inch diameter front wheel, see Figure 2.4. In late 18th century, the bicycle began to use chain drive system since the large front wheel type of bicycle was not favoured by women whose wears long skirt dress perceived it as treacherous and also for safety reasons (Dean, 2008). Since then, market of bicycles in the late 1800s was fostered by newly developed manufacturing techniques that enabled for more sophisticated parts such as bearings, metal tube, rubber-tubed tires, speed gears and brakes. These improvements were mainly derived from the idea of making activity of riding bike to be more 'safe' - making two wheels of equal size and chain connected to the rear wheel. This new design, came to known as the safety 'Rover' bicycle, look very similar to contemporary bicycle (see Figure 2.5). However, as electricity and gas-powered engines replaced pedal power, the bicycle were perceived as play and sport rather than as a transportation – at least in the Western world. On the other hand, in developing countries, pedal and treadle power becomes more viable solution to high priced and less available fossil fuelled power.

Figure 2.4 Starley's Ariel in 1871

Figure 2.5 The Rover safety bike (Dean, 2008)

Whilst people view the ‘use of human-power’ as source of energy to drive rotary mechanism, Ghandi, preeminent leader of Indian nationalism, utilised it to protest against British industrialisation. While India was ruled by Britain in early 20th century, Gandhi insisted on choosing technology that could help themselves out of poverty. He called this philosophy of local self-reliance as ‘Swadeshi’. As new technology arrived, it began to replace and continued to impoverish local workers and craftspeople. Therefore, he entreated fellow Indians to use human-powered textile mills to spin and weave their own cloth (Dean, 2008).

> “The traditional old implements, the plough, the spinning wheel, have made our wisdom and our welfare.” – Mahatma Gandhi (Rybczynski, 1980, cited from Dean 2008, p. 30)

Figure 2.6 Prisoners at Pentonville Penitentiary, London in 1890 (Shayt, 1989)

Use of human-power was sometimes coerced by others with authority. As slaves and prisoners served as oarsmen back in the past, forced labour became part of prisoner's penance in Britain. Penitentiary Act in 1779, also known as 'Hard Labour Bill' which required prisoners to serve a drudgery labour such as turning a mill or treading in a wheel (Shayt, 1989). Prisoners on treadmill, for example, held on to a bar while making steps on the treads which was connected to grain grinders (see Figure 2.6 as an example). Despite its cruelness of penalty, forced labour was beneficial, as it reduced the recidivism and contributed to the prisoners' good health.

2.2.2 HPP with energy system

The leading scholar in the field of HPP is Arjen Jansen, who has conducted a number of human-powered system related researches and projects. His research focuses on the use of non-traditional forms of energy systems in consumer products, with an emphasis on human-power (Jansen and Stevels, 1999). His doctoral thesis, 'Human-Power empirically explored' (2011), questions the viability of human-power as alternative to batteries in portable electronic products. Moreover, Jansen's work contributes with extensive amount of knowledge based on his 15 years of empirical study whereas Dean's book focused on providing more pragmatic guidelines of understanding the potential of human-power (products). Jansen's work provide more detailed analysis on existing HPP by classifying them into market situation, retail price, ergonomic, power density and its environmental impact. Jansen also defines the 'human-power' distinctively (more specifically than Dean) where his definition is a 'non-conventional power source' focusing on products featuring a conversion of muscular work into electricity (Jansen, 2011). In other words, the HPP examples presented in his work uses electricity as primary power source that is powered from the energy system - such as torch or radio (see Figure 2.8). Jansen makes clear sub-definitions of *human-powered* and *energy system* within HPP in order to clarify that the power is generated by 'human muscular work' within system of 'a technical artefact designed for converting the effects of human muscular work into electricity' (Jansen, 2011, p. 3). In order to put this into more simplified representation, Jansen developed a model of HPP describing energy flow from human muscular work, via human-powered energy system to the electronic function (see Figure 2.7).

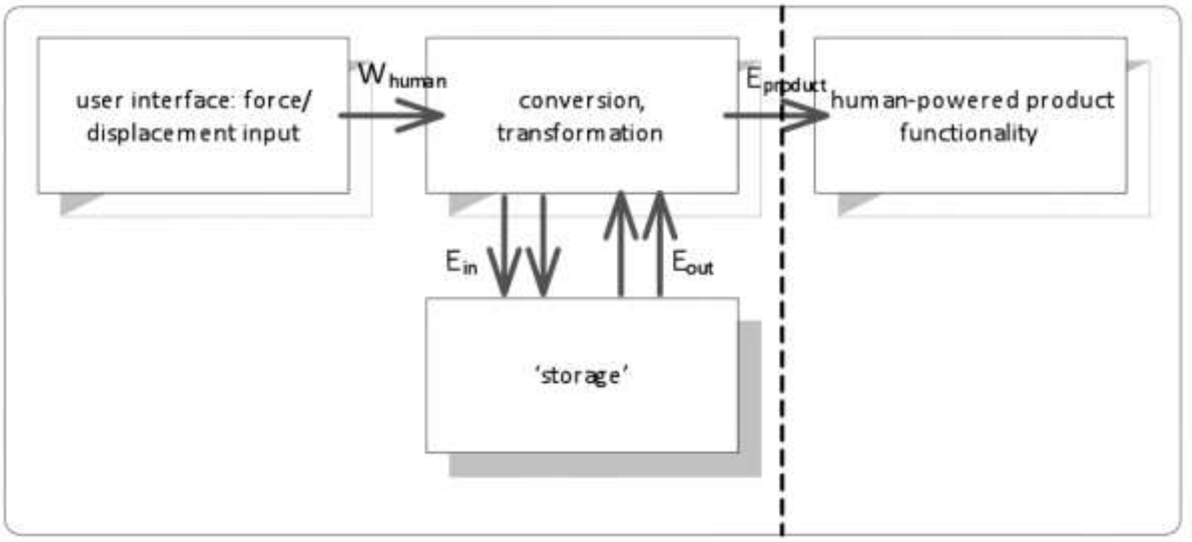

Figure 2.7 Model of Human-powered energy system. The dotted line represents the system border in case of generator type products (Jansen and Stevels, 2006)**.**

According to the figure, the energy flow is moving from left to right; starting with the user interface (i.e. crank or pull-cord), transformation of rotational energy into electricity, storage (winded spring like Baygen's radios or battery), and finally the consumption of stored energy through powering HPP functions, e.g. torch or radio.

(a) (b)

Figure 2.8 The first Baygen Freeplay Radio[5] (a) (Baylis, 1999), Sherpa LED Torch (b)

[5] The first freeplay radio uses steel spring-winding mechanism to generate electricity to run as radio. In 2001, the brand freeplay abandons using steel spring with the introduction of the Freeplay Ranger Radio which converts the direct input torque into electricity via a gearbox and generator and was 'stored' using a set of NiCad cells (Jansen, 2011)

In addition to research work of making distinctive and more detailed definitions of HPP, Jansen conducted experiments investigating the preferences of human-power applications, especially focusing on the power generating mechanism of ‘cranking’. This ergonomic study shows that both crank length and crank rate have significant influence on drawing maximum output power: 31W cranking output power can be sustained for extended period of time by 95 % of the population (Crank length 175mm, cranking speed 60 rpm). If this number is converted at an efficiency of 25 %, the power output measures at 7.8 W of electricity which is adequately enough to power a large range of portable consumer products (Jansen and Slob, 2003). Portable electronics such as IPhone (average of 5 W), TV remote, and MP3 are examples that consumes within the range of human-power output density. Table 2-1 shows the list of products with average power consumption during use, presented by Jansen and Stevels (1999). Considering this data being measured in year 1999, efficiency gained through recent technology such as LED and battery gives much greater opportunities for HPP transformation. However, it is also notable that these electrical products do evolve simultaneously and could increase the time of usage and consumption, e.g. Smartphones, Tablet PC.

product	average power consumption
small portable FM radio	30 mWatt
walkman (play mode)	60 mWatt
TV remote	100 mWatt
cell phone (talk /stand-by)	2 W / 35 mWatt
electric torch (flashlight)	4 Watt
video 8 (no LCD screen)	6 Watt
laptop computer	10 Watt
TV (53/67/wide screen)	50 / 74 / 111 Watt

Table 2-1 Measurement of power consumption for portable electronics (Jansen and Stevels, 1999)

2.2.3 Parasitic Harvesting

Despite the growing numbers of portable electronics, the development on increasing the capacity of power unit (battery) has been lagging compared to rapid progression of these devices. There is no doubt that battery technology has definitely enabled today's wireless and mobile applications. Although the battery technologies are the still prime agent behind this expansion, they also limit its penetration. This was acknowledged by Starner and Paradiso (2004), p.1 as they describe; '… all these devices still have a common difficult problem to overcome: power… battery energy is one of the most laggard trends in mobile computing'. This phenomenon straight leads to a similar question that Jansen had touched on – Is there an alternative to batteries?

While Jansen's research focused on direct force exertion of human muscles to generate power to replace batteries, Joseph Paradiso from MIT Media Lab worked on human-powered electric devices in a far more diverse way. The lab focuses on harvesting the human muscular energy 'parasitically'. The idea is to generate the power in an ancillary way whilst people are doing activities like walking or typing; or to pick up energy from the body as it breathes, pumps blood and generates heat (Paradiso and Starner, 2005). The power source gets scavenged indirectly from the user's everyday actions or sub-consciously generated by the user. Dean defines this concept as *Passive Energy Harvest*, as she describes 'a collection of human energy, whether mechanical, thermal or chemical, to generate power, given a person's minimal or unconscious effort' (2008, p. 53). The history and state-of-the art in harvesting power from user's everyday action, or perhaps showing the possibility, is well presented through work of Starner and Paradiso (2004) and also by Jia and Liu (2009) who focused on wireless computing devices. Examples and scientific data on power conversions of 'parasitic' HPP are shown from their work, recognising applicable power from sources like heat dissipation (thermal), Joint rotation, and enforcement of body weight. Acknowledging the transition in growing number of portable electrical products, these scholars view the use of human-power as a viable solution to overcome battery limitations.

Throughout this thesis the term 'sub-conscious' represents a type of input mode when the users are engaged in generating human-power, although Dean defines this concept as *unconscious effort*[6], under the concept of ‘Parasitic Harvesting’ HPP. A strong example of parasitic HPP is the piezoelectric Sustainable Dance Floor, See Figure 2.9 (Anon., 2007). This concept utilises the fancy footstep pressure energy produced by dancing movements into kilowatts to power other basic utilities. The piezoelectric technology is a smart material that creates electrical charge when its form is stress through mechanical force (Jia and Liu, 2009). The design harvests energy in an ancillary way whilst people are sub-consciously applying their dancing movement energies, i.e. footstep energy. Although described as a parasitic harvesting system, a unique feature is that the device can also provide a digital meter showing how much of electricity is being generated and fed back (charge) into the grid or storage unit which can potentially power lighting utility such as stage LEDs. The meter can encourage and enable people to feel environmentally pro-active, contributing their own human-power as a sustainable source of energy. Today, piezoelectric flooring is a technology with a wide range of applications. It is now widely being used in heavily crowded areas such as a subway stations[7], and a number of tourist attractions.

Figure 2.9 Sustainable Dance Floor (Anon., 2007)

[6] According to oxford dictionary the term ‘subconscious’ is defined as ‘of or concerning the part of the mind of which one is not fully aware but which influences one’s actions and feeling’. The word ‘unconscious’ has been found from literatures when explaining the opposite meaning to ‘conscious’, e.g. conscious decision, conscious choice. Nevertheless, the term still draws confusion as terminology used among varies different academic fields. In order to minimise grammatical and to make distinctive definition, the term ‘sub-conscious’ will be used throughout the research. The detail of using the term will be discussed in Chapter 4.2.1.

[7] East Japan Railway Company installed a piezoelectric floor in the subway stations where the system will harvest a crowd’s footstep energy into electricity to power ticket gates and display systems. In this application, the design harvests energy in an ancillary way whilst people are sub-consciously applying their walking energy. Although it is still a parasitic harvesting system, the company have displayed a meter to show how much of energy is being generated. It enables people to feel environmentally pro-active (Yousuke, 2008).

However, within the concept of ‘parasitic’ harvesting, the term does not always refer to generating electrical power but also mechanical. The earliest example of such HPP is the self-winding watch[8]. This type of products captures the vibration of walker’s movement (pedometer, see Figure 2.10 as example) which jiggles the off-centred spindle to generate rotational force that winds the timing mechanism (Starner, 1996).

Figure 2.10 Pendulum Watch (TagHeuer, 2010)

2.2.3.1 Fun Energy

Perhaps the idea of using ‘parasitic’ harvesting methods was inspired from resolving the issue of requiring deliberate muscle effort involved in HPP application which can be seen as ‘labour’. Hence, some recent works suggest harvesting human-power from playful or fun energy which can be seen as the most effective technique to motivate HPP users. The Playpump (People, 2010), Figure 2.11 is an interesting example. This product does not have any electrical output, comprising two functions from one application of physical kinetic energy. The purpose of this design is to provide a clean drinking water facility whilst children have fun spinning the merry-go-round of PlayPump. The clean water gets pumped up from underground into a 2,500-litre tank which stands seven meters above the ground. This example attempts to induce using human-power from, above all, the spontaneous activity that

[8] Most popularly known human-powered wrist watch is “Seiko” quarts wristwatch in 1988. However, Seiko’s watch is powered by a rotating pendulum connected to a pinion driving a miniature generator (Matsuzawa and Saka, 1997, cited from Jansen, 2011).

gives enjoyment at same time. Any ‘labour’ in terms of energy generation in this design is compensated by an increase in other ways.

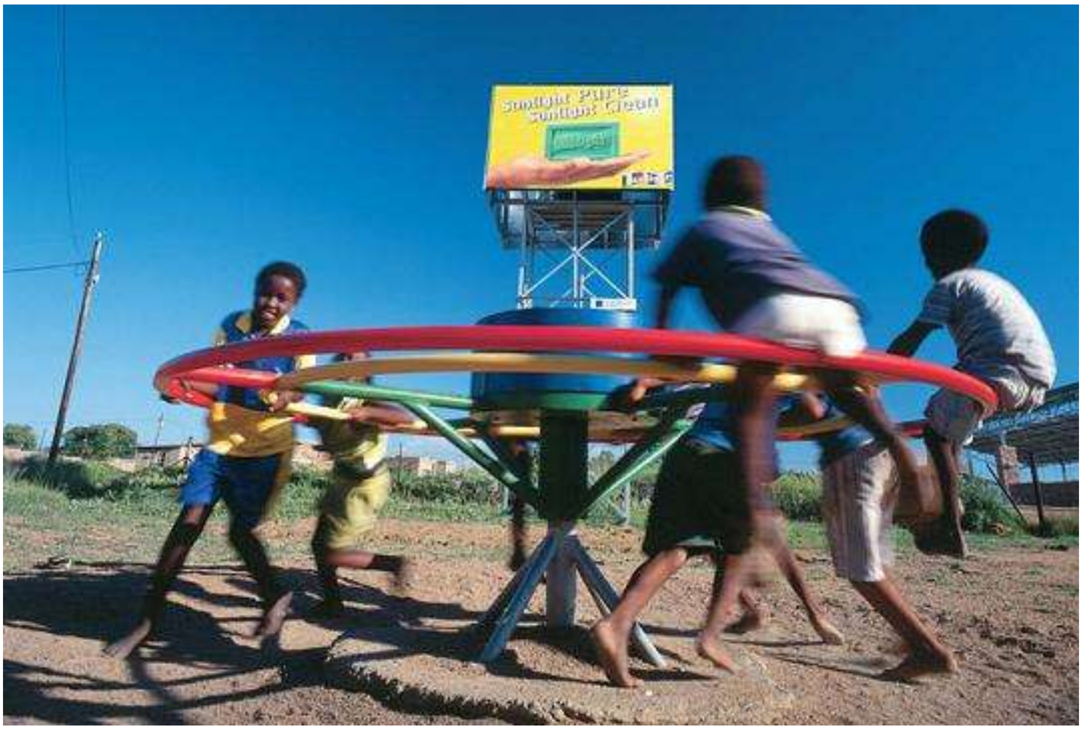

Figure 2.11 Playpump (People, 2010)

Pandian (2004) also looked at harnessing the power from children’s play in playground. By installing a pneumatic actuator such as cylinder or air motor onto devices like seesaw, merry-go-round and swing – the compressed air then transmits to electrical generator to produce electricity (Pandian, 2004). This converted and stored electricity can then be used towards powering low powered appliances as well as electrical equipment in school such as lights, fan, and ICT related devices. Interestingly, it is recognised that most of the parasitic harvesting methods focus on converting the human-power energy into a storage unit, focusing on method of ‘charging’. This is acknowledged by Jansen’s model (Figure 2.7 on page 18), where he draws dotted line to show the distinct understanding of energy system within HPP. Thus, for PlayPump, the energy system can be understood as a ‘device’ (i.e. merry-and-go) generating rotational energy and the functional output is the water pump. Whereas, Pandian’s work reflect as a system that converts human-power into electrical power rather than having a particular functional output other than generating and storing electricity.

2.2.4 Benefit of HPP

The potential benefits of using human-power as alternative energy source, above all, the most efficient benefit will be the portability and availability on demand (Dean, 2008). As noted before, despite rapid growth in wireless or portable electronics, battery technologies have been lagging. It is assumed that its capacity or energy density will never be satisfied by users of these products. Thus, against these proliferated usages of portable electronics, human-power comes into the spotlight more than ever. While Dean emphasise on re-use of languished human-power, Jansen has been suggesting this energy source as alternative to batteries, or as mobile power by (Jia and Liu, 2009; Starner, 1996; Starner and Paradiso, 2004; Yun *et al.*, 2008).

Particularly, Jansen comprehensively described the advantage of using human-powered devices in more depth by manifesting into three areas of ecology, economy and user-related aspects. From economic and user-related aspects, the advantages are (Jansen and Stevels, 2006, p. 1301):

- Long shelf life (particularly becomes valuable in emergency situation)
- Independent from energy infrastructure
- Independent from availability of batteries and cost associated value
- use of energy that is otherwise ‘lost’ (as in motion damping system)
- applicable in products where user accessibility is undesired (i.e. not making the interior of products accessible in order to exchange batteries)

Moreover, he describes three benefits of a HPP from eco-design stand point. These are as follows (Jansen and Stevels, 2004, p. 499):

- Material benefit - do not consume energy from non-renewable sources during the use-phase of the life cycle.
- Immaterial benefit - the convenience, there is always power available.
- Emotional benefit- human-powered products enhance the quality of life by making the consumer feel environmentally pro-active

Additionally, it is anticipated that benefit of HPP will soon be realised in wider context due to increase of energy efficiency of electronic devices, meaning that electronics will shift towards ever-decreasing wattage requirements. This shift makes the feasibility of using human-power application more practical as alternative energy source and it will provide more opportunities in much broader ranges of electronic devices.

2.2.4.1 Environmental Benefit of using human-power

The benefits of using HPP may associate with cost reduction from no longer consuming batteries and potentially reducing the environmental impact (Jansen, 1997), or having sense of empowerment that you can generate the power in need whenever without relying on other non-renewable energy source (Dean, 2008). However, from acknowledging the fact that the ‘use-phase’ contributes significantly to the total environmental impact during life cycle of product-use, it come to question of: Does HPP reduce environmental impact when compared to battery powered products? If so, what is the minimum length of use-phase (life cycle) do it requires to meet that condition?

To answer this question, Jansen conducted a life cycle assessment showing the total environmental impact of comparing the Baygen Radio (Baylis, 1999) with three other battery powered radios (Jansen, 1997). The experiment concludes that human-powered radios show a greater environmental impact from a production perspective, due to factors such as heavier weight and the number of extra components for embedded dynamos. However, after averages taken between 1.4 and 2.9 years of life time, the environmental impact of the battery powered radio will be equal to a human-powered radio and will eventually be less efficient due to the further consumption of batteries. More detailed discussion on the beneficial incentives is presented in Chapter 4.4.

2.2.4.2 Health vs. Cost Saving vs. Motivation

The cost factor may be a real driver when consumers decide to purchase a HPP. The amount of potential saving and its unit of cost may stimulate their purchase or they may consider the size of required contribution against the value of money invested. From this context, the benefits asserted from academic studies may contrast to what actual consumers expect from using the HPP.

For example, running a 100 watt TV for an hour will cost about average of £ 0.0145[9] in the UK. That means the cost saving for applying human labour to power 1 hour worth of TV watching will be equal to this figure. How futile is this? Dean and Jansen present distinct interpretations when discussing the benefit of using HPP. Dean criticise on the relatively low prices of fossil fuels that we pay, and that people are not aware about these masked expenses beyond what it cost at production and domestic consumption levels. From consumers and producers' perspective, these external costs may not be responsible to individual agents at the moment of paying electricity bill and are relatively low, but society as a whole must pay for their consequences. The external expenses may encompass human health problems caused by air pollution from coal burning, global warming and so on (Armaroli and Balzani, 2007). Therefore, Dean argues that overall environmental consequences of using human-power are far less detrimental, beyond the cost saving, than burning fossil fuels.

> "In summary, human power is best suited to applications that require small amounts of power, that benefit from portability or exist in remote locations, and that need to be available on demand and that are relatively inexpensive. It's also well suited to those who want a healthy body and healthy environment" (Dean, 2008, p. 76)

Jansen's life cycle analysis result (environmental impact), presents the breakdown in detail of actual cost of ownership comparing 1 human-powered flashlight with 3 other battery-powered products. The total life cycle costs are determined by calculating the purchase cost and additional cost for consuming battery over period of 2 years. It concluded that battery-powered products spend up to 3 times more than human-powered torch. This notion of reducing the total costs of ownership by using the human-power proves to be a real consumer benefit from financial perspective (Jansen, 2011). However, it is also realised that consumers may tend

[9] Average electricity cost in the UK is £0.145 per kWh. (100 W / 1000) x 1 Hour = 0.1 kWh.

to only consider the initial costs of purchasing a HPP, rather not realising the cost arising from consuming additional batteries.

Thus, acceptability of HPP may vary depending on different users' motivation and intentions towards using such product. Measuring levels of these internal attitudes is very difficult since it relates with different variables like cost or ecological interests. Moreover, there may be an issue of adoptability towards 'added discomfort' in the application of HPP (Jansen and Slob, 2003). In other words, feeling 'physical fatigue' while exerting human-power, although this fatigue may benefit some users with exercise in mind.

2.3 Future of HPP

The most recent database of HPP is best analysed in Jansen's PhD work (Jansen, 2011). It included a list of 211 HPP with detailed description of each, collected through internet search using a google search engine. While his study provided HPP mostly available in current market, current research had been collecting HPP concepts through subscribing online newsfeeds from various online media such as 'Inhabitat'[10], 'Gajitz'[11], and 'Design boom'[12]. Instead aiming to make an extensive list of database, these sources were used in developing a taxonomy of HPP types and the mapping process, and also, to be trend-conscious towards future development of HPP. Among various concepts found dating from 2010 to 2013, below are 4 notable products/concepts that shed light on the future development of HPP.

[10] http://inhabitat.com/
[11] http://gajitz.com/
[12] http://www.designboom.com/

Figure 2.12 RB2B (Thetard, 2010)

RB2B, Figure 2.12, was developed by designer Christoph Thetard for diploma degree project at Bauhaus University in Weimar, Germany. The device is a mechanical flywheel drive which powers a set of kitchen appliances. His aim of the project was to develop a kitchen appliances that could be powered without using electricity. The central drive unit consist of flywheel system that provide the energy needed from pumping the pedal spin. The power of flywheel is up to 400 rpm which is equivalent to 350 Watt of energy to power the appliances by direct mechanical rotation. These rotational energy can be increased up to 10,000 rpm using geared transmission as user attach multi-functional kitchen machine such as blades, a slicing disc and whip. While still being at prototype stage, the concept stands out as an example of utilising mechanical human-power and proposing an energy system which instantly stores the non-electrical power. Although the feasibility and technicality may be in question, it deserves a credit for presenting a HPP concept that challenges the current limit of HPP which are known to power portable or battery consuming electronics.

Figure 2.13 Reactor (Gridcase, 2013)

Most of heavy mobile user must be tethered to power sockets or computer cords to charge their smart devices. 'Reactor' is a concept of an IPhone case which a patent-pending ultra-thin generator is embedded inside, Figure 2.13. The case enable user to manually charge the battery through crank motion. While the product is still at concept level, the company is gathering a budget via social funding scheme[13] to help bring it to market. Although the method of power generation is not a novel idea; however, the concept do shed light on how human-power can be a viable solution at emergency. This issue of emergent use was also heard during the interview conducted at pilot study (Chapter 6.2.2) and Home User Study (Chapter 7, Chapter 8). As mentioned earlier, the battery technology is still perceived to be the most laggard trends in mobile computing. Another account of this issue can be related to the mobile dependent life-style which eventually increases the use-time of these mobile technologies. Therefore, it can be seen that the opportunities co-exist with future battery developments and wider applications of HPP.

[13] http://www.crowdsupply.com/gridcase/reactor-for-iphone-5

Figure 2.14 Gravity Light (Deciwatt, 2012)

Gravity light (Figure 2.14) is introduced by company named Deciwatt, aimed to design a lighting device for developing countries. The device uses a gravity force to power 30 minutes-worth of light by attaching a bag filled with around 9kg of material such as sand. The designer's aim was to eliminate the need of kerosene use and by replacing it with forces of gravity, the device requires a single attempt of human-power to lift up the weight as it gradually descends to power the light. The idea shows interesting concept to minimise the required labour in generating human-power. Although the device's output is electrical light, it shows similar interaction to pendulum watch where a single attempt of human-power input gives relatively prolonged period of sub-conscious energy use.

Among many of 'parasitic' HPP concepts, nPowerPEG (Figure 2.15) is a product that is available for purchase. The product has been introduced through various medium of online media. The device uses a kinetic energy from our daily movement such as walking. The generated electricity can be stored in the internal battery. The device contains a magnet weight, spring, and inductive coil which generates electricity as user constantly apply kinetic movement. The company notes that the device are yet enough to power high wattages electronics like laptop or an IPad. However, greater performance is expected in near future as energy efficiency (including the battery technology) of EuP increases.

Figure 2.15 nPowerPEG (2012)

Nearly 100 concepts and real product were monitored through online media. It is important to acknowledge that dominant idea/concept/product were categorised into ‘parasitic’ group. However, effectiveness of these concept are still ascertain, no hard evidences are supported. Nevertheless, during three years of subscribing the online media newsfeed, it is important to recognise that the idea of using human-power still considers to be one of favoured methods in powering portable devices and as a source to replace conventional energy source.

2.4 Energy Consumption

This chapter shows the literature review in relation to energy consumption and synthesis of published work dealt with changing behaviour in means of bringing sustainable energy consumption. The reviewed works are outside of HPP study realm; however, as this research addresses the over-consumption of energy as one of research problem, understanding its cause is crucial. Below are the relevant research questions to be addressed:

Q4.1: What strategies have been discussed in the past research about behavioural change?

2.4.1 Over-consumption of energy

Over the past decades, our society has seen an extraordinary increase in the number and choices of consumer products, and one of largest sector of increase has been in energy-using products (EuP). According to Energy Saving Trust (2006), between 1972 and 2002, the total use of electricity by household domestic appliances (not including the lighting) in the UK doubled from 44 TWh to 89 TWh. In particular, this publication highlights the importance of the ‘Consumer Electronic’ sector as the most significant growth area of electricity consumption in households. In 2010, Defra, DECC and Energy Saving Trust jointly commissioned a study designed to investigate the actual electricity consumption habits in the UK. This study suggests that the number of energy using appliances in the average household has tripled in the last 3 decades, owning 41 appliances in average, compared with average of 12 in 1972 (Owen, 2012). Although these appliances’ energy efficiency has improved, the growths in the number of these EuP have overwhelmed those gains. It is expected that, by 2020, 45 % of total electricity use (excluding the electric heating) in households will be from the energy consumption of Consumer Electronics and ICT related products such as entertainment, computers, and gadgets (Energy Saving Trust 2007). Some may argue that our destructive and unsustainable use of natural resources is due to the increase of human population and continuing fractionation of families: however, some disagree, and state that statistically the increase of population is not necessarily related with increased resource consumption. As Chapman (2005) describes,

> “it would be more accurate to say that although an increase in human population will bring an obvious increase in resource consumption, the mess we are in today is more likely to be a result of unsustainable development in the way we design, manufacture and consume objects in the modern world.” (Chapman, 2005)

The increased ownership of electronics and other electrical products have influenced people to involuntarily consume energy from the use of daily and socially meaningful objects. In other words, pattern of energy consumption can be described as ‘the routine accomplishment of what people take to be the *normal* ways of life’ (Shove, 2005, p. 117). In real life, people do not consume the energy; they consume the ‘cultural energy service’ that happen to depend on electricity (Wilhite and Lutzenhiser, 1999). Shove (2003) also describes this phenomenon as ‘inconspicuous consumption’. Most energy consuming behaviours are part of these inconspicuous habits and routine. Through use of EuP and its services, people are promised with better performance such as having multiple features to accomplish daily tasks in relatively short-period, reduced labour and enhanced portability. It is assumed that these proliferative developments of such devices are now indispensable in everyday life style and their daily ‘practice’ within today’s society. Therefore, this brings attention to research study focusing on the relationships between the user ad product among micro-level design problems (e.g. invisibility of energy consumption through use of EuP) which leads to increase at macro-level (e.g. increase in overall household energy consumption).

2.4.2 Consumption and theory of practice

Drawing from Giddens’ theory of ‘Structuration’ (1984), especially in the subject of sustainability, many academic researchers have focused on applying ‘practice theory’ as a basis in conducting empirical research involving the performance of everyday practices (Reckwitz, 2002; Røpke, 2009; Shove and Pantzar, 2005; Warde, 2005). It predicates the notion that human agent and social structure constitute together through reciprocal interactions and by accepting the responsibility of environmental problems like energy over-consumption and by changing everyday practices to decrease future detrimental impacts. The system of new product development and re-establishment of new practices are embedded in every society. In the context of innovation, the ‘link between new technologies and new forms of demand has to do with the psychological fabric of society and the relationship between different types of risk taking’ (Shove, 2003, p. 11). While people purchase these new technologies, consuming energy through habits and routinised daily practice of using such products, research studies such as; increasing the awareness of consuming less energy (Jackson, 2005b), change behaviour through design (Jelsma and Knot, 2002) and slow design (Fuad-Luke, 2010) has been receiving attention and became an essential area of research enquiry. However, the notion of practicing ‘sustainable energy consumption’ or 'energy saving behaviour' is unlikely to become relevant issue to consider at the time when those habits occur. This is due to most of everyday energy we use being invisible (Darby, 2001). Meanwhile, companies continue to search for ways of making existing products to consume less energy, yet they produce new products in order to generate new demands for new market (Røpke, 2001). Ingram *et al.* (2007) also argued that design activities and processes are frequently initiated by similar kind of opportunities where it indicates how consumer practices stimulate design; and that new products stimulate new practices. This escalation of demand will inevitably lead to increasing production of new products, services and ownership of products that are more likely to depend on the use and consumption of non-renewable energy sources.

2.4.2.1 Inconspicuous consumption

Although the units of consumption is difficult to measure, Shove (2003) argues the necessity of investigating the invisible forms of practices around everyday life which contributes towards its increase. People tend to inconspicuously become routinised through habits of interacting with everyday products. Shove (2003) has argued that the ever increasing and upward path of demand co-evolves with interdependencies between devices, systems and practices as a part of ordinary sequence. Some criticisms were made against the progress of current approaches that most of attention has been paid to consumer culture and purchased personal commodities (i.e. through style and taste); therefore scholars (e.g. Shove and Warde, 2002) have argued that its approach should also account interdependent practices and habits derived from background notions such as comfort, conveniences, security, and normality. Keeping in mind that much everyday consumption is invisible, modern consumerism put consumer into 'lock-in' (Sanne, 2002) where they find themselves in patterns of unsustainable consumption over which they have little individual control. Therefore, current approaches of many sustainable consumption strategies are fundamentally limited due to focusing on individual behaviour and narrow understanding of social norm, rather than understanding how practices are organised and performed in everyday life (Shove, 2005; Warde, 2005). User behaviours are always subject to influence. Users are not free individuals in the system, but one who is constantly open to influence, the most important of which he or she is generally not conscious of (Fabricant, 2009). Therefore, in some cases, the impact of a design decision may only be one feature of influence among many and due to complexity involved in ‘practice’; it is often not effective as intended by designers.

This notion of understanding the ‘practice’ and consumption has led the author to further review literature on the theory of practice (Reckwitz, 2002; Røpke, 2009; Shove, 2003; Warde, 2005). According to Warde (2005, p. 140), the theory of practice emphasises the processes such as ‘habituation, routine, practical consciousness, tacit knowledge, and tradition’, and sometimes, conventional practices are not fully conscious or reflective. Shove (2003) makes a similar argument that the bulk of consumption is embedded in relatively inconspicuous routines occasioned by the characteristically mundane socio-technical systems of everyday life. Therefore, it can be stated that the normality of energy consumption is constantly changing. But the problem, as much as other literatures argue, is that the users are not aware of the energy consumption while its growth has always been in incremental pace. In many cases, the consciousness of energy use can only be recognised when people have difficulties in using the energy such as moment of blackouts, or when the utility bill arrives.

> “Consumption – which is interesting from an environmental perspective – comes in as an aspect of practices: performing a practice usually requires using various material artefacts, such as equipment, tools, materials, and infrastructures; however, this aspect does not make people conscious of the fact that they are consuming resources in their daily activities. Primarily, people are practitioners who indirectly, through the performance of various practices, draw on resources”. (Røpke, 2009)

2.4.2.2 Material, Meaning, and Competence

While some scholars argue about the invisible or inconspicuous form of consumption occurring in practice, Reckwitz (2002) emphasised that practice theory should not be just approached by, relatively close to, centralising on ‘agent’ and their behaviour. Reckwitz describes the definition of practice as ‘...is a routinized type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, *things* and their use, a background knowledge in the form of understanding, know-how, state of emotion and motivational knowledge' (2002, p. 249). Thus, practice can be seen as an array of heterogeneous elements interconnected to each other, and the artefacts (*things*) are included as elements in the constitution of practice (Røpke, 2009). Based on the work of Reckwitz, Shove and Pantzar (2005) intended to materialise social theories of practice by developing a framework, influenced and echoing the work on relationship between object and people developed by social and technology studies such as Latour (1992), and as well as work on social practice theory by Schatzki (1996). They have argued, in more simple terms, that practice is a configuration of three elements of *Material*, *Meaning*, and *Competence*. Røpke (2009, p.2492) takes this account further to explain each element through concept of 'practice-as-entity', as he describes 'is a set of bodily-mental activities held together by *Material, Meaning* and *Competence*.'

The *competences* require skills and knowledge to carry out the practice which are often learned by experience and training. The component of *meaning* is described as '… about making sense of the activities…, the emotions related to the activities, the beliefs and understandings. Also *meanings* can be generic, in the sense that they are shared by many practices, such as the idea that doing something is healthy' (Røpke, 2009, p. 2492). Last, the *Material* includes the object, equipment, and bodies involved in performing the practice. Røpke's perspective on 'practice' emphasises the challenge involved in promoting sustainable consumption where consumers may be motivated through symbolic actions to reflect their inclination towards a green life style, but most daily practices are undertaken with little consideration for the surrounding environment. Therefore, patterns of sustainable consumption require and are strongly dependent upon the development of sustainable socio-technical regimes (Shove, 2005; Wilson and Dowlatabadi, 2007), and upon reoccurring performance by real-life practitioners (Shove *et al.*, 2007).

Recently, design methods like 'participatory design' (Sanders, 2008) and 'collaborative design' (Jégou *et al.*, 2009) receive attention when the design processes, particularly, involves the understanding of 'actual use' phase of products. The methods become useful when it aims to achieve sustainability by understanding the dynamics of user and object relationships where they are being served by those material artefacts (Jackson, 2005a). The approach often involves inviting user to collaborate in between design process with the design team to identify innovative design strategies and potential domestic goods that are likely to induce energy-saving practices (Jégou *et al.*, 2009). Reckwitz (2002) have suggested that materials play a crucial role in that they make certain practices possible as well as constituting patterns of bodily behaviour and form of mental activities; treating both as elements in constructing somewhat complex system of practice. Acknowledging its complexes, Shove *et al.* (2007), in contrast to the theories of consumption, criticise that role of *things* are still hazy. *Things* are not merely passive tools involved in the performance or accomplishment of everyday practices, but can be a ‘pragmatically useful’ in reproduction of new practices.

2.4.3 Sustainable energy consumption

2.4.3.1 Sustainable consumption – the product longevity.

The literature on sustainable development increasingly recognises the need to address the resource throughput, e.g. using environmental friendly materials; but it rarely discusses the potential role of longer product life spans (Chapman, 2009; Cooper, 2005; Fuad-Luke, 2010). Product longevity means achieving greater intrinsic product durability through maintenance and services of careful use, repair, upgrading, and reuse. It is argued that durability could potentially reduce waste and increasing material productivity (Chapman, 2009). Cooper (2005) points out that despite our prevailing throwaway culture, product life extension has attracted relatively less research interest to date. Thus, he proposes and presents a theoretical model demonstrating how product with longevity may influence on continuity of sustainable consumption. Cooper’s model of sustainable consumption emphasise that such problem may overcome through providing both efficiency and sufficiency. They are a means by which materials and energy are used more productively resulting in longer service with the same quantity; and throughput is slowed by durability, resulting in less frequent replacement of commodities. But there are still many considerations and debates being raised such as downside of upgrading appliances since delaying the replacement will enable the purchase of new appliances that are more energy-efficient. While manufacturers continuously adopt advanced technology to reduce other environmental impact, e.g. use recycled material, reduce use of energy and water for production, some academics argued that planned obsolescence may necessarily bring achievement of technological development. For example, Fishman *et al.* (1993) argued that if products are designed with durability, potential innovators would have less incentive to invest in the development of new technology. This is due to increased durability of products may lock society into stock of using inefficient electronics, resulting in realm of impediment to developing more energy efficient technology. However, measures are still in need for promoting designed products with increased durability for encouraging owners to take extra good care of consumed commodities and to provide greater market incentive for longer-lasting products (Cooper, 2005).

It is recognised that there is an inequality of resource share at global level. The debate of over-consumption of energy will not be relevant to elsewhere other than ‘developed’ countries where they use significantly larger share of available resource. 20 % of world population, largely living in this ‘developed’ countries accounted for over 80 % of overall resource use (Fussler and James, 1996, cited in Fuad-Luke 2010). However, it is suspected that this bulk of consumption does not always occur as people increase ownerships of electricity consuming products but also because of the prolific pace in modern society. Therefore, emerging paradigm like ‘slow design’ is beginning to grow and challenge the notion of continuous production, over-consumption, and unsustainable life style. It represents the opportunities to encourage new levels of awareness and understanding towards consumption while at same time reduces detrimental impact of environmental, social and economic (Fuad-Luke, 2010). This shows analogy with the definition of sustainable consumption defined by Organisation for Economic Cooperation and Development (OECD) as ‘the use of goods and services that respond to basic needs and bring a better quality of life, while minimising the use of natural resources, toxic materials and emissions of waste and pollutants over the life-cycle, so as not to jeopardise the needs of future generations’ (OECD, 2002, p. 2). Although its movement is not focusing just on the energy sector, this type of approach mainly underlines how design can, potentially, bring positive impacts while generating improved relationships and experience between product and user. This notion of increasing the empathy in product-user relationship often offer vision of revitalising our perception about product life-spans which can encourage product longevity through ‘emotionally durable design’ (Chapman, 2005; 2009).

> "…empowering alternative modes of consumption through provocative genres of objects that expand our experience of daily life, rather than closing it down through endless cycles of desire and disappointment." (Chapman, 2005)

Sustainable consumption and interrelated behaviours are such complex subjects, when looking from diverse angle of economic, environment and social. In terms of longevity, it appears that extending life time of product will have positive outcome; yet not simple as it may first appear. There have been vast ranges of approaches taken by designers for strategy within sustainability paradigms such as design for disassembly, design with recycled material and design for reuse. These agendas were summed up by early designers like Papanek (1972) and as recently as Manzini and Jégou (2003) – who realise the potential role in slowing down the environmental decay through appropriate design solution. Chapman (2005, p. 48) puts forward the idea that, in order to avoid such wasteful obsolescence, product must 'mutually evolve alongside users, sustaining value by revealing their true beauty only through the slow passing of time'. He argues that certain empathy rise at point of purchase, and product longevity depends upon maintaining the sustainability of that empathy.

2.4.3.2 The Energy Consumption

In the context of energy sector, increasing the energy efficiency of electronic devices surely brings a reduction in a long term accumulation. However, study has been found that such innovative implementations, though, may not lead to sustainable development as long as consumption of EuP continues to increase. For example in Netherland, OECD (2002) reported that despite significant increase in energy efficiency of many appliances, the electricity consumption were increased by 14 % between 1974 and 1994. On the other hand, some studies has been suggested that policies and programmes need to accelerate the replacement of older appliances that are older than 12 years and combination of new sales based only on A+ class (energy efficiency level) will deliver large energy savings (Bertoldi and Atanasiu, 2007). For example, Rüdenauer and Gensch (2006) have claimed that by replacing 188 million existing appliances older than 10 years with the most recent energy efficient products, it is speculated that 44 TWh can be saved. Also, the reduction of standby losses may offer attractive saving potentials. For example, as results of the EICTA [14] unilateral voluntary agreement introduced in 1997, new TVs use significantly lower standby power than older models. Despite this, the overall consumption is likely to be a continuous increase due to more hours of TV viewing and as well as increased number of new equipment around such as converter boxes and DSL modems. For example, total sales of TVs have seen a dramatic 15 % increase between 2004 and 2006 (Energy Saving Trust 2007). However, the combination of high consumer spending and the increased level of innovation such as ‘flat screen’ TVs seems to be the power driver for increasing sales.

This prolific increase of consumption towards ICT (Information Communication and Technology) related devices takes significant part of overall energy consumption in households. Therefore, studies within interaction design (e.g. HCI), the sustainability draws attention as central area of concern (Blevis, 2007). More precisely, studies have been focusing on investigating domestic energy consumption (Chetty *et al.*, 2008; Pierce *et al.*, 2010b; Strengers, 2011), sometimes approaching the problem by re-designing the system that is simply beyond the computer interfaces (Backlund *et al.*, 2007), in order to bring a reduction of energy through use of these devices. Studies within HCI has been using the term *Sustainable Interaction Design* (SID) founded by Blevis (2007, p. 503) under definition of ‘an act of choosing among or informing choices of future way of being’. This framework outlines the implication of technological designs practicing ‘cradle-to-cradle’ (McDonough and Braungart, 2002) mentality, highlighting the ways we can design products for better reuse, and opportunity to fundamentally rethink the methods of HCI in order of addressing sustainability (DiSalvo *et al.*, 2010).

In a similar context, the study of HPP should not only focus at bringing the increased efficiency but also look into ways of how design can help the longevity of its use. In other words, approaches should not simply be reliant to applying technological solutions, but also consider how changes in behaviour during the use-phase can bring greater impact in addressing the issue in question. The realm of designer’s role in achieving the sustainability also resides in a position to reduce use impacts by purposefully shaping behaviour towards more sustainable practices.

[14] European Industry Association for Information Systems, Communication Technologies and Consumer Electronics

2.4.4 Rebound Effect

Although many electrical products' eco-efficiency has significantly improved, statistics show that the aggregate consumption of energy, especially electricity consumption, has continued to grow or remained static in UK (DECC, 2011b). For example, total use of electricity by household domestic appliances in the UK doubled from 1972 to 2002 (Energy Saving Trust 2006). Therefore, the word 'rebound effect' or 'take back'[15] has been, theoretically, neutralising the gains of any artefacts made with eco-efficiency in mind. This effect is also known as 'Khazzom-Brookes postulate' (Herring, 1999), where it was coined by US economist Harry Saunders in 1992, and also influenced from a paper by William Stanley Jevon, first published work "The coal question" in 1865, also widely known as 'Jevon's paradox'. According to this paradox, the invention of products requiring less coal consumption actually led to greater overall coal consumption due to increased number of cheaper-to-operate products. Recently, the concept claims that technological advances may cause a decrease in energy consumption initially, but in the long run, it will increase the consumption due to a growing volume of activity that will eventually offset the initial gain (Herring, 1999). For example in UK, in between 1999 and 2003, average unit energy consumption of washing machines fell by 4.5 % but total consumption rose by 18.5 %. At the same time, the number of washing machines rose from 20.4 million to 25.4 million (DEFRA, 2003).

These days, the term applies to many technological interventions implemented with the purpose of reducing the impact of their product use or reducing energy consumption through improved energy efficiency. From an energy economic perspective, the results of energy efficiency measure includes behavioural change leading to a cost reduction from use of energy services (Hertwich, 2005). However, the rebound effect arises when confronted with actual use behaviours, where unintended uses of products leads to unpredicted and often negative environmental, economic or social consequences (Greening *et al.*, 2000). For example, people may buy an energy efficient TV but they may end up watching more by believing that it

[15] The term 'take back' sometimes refer to manufacturer's service scheme of taking back the used white goods to recycle, reuse, or refurbish for resale or reproduction (Huisman *et al.*, 2004). However, in this chapter discussing about the 'rebound effect', the same term has been used by referenced authors to explain the rebound of conserved energy from increased efficiency.

will still consume less. This rebound effect may become more ordinary as people are confronted with an increasing number of ICT related devices. These intangible interactions, but arguably efficient, tend to be added to our daily practices and becomes more un-sustainable through what Manzini (2003) says are 'access-based' rather than 'product-based' interactions. These dematerialised services in age of 'access-based' has a tendency to saturate contemplative time, considered as privilege in old days, due to accelerated processing capability; and by enabling people to do several tasks, and more, at the same time. Arguably, technological progress and its improved efficiency put people into 'lock-in' (Sanne, 2002) and they tend to 'take-back' some of the 'savings' occurred from these efficiency. In contrast, Greening *et al.* (2000) reviewed literature of empirical evidence measuring the size of rebound effect in US residential energy use such as water heating. The paper critically reflects on the notion that the size of rebound effect is remarkably small, sometimes less than 1 %, especially in white goods sector. Therefore, in an energy sector, the estimates of rebound are relatively low and its effect is not significantly noticeable to consider for any moderation. However, these studies emphasise that it is missing the unified definition to evaluate such effect and their measures which affects from different variables[16] of end-use; therefore, the results not so definitive at micro-level (Binswanger, 2001; Hertwich, 2005). Also, such effect is often not directly observed but rather derived by escalation of service demands and associated income which could increase the over-all consumption at macro-level.

2.4.4.1 HPP & Rebound Effect

While many technological interventions focus at supply side; i.e. increasing the efficiency of power supply unit; the idea of using HPP, at least in this research, focuses on the effect of how demand towards using conventional energy source can decrease; or observing the increase of demand towards using human-power during the actual use-phase of HPP.

This research started off by setting a scenario based hypothesis that HPP has the potential in bringing about the reduction of energy consumption at macro-level by

[16] Key variables may include income, other expenditure, household demographics, cost per capital, etc. Also, Greening's (2000) evidence describe the effect through single-service model like changing room temperature rather than on the demand for energy per se.

increasing the number of HPP used in household. This idea was explored through 'scenario building' (Fulton Suri and Marsh, 2000) as a tool to develop alternative fictional use of HPP. The scenario was based on the idea of substituting current micro-level consumptions which rely on the grid power; to micro-level consumption from energy generated by HPP. Figure 2.16 is a diagram demonstrating the process of how 'Rebound Effect; or 'Take-Back' occurs comparing with HPP scenario. In a normal energy consumption scenario (left section of the diagram), it shows a projected scenario of using micro-level of consumptions, e.g. energy consumption arising from using consumer goods, which is outlined in bold to show the overall consumption at macro-level. Moving from left to right, as energy efficiencies of micro-level consumption increases (the size of red box became smaller), the overall macro-level consumption shows a conserved energy gap – the potential 'saving'. The rebound effect arises as people start to believe that overall consumption will still be less due to increased energy efficiency, and people tend to consume more and add extra micro-level consumption; therefore, macro-level consumption increases. However, in case of HPP (right section of the diagram), the increased efficiency means that the size of generated power from these systems or devices will increase the capacity; therefore, it contributes in reduction of overall energy consumption at macro-level; generating more 'off the grid' power. Energy efficiency in HPP will eventually decrease the energy consumption to drive attached functions from stored energy and therefore increase the size of 'free power' from same required labour. In other words, it is 'taking back' from what is 'earned' (micro-level HPP) from generating its own electricity; rather consuming from 'saving' (conserved) that is gained from increased efficiency. Thus, from an energy consumption perspective, the words 'efficiency' and 'rebound effect' are unlikely to be applied nor derived at the discussion of sustainable consumption in the field of HPP.

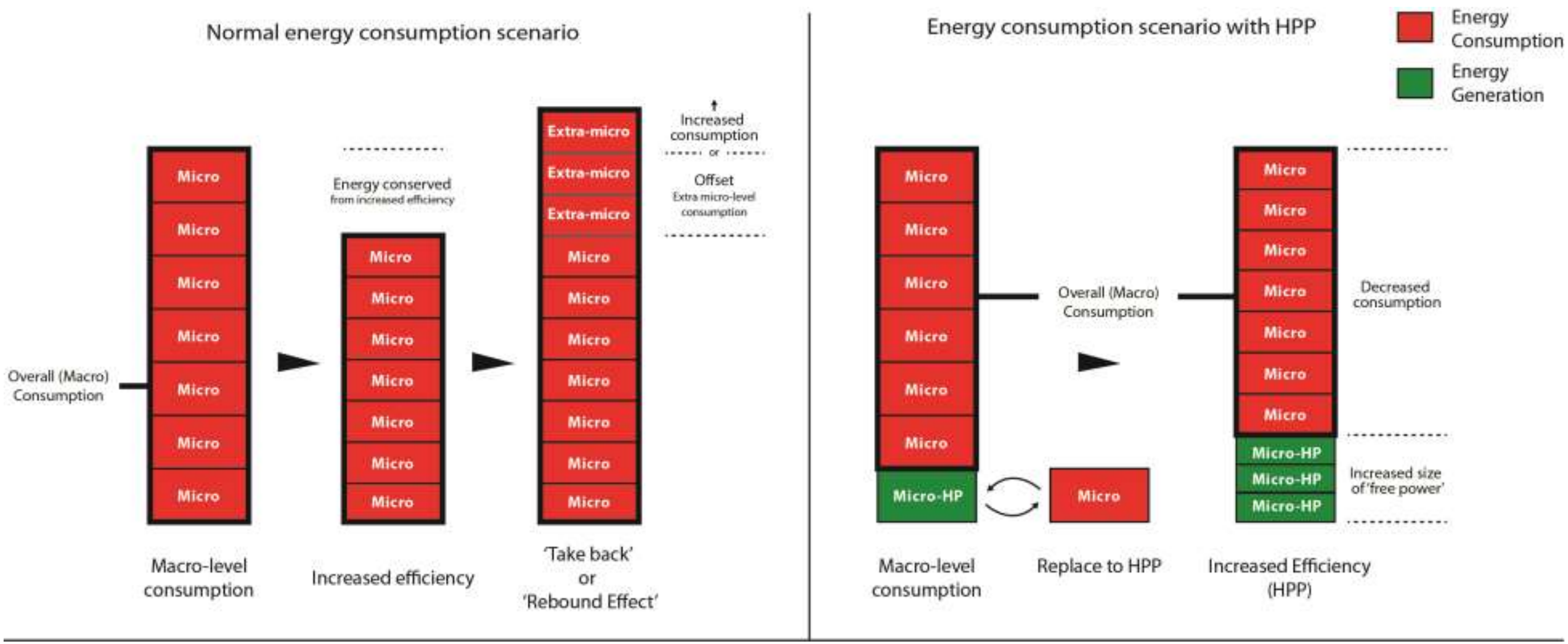

Figure 2.16 Model (hypothetical) of rebound effect affected by increased efficiency and model of energy consumption affected by increased efficiency for HPP

It can be argued that using HPP is a ‘curtailment behaviour’ which involves the effort of reducing the energy consumption, such as turning off more lights which requires constant actions; rather an ‘efficiency behaviour’ - one-shot actions that entails a lasting effect, such as buying a hybrid car or insulation (Gardner and Stern, 2008); also known as ecological modernisation (Spaargaren and Van Vliet, 2000). However, ‘increased efficiency’ in power output of HPP, meaning higher output density, may be considered as necessary step in future developments of HPP for achieving greater savings. Nevertheless, the rebound effect may occur as purchase of these products increase at some level where actual cost savings are not achievable due to much larger costs invested at over-purchasing such products.

2.5 Inducing Sustainable Behaviour

This chapter brings together the literature review that relates to theories inducing sustainable behaviour and design interventions in relation to eliciting energy saving behaviour. It also includes theoretical notions of how motivation influences habitual actions, and discusses some deficiencies of current design approaches for instigating behaviour for encouraging sustainable energy consumption. The literature review covered in this chapter aimed to provide background knowledge for investigating answers to following research questions:

Q 3.3: What are the missing elements or barriers in design of HPP that prevent people from using it for longer-term or even short-term period?
Q4.1: What strategies have been discussed in the past research about behavioural change?

2.5.1 Changing attitude; motivating pro-environmental behaviour

One of the main causes of over-consumption is suspected to be households’ lack of understanding and awareness of the link between actual energy use and environmental consequences, including the monetary aspect. Thus, changing energy consuming behaviour is far more complex than dealing with psychological, social and cultural attitudes. The solution to this problem has often been found from the provision of large-scale information and knowledge dissemination implemented through governmental campaigns or policy makers. These info-based interventions encompass motivational factors such as commitment, goal setting, information, and modelling which are so-called ‘antecedent interventions’ (Abrahamse *et al.*, 2005). These types of interventions aim to influence behavioural determinants which potentially lead to pro-environmental decisions or behaviours. Scholars have been conducting reviews in literature discussing the models of behaviour change and empirical evidences to support various theories. Especially in relation to sustainable consumption and pro-environmental behaviour, many have used socio-psychological models of decision making and how attitude-behaviour tradition formulates (Jackson, 2005b; Wilson and Dowlatabadi, 2007), in order to gain greater acceptance of interventions aiming to bring pro-environmental behaviours. Nevertheless, a more complex model continues to grow. Jackson (2005b) even acknowledges this through his work on reviews of literature on behaviour model that ‘borders on the unmanageable’, as it comprises over sixty models including an integrated model.

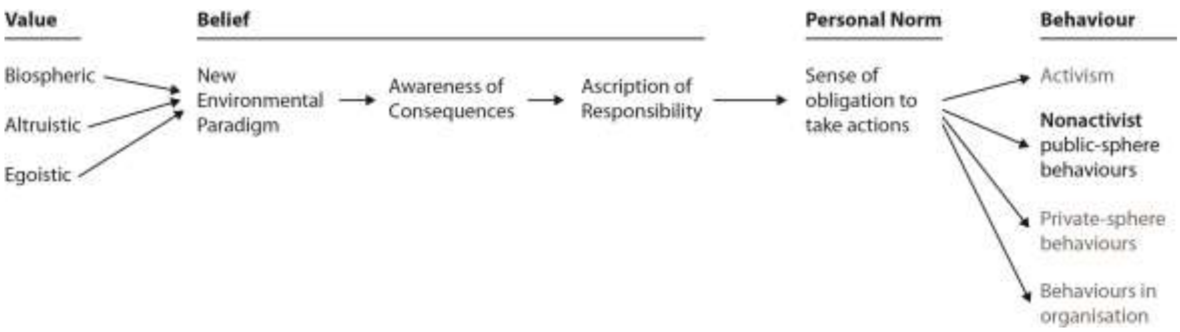

Figure 2.17 Stern’s Value-Belief-Norm Model (Stern, 2000)

From a social psychological point of view, identifying the determinants leading to pro-environmental action has become a central concern. These determinants mainly revolve around how propensities or dispositions formulate to activate such action with a pro-environmental intent. Most prominent theories are developed by Stern (2000), ‘Value-Belief-Norm’ Theory (VBN), Figure 2.17, of environmentalism which builds on from Schwartz’s ‘Norm-Activation’ theory. These theories view pro-social motives as, one of, most important activators rather behaviour driven by ‘self-interest’ (Bandura, 1994); based on the premise that moral or personal norms are main basis for predisposition to pro-environmental action. The VBN theory extends the view by emphasising that value-based attitudes or personal norms get mediated by particular values, such as personal achievement (egoistic), value other species (altruistic), and curiosity towards environmental consequences (Biospheric) (Stern, 2000), or sometimes by collective guilt (Ferguson and Branscombe, 2010). All these attitudinal factors suggest that pro-environmental behaviours can be influenced once awareness of consequences are recognised through interventions. However, Stern underlines that these moral and antecedent interventions which activate certain behavioural change have not been so effective, but strong evidences support that combination being much more effective than applying sum of two interventions (Stern, 1999). The variables in this combination include influences of attitudes and contextual factors such as monetary incentives, physical capability and constraints, legal penalty, and social norm (Barr, 2003).

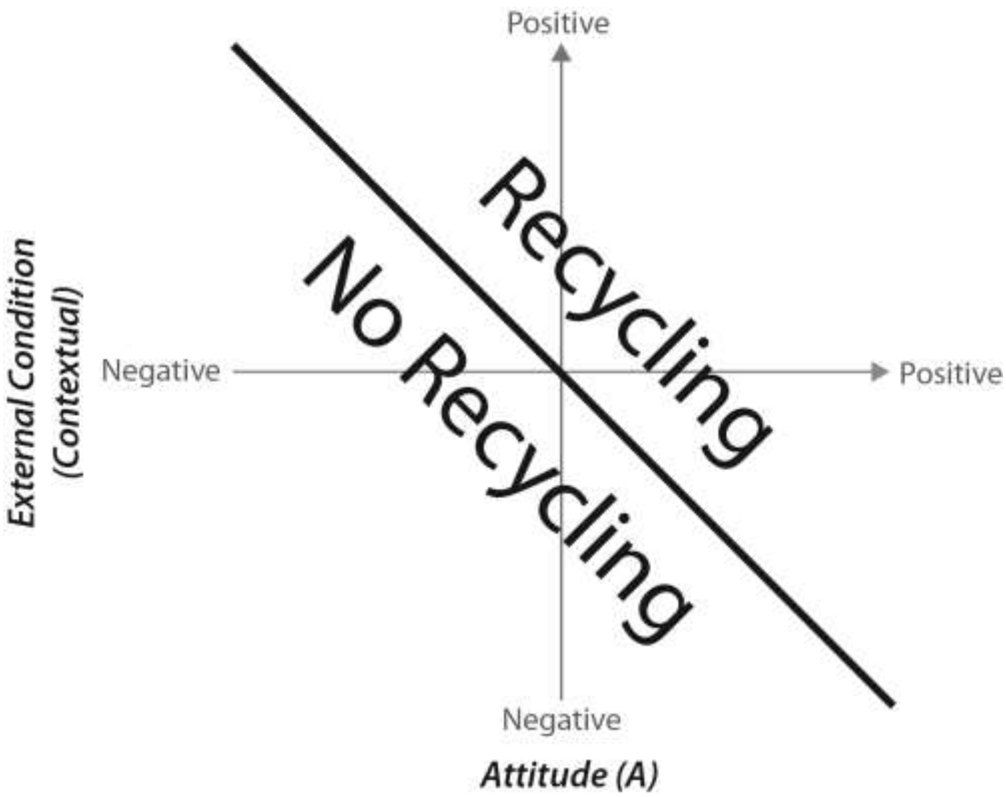

Figure 2.18 Attitude-Belief-Contextual Model of recycling (Stern, 2000)

This notion of encompassing both attitudinal (internal) and contextual (external) factors as determinants in bringing behaviour change led to development of model called ‘Attitude-Behaviour-Context’ (ABC, Figure 2.18) theory developed by Stern (2000). The model advocates the concern over studies using a single variable resulting in inconsistency of end results and incomprehensive understanding of how behaviour change occurs. Therefore, it associates external conditions (contextual) to bring a behavioural change. As model demonstrates, providing positive external conditions such as incentive enhances the effect of recycling behaviour. However, it does not mean that pro-environmental behaviour cannot be influenced through antecedent interventions. Some studies apply the intervention outside the regime of external condition. For example, McMakin *et al.* (2002) examined the behavioural change model (campaign) that is tailored to individual environment through pre-intervention consultation. The targeted energy consumers were residents of government-subsidised facilities, who do not pay their own utility bills, therefore unlikely to be influenced by any external condition like incentives. The study suggests that people made behavioural change as a result of campaigns undertaken at two different locations. The end results show that measurable reduction of energy use was observed, mediated by social and personal motives such as altruistic belief (e.g. need to do the right thing) and to model good habits for their children. McMakin *et al.* (2002) emphasise that customised interventions are effective under conditions of tailoring the information to target demographic through pre-intervention consultation, understanding other variables that influence on behaviour in a specific environment.

2.5.1.1 Delivering Incentive and Penalty Information

Whilst most antecedent interventions focus at stimulating attitudinal factors for influencing pro-environmental behaviour, it is noted that there are other external factors affecting on its determinant; and information campaigns alone may not be so effective. A wide range of studies have been undertaken, with empirical evidence to highlight the need of taking into account of different external variables like incentive and penalty to overcome such barriers (Pierce *et al.*, 2010b; Stern, 1999; Verplanken and Wood, 2006). For example, notable incentive has influenced on determinants of purchasing high-efficiency appliances and home insulation to conserve energy (Bertoldi and Atanasiu, 2007). An example of penalty can be seen at policies prohibiting car lanes for carpooling – known as ‘Coercive Motivational Technique’, and prompting signage showing energy consumption rate of an elevator to encourage use of stairs, known as ‘Persuasive Prompts’ (De Young, 1993). These strategies, based on assumption, focus at attaching information of positive or negative consequences of intended behaviours in order to gain certain rewards from performing changed, and positive, behaviour. As people respond to either antecedent interventions or positive incentives, when these strategies fail to achieve anticipated result, penalties can be enforced to limit unsustainable behaviours. This type of approach, often called 'carrots and stick' approach, originates from behavioural psychology arguing that 'we learn what to do (and what not to do) by experiencing positive (and negative) reinforcements (rewards or penalties) for our behaviour' (Jackson, 2005b, p. 109). However, according to Chetty *et al.* (2008), it was found that financial incentive may not be sufficient to motivate all households to manage energy consumption since labour around bill paying is dispersed and that only certain people take prices into consideration. Moreover, there are downsides to these 'consequential interventions' where once incentives are taken away, the changes are likely to fade away (Darby, 2006). Stern (1999) points out that these consequences (e.g. financial incentive) may influence on behavioural change but less likely to occur unless appropriate information makes individuals to be aware that incentives are available. In other words, certain feedback must be provided and inform the consequences of those new behaviours.

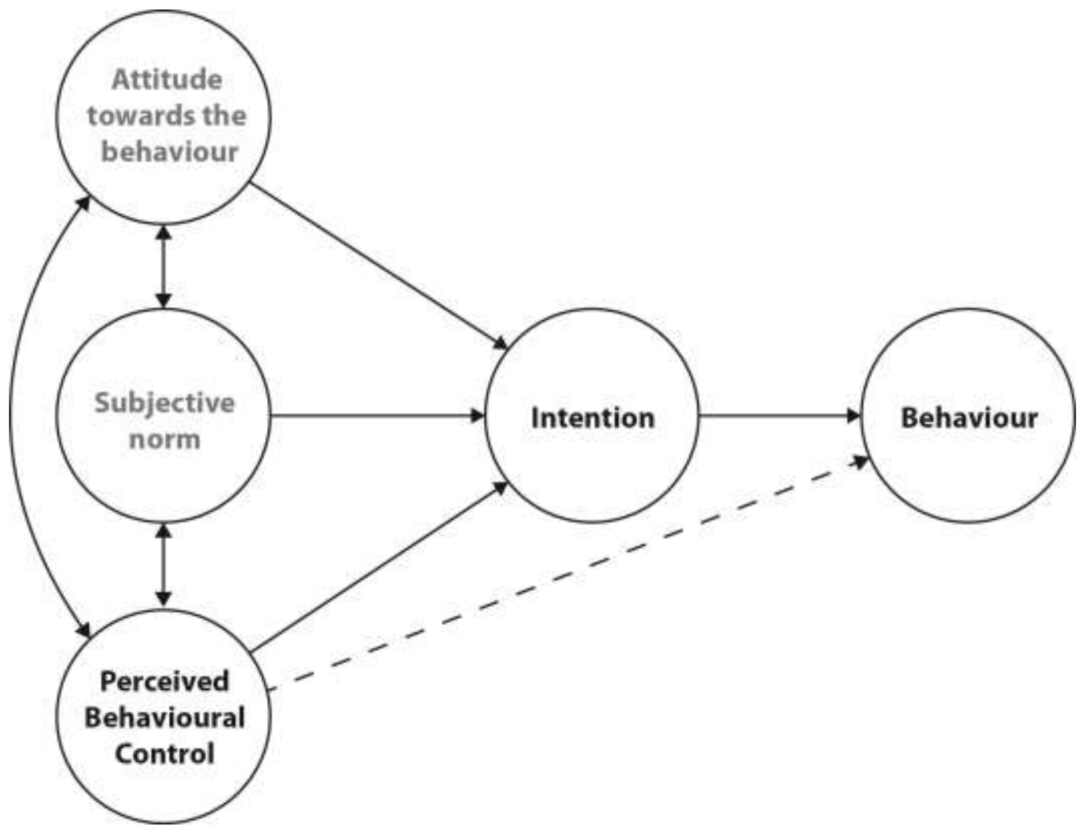

Figure 2.19 Theory of Planned behaviour (Ajzen, 1991)

Feedback is often implemented to reinforce ‘self-efficacy’ (Bandura, 1994) that leads to pro-environmental intent. For instance, when feedback information about potential energy saving (incentive) is given to households, perceiving possibilities of conserving energy, it may eventually increase self-efficacy to reduce further energy use (Abrahamse *et al.*, 2005). Ajzen’s (1991) ‘Theory of planned behaviour’ (TPB), Figure 2.19, explains this process by calling it ‘perceived behaviour control’ (PBC) whereby people will assess the outcome of consequences and make it into a belief as to how easy or difficult that behaviour is. Beyond the determinants of attitude and subjective norm, Ajzen (1991) argues that ‘PBC’ become an additional indicator for intention and action towards new behaviour. He argues that if the individuals have volitional control over their actions, having confidence to master a particular activity, then intention is likely to correlate closely with behaviour.

According to Van Houwelingen and Van Raaij (1989), there are several functions to feedback. First, feedback has process where consumers learn the energy consequences of specific behaviours through acknowledging the information (e.g. energy costs and unit, the incentives). Second, it is formation of habit, going through process of routine actions being set and reinforced. The third function is internalisation of behaviour. People become energy-conscious as consequences of their energy usage behaviour are confronted, and adopt new attitudes to their new or changed behaviour. Particularly when using the feedback as combined intervention with antecedent intervention like goal-setting, the effectiveness of such intervention achieves better results in bringing about the change (Abrahamse *et al.*, 2005; McCalley, 2006; Van Houwelingen and Van Raaij, 1989). Despite the functions of feedback which allows energy users to associate their consequences of behaviour or consumption, whether positive or negative, the effectiveness may differ upon its frequency in delivering the consequential information. Abrahamse *et al.* (2005) reviewed literatures exploring different ranges of feedback frequency such as continuous feedback (e.g. monitor displaying electricity use in cent per hour), daily feedback to more long-term feedback like monthly energy bill. The study suggests that more frequent the feedback information is given to users, the effectiveness measured much high. As noted from antecedent interventions studies, single intervention may not bring as much anticipated result in bringing a behaviour change. A typical study was conducted by Van Houwelingen and Van Raaij (1989), investigating the impact of using multiple interventions in residential homes located in province of Utrecht (Netherlands) on reducing natural gas consumption. The interventions include technique of goal-setting and providing daily consumption, comparing at continuous (i.e. instantly showing the consumption in per hour cost) and long-term frequency (i.e. monthly feedback). The result found that continuous feedback in conjunction with goal-setting reduced the consumption of natural gas by 12.3 %. Thus, the feedback is seen as a tool prominently being used among related study of investigating the possibility of energy conservation through interventions. It is also perceived as reinforcement for maintaining the changed behaviour. Also, the effectiveness may vary depending on how feedback information is interacting with people Stern (1999).

2.5.1.2 From Socio-Technical regime

All of the studies around finding the effectiveness of interventions in an attempt of bringing behavioural change, whether they deal with antecedent or consequential factors, or both, share basic assumptions that many different variables affect their end result. For instance, Jackson (2005b) explains the weakness of such approach using an ABC model as an example that when behaviours are limited by external (contextual) factors, essentially there was no link between attitude and behaviour. So, once external factors create certain personal benefit, the intervention should focus on relating internal factors such as attitude and norm that eventually avail activating new behaviour rather than further increasing the external factor (e.g. incentives) (Stern, 1999) or vice versa. However, it is argued that interventions addressing single factors are likely to be effective in short-term and that attitude may have weak impact when behaviours are strongly regulated by external factors (Jackson, 2005b; Wilson and Dowlatabadi, 2007). This is, arguably, due to lack of understanding on how those behaviours formulate within regime of social practice and ignoring complex issues like subjective experiences of interacting with feedback information. Thus, the effectiveness of combined interventions depends on how well the feedback information is explained and interacting with the energy users. While contextual variables are favoured by psychologist in discussion of changing behaviour, sociologist like Shove (2003) has argued that external variables co-existed and evolved along with development of technology to regulate behaviour. From socio-technical perspective, individuals’ decisions are constructed through complex relationship between social and technological systems rather being an autonomous agent (Shove, 2003; Wilhite and Lutzenhiser, 1999). From designer's perspective, this notion brings attention to how we design the element of *Material*. As mentioned earlier, people do not consume nor have direct decision on energy consumption but rather they consume the meaningful services which enables social and norm activities within the pattern of energy consumption. Thus, feedback is necessary but not as sufficient in bringing about changes in behaviour without acknowledging wider social and cultural influences on everyday household energy use (Lutzenhiser, 1993).

This notion of linking the individual's act and social norms are mediated by implications of how everyday 'habits' are formed through repetition and reinforcement in practice. Many precedent habits are less likely to link with the confronted issue (e.g. over consumption of energy) because the issue was not a relevant concern at the time when the habits were formed (Fischer, 2008). In other words, the focus changes from individuals' capabilities of making choices for their behaviour, to understanding of how these agents are constrained and influenced by social-technical systems through aspects such as habits and attitudes. Barr (2003) has argued that policymakers are yet fully appreciating this complex relationship between individual and social structure that influences the behaviour; and abide around notion that appropriate campaign, linking macro-level issue (e.g. global warming) to micro-level activity, will have some effect. Barr has presented several flaws in approach of information-based interventions that attempts to bring effect through increasing the awareness of environmental problem. For example, the first flaw is that the behaviour is contingent upon factors such as personal situation, psychological perceptions, and environmental value. Policymakers take little account of demographic trend in environmental behaviour in which the greater impact can be achieved if interventions are targeted and tailored (see McMakin *et al.*, 2002; Roundtable, 2006). Additionally, more attention should be given to account of how practices get formulated within regime of socio-technical systems at particular domain of everyday life (Hargreaves, 2011).

2.5.2 De and Re-routinisation

According to Giddens (1984), habits are part of routine performance of daily activities going through actions of ‘practical consciousness’ that are repeatedly performed and familiarised in daily life. These habits are sometimes reinforced through actions of ‘discursive consciousness’ where people have the ability to examine and evaluate their own behaviour through reflection on social discourse like information campaign. However, Spaargaren (1997) argued, as well as other academics have been, that one-sided emphasis of an intention, attitude or individual motives are only effective in the short-term; and that the most important aspect in behavioural change is the process of re-routinising the de-routinised behaviours.

The word ‘de-routinisation’ refers to a moment when internal or external factors enable people to examine and assess their routines or behaviour patterns from an environmental perspective; similar to ‘perceived behaviour control’ (Ajzen, 1991). For example, people hardly pay attention to the functioning or performance of the water system when using the tap because they are ‘inconspicuous’ (Shove and Warde, 2002). However, once interventions like brown water coming out of the tap or a very high utility bill appear in between their behaviour, these external factors enable them to assess their precedent routine of consumption. Articulating from sustainability of subject-object interaction, Chapman (2005) argues that due to material culture, interactions have become an unconscious process that people are not aware of until the object misbehaves. Fischer (2008) also explains that a conscious decision is required to be put in place for new norms and considerations to enter the decision-making process, meaning that habits must be broken up somehow. Fischer called this process a ‘norm activation’ stage where the person realises that there are various options to choose from, making his or her behaviour relevant to the problem, and become conscious that they have possibility to influence and change their behaviour. As highlighted before, the feedback or its system plays a crucial role in this case, and most importantly, it is perceived as a function of *Material* (Røpke, 2009) interacting with the user to help carry out a practice. Moreover, it can also be a ‘pragmatically useful’ for reproducing new practice (Shove *et al.*, 2007).

In more simple terms, people are going through a learning process where information (feedback) challenges their previous choices, and adjust themselves into exercising a different choice in practice. Spaargaren (1997, p. 148) explains the similar process that people ‘become aware of certain habits…and thus learn something about their own behaviour which can eventually induce them to change that behaviour’. From a ‘re-routinisation’ perspective, it is argued that such successful performance of a particular behaviour also reinforces later performances of the same action (Jackson, 2005b), and that sources of changed behaviour lie in the progress of practices themselves which accommodates reproduction of behaviour and innovation of socio-technical system (Shove *et al.*, 2007). For example:

> ‘I am happy with the taste of the new coffee and its ethical sourcing offers an additional satisfaction. When the action itself is associated with a clear positive reinforcement, and repeated over time, a ‘cognitive script’ is developed which enables me to repeat the same action in similar circumstances with very little cognitive effort. This final *procedural* stage locks me into a new coffee-buying habit and virtually without thinking now I toss the ethically traded coffee into my supermarket trolley week after week. At this stage, my behaviour is more or less automatised and bypasses rational deliberation almost completely’ (Jackson, 2005b, p. 114)

It is argued that changed behaviour can be maintained through repeated exposure to similar interventions (Geller *et al.*, 1990). In other words, once the habits are broken, repeated intervention can be an essential activator and becomes a reminder. But habits or routine behaviours, in many cases, are difficult to change. So far, there is a remarkable theoretical and empirical understanding that provides knowledge into changing environmentally detrimental habits through interventions. However, it has been noted that many previous techniques in bringing pro-environmental behaviour have been promoting interventions that are modulating short-term behaviour. De Young (1993) argues that real challenges should focus at maintaining the stability of changed behaviour, and at same time, minimising or eliminating the need for repeated intervention. In addition, the effectiveness of interventions depend on the process of changing existing habits, initiating new behaviour, and maintenance of that behaviour (Steg and Vlek, 2009; Verplanken and Wood, 2006).

While other academics emphasise on the interventions dealing with feedback or implication on external factors (extrinsic motivation), De Young (1993) highlights the importance of ‘intrinsic motivation’ which has effect beyond tangible rewards like incentive. He argues that ‘intrinsic motivation’ may reduce the side effects of intervention by making individuals discover a behaviour that is worth doing for its own right; inherent satisfaction gained by direct experience of those interventions. However, in the view of HPP, Jansen and Stevels (2006) explains that users of HPP are required to apply certain ‘added discomfort’ to generate an electrical power and certain level of motivation to support the intention. In return of applying that energy, users need to go through learning process of perceiving the feedback information such as; power required to drive the product, absolute time of charging, and interaction of product interface. Still, it is under speculated and yet investigated whether publics accept those feedbacks or those interventions as positive or negative; moreover, whether design of HPP does provide sufficient consequential feedback in order for user to go through a ‘perceived behaviour control’ (Ajzen, 1991) or ‘norm activation’ (Fischer, 2008).

With this notion in mind, current research rationalised the decision on excluding the further investigation of HPP that powers by parasitic harvesting methods; due to the fact that such system does not involve any ‘breaking the habit’ nature nor concept of ‘re-routinisation’. It was pointed out that interaction in today’s material culture becomes an unconscious process and people are unaware of until objects misbehave. This decision also derived from reviewing two distinctive definition of energy saving behaviours used by Gardner and Stern (2008); they are the ‘efficiency behaviour’ and ‘curtailment behaviour’. They have suggested that ‘efficiency behaviour’ - one-shot behaviours that entail the purchase of energy-efficient equipment; are generally more effective in producing larger savings than ‘curtailment behaviour’ - requiring repetitive effort to reduce energy use, i.e. lowering thermostat setting or turning more lights off . Most parasitic harvesting HPP are perceived as a device generating ‘free energy’ which utilises daily human movement; they are ‘Self-powered devices’ (Paradiso and Starner, 2005). If one chooses to reduce the energy consumption through adopting a new technology such as a piezoelectric floor system in their domestic environment, it can be perceived as ‘efficiency behaviour’ - free energy are being ensured and entails as people purchase the device at one-shot. These technological interventions mainly have the important psychological benefit of requiring few actions or with little need for continuing attention and effort (Gardner and Stern, 2008). However, in the context of bringing pro-environmental behaviour, it has been suggested not to view the *things* as merely as passive tool involving in performance of everyday practices (Shove *et al.*, 2007). Moreover, such system is not perceived as intervention which puts people into learning process, realising their electricity saving paradigm.

Most of parasitic harvesting system aims to ‘indirectly’ scavenge energy source from people’s everyday actions; therefore, it is sub-conscious. The concept of these type of systems sheer away from main aim of this research; investigating how the ‘use of human-power’ and designed interactions in HPP could lead to an interventions for instigating the change of existing attitudes and behaviour in regards to energy use and consumption. The review on literature so far discussed interesting aspects in behavioural change towards bringing positive environmental impact (e.g. prevent over-consumption of energy) through interventions; providing educational information (e.g. campaign), motives, and incentives. Since many intervention techniques exist, it is important to clearly rationalise any future HPP study in aiming at bringing a reduction of energy consumption, whether their focus is generating free energy by stealth; changing precedent patterns of inconspicuous energy consumption; inducing a curtailment behaviour or to encourage practice energy saving behaviour. However, it is recognised that providing feedback information along with parasitic harvesting methods (e.g. a sustainable dance floor with a display indicating the amount of power being generated, see Figure 2.20) may provide a learning process through displaying consequential information which in turn gain some knowledge about human-powered systems, therefore sheers to becomes a ‘conscious’ activity. In the past few years, the company commercialising the ‘Sustainable Dance Club’ has been focusing on developing ranges of feedback systems that combine with their Energy Floor module. The applications are aimed at delivering tailored interactions based on the location of the installation such as a festival or a night club. The feedback system can be integrated as a product that adds value to the experience involved in interaction such as through screens, sound system, lights, and gaming software (Anon., 2007)[17].

[17] Sustainable Dance Floor

Figure 2.20 The Energy Tower (Feedback application) for Sustainable Dance Floor module (Anon., 2007).

2.5.3 Energy Feedback system

Most of interactions with everyday EuP seem to be performed without conscious consideration of energy. In most households, for instance in UK and western countries, the standard route to track the energy consumption is information presented through text-based electricity bill. Energy consumption is not, sometimes, seen as coherent field of action, but rather it involves daily activities like listening to music and working on a computer. Moreover, the energy use turns out to be a 'low interest' interaction due to its cost not significantly affecting on overall household's budget, as yet, although they regard electricity (energy) as a necessity (Fischer, 2008). Therefore, research on making energy more visible has received increasing attention over the last years (Darby, 2001; Dwyer *et al.*, 1993). Typical interactive system of feedback, also called IHD (In-Home Display) by Strengers (2011) or REFS (Residential Energy Feedback System) by Pierce *et al.* (2010a), provides digitalised display that shows instant usage of energy within household. The device aims to encourage householders to 'save' consumption and minimise 'waste' that are related to existing everyday practices. This idea avails from the growing recognition that efficiency of energy alone is inadequate to achieve a larger scale reduction in their consumption (OECD, 2002), at that the impact can also be achieved through changing people's behaviour. Additionally, recent studies (e.g. Pierce *et al.*, 2010b) support the notion that most of households do not track their energy consumption nor knowing in units; and shows a lack of knowledge about basic per unit costs[18]. Energy consumption during the use phase of EuP has a significant environmental impact mostly regulated by user's behaviour (Lilley *et al.*, 2005; Lockton *et al.*, 2008; Wever *et al.*, 2008). Thus, motivating sustainable behaviour through system of feedback on peoples' energy consumption may give control over their consumption, giving an 'empowerment' (Dean, 2008; Hargreaves, 2011; Hargreaves *et al.*, 2010), and eventually save energy (Fischer, 2008).

The system of feedback on energy consumption, also known as 'eco-feedback' motivates users to increase awareness of their energy usage. Darby (2001) classifies three major types of feedback system – direct (learning by looking or paying, e.g. Smart Meter), indirect (e.g. frequent bills) and inadvertent (energy conservation, e.g. photovoltaic). Her review of 38 feedback studies indicate that 'feedback' plays significant roles in raising energy awareness and achieving reduced energy consumption of the order of 10 %. The most popular feedback system was an energy meter where the user is presented with specific data-based information on the impact of his or her current energy consumption; however, it is still reliant on the decision of each user whether or not to sustain the adopted new behaviour(s) affected by these feedback systems. The eco-feedback systems, in theory, may be recognised as an applicable method in increasing the awareness of one's behaviour (Fischer, 2008), especially when the electricity consumption links with appliances and associated activities. However, the effectiveness of these systems is still in debate (Pierce *et al.*, 2010a). Some criticisms were presented against eco-feedback systems that they have a similar strategy to an educational intervention where information itself does not necessarily lead to behaviour change. According to Strengers (2011), eco-feedback is likely to appeal only to those who are environmentally motivated, and conservation benefits may languish over a period of time. Recent studies (Hargreaves *et al.*, 2010; Pierce *et al.*, 2010a; Strengers, 2011) shows that many householders discontinued using the energy

[18] Pierce has conducted simultaneously obtaining both qualitative and quantitative data, focusing on everyday interactions with energy-consuming products. The survey results showed that 80.5% of respondents personally paid their monthly bill, only 25.8% claimed to be "very sure" of rough figure; 24.1% had "no idea" or were "just guessing" (Pierce *et al.*, 2010b).

feedback system, or the anticipated behavioural change was absent due to the disconnection between consumption data and the perceived non-negotiability (e.g. blowing a hair dryer every morning) of everyday practices. This emphasises the fact that the feedback device only gives information data of how much people consume, rather than providing a solution to encourage people to instigate behaviour change such as energy saving behaviour. Prochaska *et al.* (1993) touches again on this point from an intervention design perspective, that it should consider the particular processes that influence change at each stage. Considering thermostat-setting as an example, early stage may be more relevant with increasing the awareness of thermo condition; however, it is more important for interventions to reinforce choices to sustain the intended behaviour at later stages. In other words, the system may help to 'de-routinise' the precedent behaviour by increasing the awareness but may not be so effective at bringing new behaviour into 're-routinisation' process. Yet, most of households in UK have fewer options to choose other than using the conventional feedback method (e.g. periodical energy bill) where people find difficulties in correlating the units of consumption to their actual consumption habits (Darnton, 2004). This highlights the inadequacies of energy tracking methods among those who are keen in changing behaviours to reduce their consumption (Chetty *et al.*, 2008). This is why recent technological approaches in HCI realise a promising opportunity in investigating the effectiveness of IHD [19] or REFS [20] (Froehlich *et al.*, 2010); designing more interactive and frequent delivery than those paper-based feedback, to bring a reduction, and behavioural change in residential energy consumption.

Eco-feedback technologies have been widely used among academics of psychology and HCI to understand their role in changing behaviour. Froehlich *et al.* (2010) analysed nearly 200 papers from both disciplines in relation to using feedback as an intervention to promote pro-environmental behaviour, e.g. energy saving behaviour. While psychology disciplines focused at finding the effectiveness of the system itself, scholars in HCI have oriented their study in behaviour change using artefacts (e.g. mobile phone app, ambient display). Nevertheless, Froehlich has identified the profound gap in between two disciplines that many of HCI papers discussing the notion of eco-feedback did not link their findings back to the notion

[19] In-Home-Display
[20] Residential Energy Feedback System

of environmental or behavioural psychology or vice versa. This again spurs the need of understanding on how those new behaviours can be maintained in a longer term. From this notion, a new research area called ‘eco-visualisation’ (Holmes, 2007), often called ‘Ambient Interface’, draws attention as it potentially brings interplay between combination of micro-level (e.g. determinants of energy use, attitude, and psychological motive, satisfaction on visual element) and macro-level factors (e.g. effectiveness of intervention reducing on over-all energy use). The information in the system of feedback provides information on how behaviour and energy use is interrelated at an early stage. However, it is noted that data-based information on an eco-feedback system has some ineffectiveness at a later stage (Fitzpatrick and Smith, 2009; Pierce *et al.*, 2010a). Thus, strong consideration should be equally given to ‘design’ of eco-feedback system (e.g. eco-visualisation) which may influence a psychological motive like ‘intrinsic motivation’, leading to the perpetuation of pro-environmental behaviour (He and Greenberg, 2009). For example, Figure 2.21 shows the persuasive ambient display called ‘Coralog’ which is an effective visualisation style of display as system of feedback (Kim *et al.*, 2010). The display renders the user’s computer usage statistics through iconic image of coral reef and fish which metaphors ecological changes impacted by pollution.

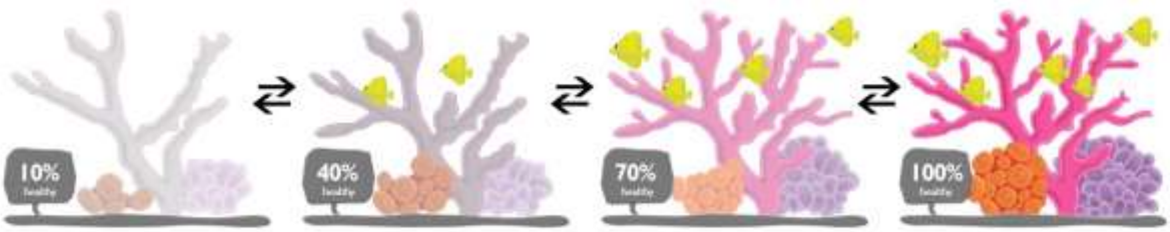

Figure 2.21 ‘Coralog’, showing gradual change of coral reefs and fish according to the health condition (Kim *et al.*, 2010)

Another example is ‘Power-Aware Cord’, developed by (Gustafsson and Gyllensw, 2005), Figure 2.22. It is a prototype of ambient display that has three electroluminescent wires bounded together with ordinary copper wire for electric conduction. The wire stays as ‘white’ when unpowered. But when power current is introduced, and as user consumes more power by plugging extra EuP, the intensity level of consumption is represented by shifting colours of blue-green lights.

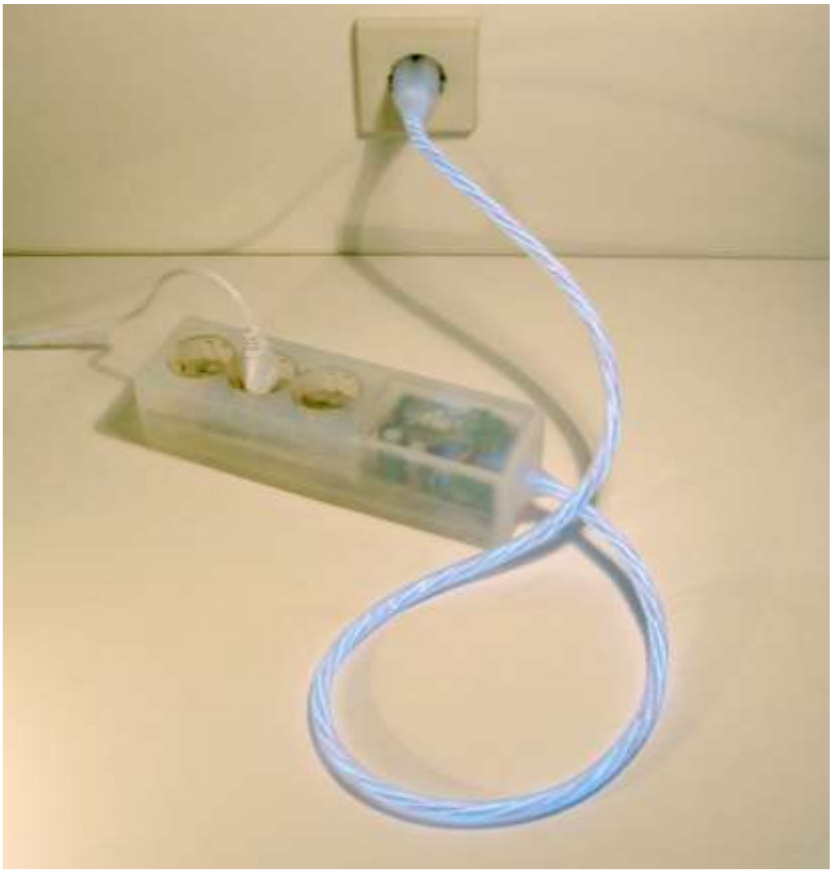

Figure 2.22 Power-Aware Cord (Gustafsson and Gyllensw, 2005)

> 'The interface of the Power-Aware Cord invites users to plug in different appliances and experiment with how these relate to each other in terms of energy. Our idea is that, by integrating the information about electric flows where they actually are, will result in a more intuitive, playful and metaphorical display than what would normally be produced. Such an approach might inspire users of the Power-Aware Cord to explore and reflect upon the energy consumption of other electrical devices in their home, using the cord.' (Gustafsson and Gyllensw, 2005, p. 1424)

2.5.4 Encouraging sustainable behaviour through design

It is widely accepted that the use-phase of the electrical product's life cycle is the most significant in the context of energy consumption, and mostly, they are determined by user behaviours (Lilley *et al.*, 2005; Lockton *et al.*, 2008; Tang and Bhamra, 2008; Wever *et al.*, 2008). Shifting consumption patterns depends on the thorough understanding of not only what motivates users, but also on how behavioural change gets formulated; and how it can be influenced through applied interventions (Jackson, 2005b). There have been different types of interventions introduced for the attempt of changing user behaviour around energy reduction. For example, the UK government has continuously provided promotional campaigns or similar activities to involve people in the debate of low energy consumption through educational interventions. However, it has been discussed that such interventions like technological (e.g. eco-feedback or energy efficient product) and educational approaches have not been sufficient in bringing continual behaviour change and have some limitations towards practicing ‘curtailment behaviour’[21]. In terms of designing the interventions, building a universal model of behavioural change is far more complex since it is limited by different theoretical preferences from various disciplines of research related to energy consumption (Lutzenhiser, 1993).

Many argued that intervention should facilitate interactions between households, devices in use, and all the other systems that becomes essential in constructing everyday life and routinised behaviour (e.g. Shove, 2003). It becomes more apparent from practice theory that even new behaviours will require routinised type of behaviour interacting with *Meanings*, *Materials*, and *Competences* (Reckwitz, 2002). Particularly for designers, the objective of designing these interactions should be foreseeing the future socio-technical conditions which helps people to reduce energy demand or to influence their expectations and norms (Wilson and Dowlatabadi, 2007). Rather simply making design artefacts (*Material*) as initiative, designers should carefully consider how actual demand for energy arises during the use-phase, and how people use a product in daily practice. Shove (2003) argues that much attention should shift from energy efficient technologies to energy service provision. Thus, it has been suggested to apply design strategies into interventions for inducing more sustainable behaviours through the use of services/products; often called, design interventions (Lilley, 2009; Lockton *et al.*, 2008; Mazé and Redström, 2008; Rodriguez and Boks, 2005; Wever *et al.*, 2008).

The notion of design intervention originates from many scholars’ view on a material world that user interactions with particular *things* are built into the *meaning* of everyday practice. Often, these practices are not formulated through rational

[21] Curtailment Behaviour involves the effort of reducing the energy consumption, such as turning off more lights which requires constant actions (Gardner and Stern, 2008)

choices or predisposed by incentives/penalties, but sometimes through routine activities of non-economic factors such as habit, comfort, and convenience (Shove, 2003). Some criticisms were made against attitude models of behavioural change that what people say or believe does not always correspond to favoured behaviours or subsequent actions, so called ‘value-action gap’ (Darnton, 2004). This builds on from Stern’s (2000) suggestion that interventions addressing single variable like personal motives, are not sufficient to bring greater impact on changing behaviours; and that behaviours can also be changed without necessarily first changing the attitudes (Jackson, 2005b). In this context, it has been suggested that when designing an eco-feedback device such as IHD or REFS, it should thoroughly consider whether the aim is to change behaviour and/or to motivate energy user, prior to making a study prototype (Froehlich *et al.*, 2010).

2.5.4.1 Design Strategies for sustainable behaviour

While earlier phases of eco-design research (e.g. technological interventions) focused at bringing increased energy efficiency, in recent years a ‘design for sustainable behaviour’ (DfSB) community has received growing interest (Backlund *et al.*, 2007; Jelsma and Knot, 2002; Lilley *et al.*, 2005; Lockton *et al.*, 2008). It aims to reduce behaviour related to environmental impacts through the (re)design of product or services in means of using; such as social psychology, persuasive technology (Fogg, 2002), or interaction design. Especially, the strategies focusing at the use-phase of a product become prominent, shifting the behaviour towards more sustainable action. Among various different strategies, Boks (2012) presented a comprehensive overview of each category and terminologies used by different scholar in the field, see Figure 2.23.

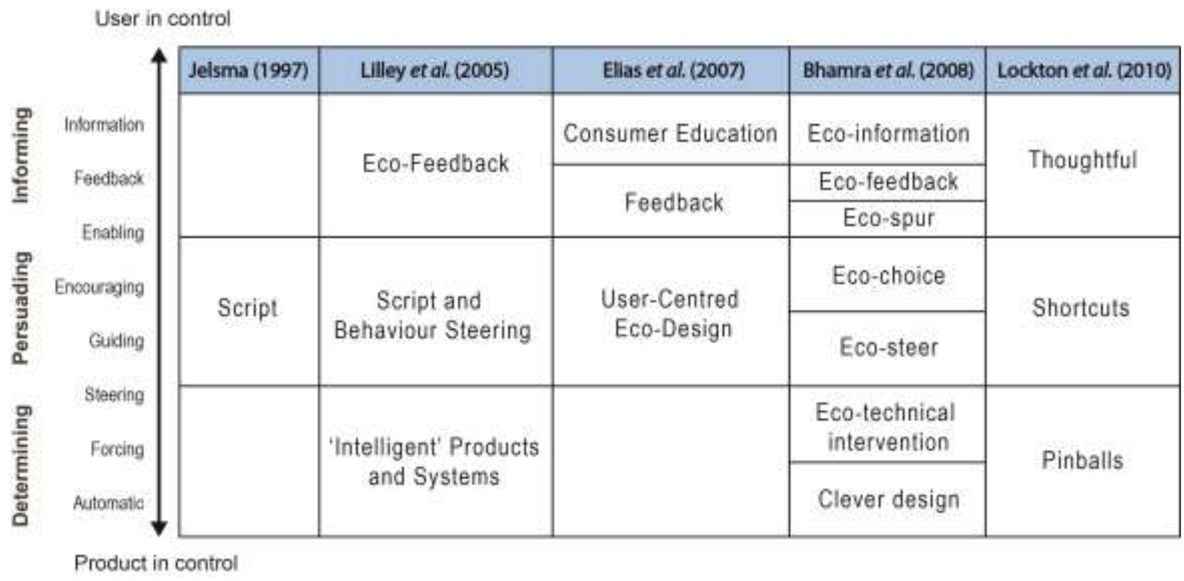

Figure 2.23 Comparison of design strategies for sustainable behaviour (Boks, 2012)

2.5.4.2 Scripting, Affordance and Intelligent Product

One of the early principles used in 'design for sustainable behaviour' (DfSB) is the 'script' approach mainly introduced by Jelsma *et al*. (2002, p. 120), and described it as 'a product layout guiding the behaviours of the user, *in a more or less* forceful way'. The approach enables users to perform certain behaviours through scripted design of 'value, incentive and rules' that are embedded in between the service and product. However, Jelsma points that 'script' can also constrain certain behaviours through design characteristics such as shape, mechanism, signals, et cetera. Norman (1999) describes this condition as 'affordances' and 'constraints'; appearance of the device providing clues to operate. For preventing certain actions, Norman introduced *forcing function* where one condition must be complied, without consciously processing relevant information to that action, before a function is enabled, e.g. an interlocking seatbelt[22]. Norman later details the distinction between 'perceived affordance' and 'real affordance' due to complexity related with 'cultural conventions'. He argued that affordances can guide certain behaviours through 'real' physical objects without having people to think about their own actions; whereas the 'perceived affordance' is a scripted design application that allows users to perceive the 'possibility' for a certain action. Also, their role are very different depending on

[22] Interlock seatbelt system doesn't allow engine to start until driver passenger fastened their seatbelt.

whether perceived interactions arise in physical object or from screen-based products. For example, the script embedded on the door knob communicate that the required action is turning; this is a ‘real affordance’, and people tends to perform the action of turning without thinking. For ‘perceived affordance’, it requires conventional learning through feedback which advertises the affordances. For instance, the cursor in a window screen that changes the shape as to guide certain action but these actions are possible through users already interacting with the controls of mouse that are ‘real affordances’. Looking from DFSB perspective, the best example using both factors of affordance and constraint is the Unilever’s Powder Tablet (2000), encouraging user to perform an action or behaviour as intended by the designers, so called ‘Behaviour Steering’ (Lilley *et al.*, 2005). Unilever introduced a detergent tablet in 1988, where the size of each tablet counteracts towards over dosage of detergents; therefore, changing user behaviour and creating less chemical disposal in the environment. Of course, this type of designed intervention influencing in creating new behaviour will require a strong market penetration to bring greater impact.

Norman’s view on ‘cultural convention’ give clues that can address some of the complexities discussed in relation to influencing behaviours. Norman’s extended definition of ‘perceived affordance’ mainly accounts for interventions applied in many HCI studies where any attempt in influencing behavioural change will require a ‘decision-making process’ (Fischer, 2008). These processes usually go through ‘cognitive script’ that is enabled by knowing and learning the incentives derived by the consequence of new behaviour (Jackson, 2005b). Once ‘cognitive scripts’ are in place, little effort is required to perform the same behaviour (Jackson, 2005b); becoming a habitual behaviour. However, in order to formulate as a ‘practice’, new behaviour must activate the norm which requires ‘what people believe and do… not in the usability testing rooms, but in their normal environment’ (Norman, 1999, p. 41). This links with the notion that antecedent and consequential interventions can generate short-term behaviour change, however, they cannot so readily change the ‘social convention’ or ‘habits’ in practice. According to Spaargaren (1997), human beings as knowledgeable and capable agents make use of sets of rules and resources within reproduction of social practice. The rules and resources involved in constituting the new behaviour gets, at the same time, reproduced by people within a social practice.

Although Boks (2012) has comprehensively categorised the design strategies and its terminologies used by different scholars, literature presenting models of typology on design interventions seem scattered. Therefore, it requires not only empirical evidence to extend the knowledge on suggested models, but to build a framework as a basis to design one. The first attempt at such a framework was developed by Lilley *et al.* (2005) , naming ‘product-led intervention’ which accommodates; eco-feedback, behaviour steering and intelligent product. The term applies to design interventions that aim to induce behaviour change through product design. Lilley also categorises the other two types of intervention; educational intervention – linear dissemination of information, incentive and penalty, and guilt; and technological interventions – bringing reduction through energy efficient appliances/devices. Tang and Bhamra (2008) builds Lilley’s framework into more detailed, identifying seven intervention strategies that can be applied within a design sector. Figure 2.24 shows the hypothesis of their behaviour change framework including the seven different levels of design interventions linking with three antecedent elements of behaviour change and they are; intention, habits, and control. They go on to give examples of each strategy. For example, Unilever’s powder tablet will be included within the ‘maintain the change’ section of intervention level since it ‘encourages user to behave in ways prescribed by the designer through the embedded affordances and constraints’ (Lilley, 2009, p. 705). As a first framework, these subdivided terminologies seem supportive for intervention designers. As Froehlich *et al.* (2010) suggested, it is important for designers to deeply consider and study particular behaviour that they hope to change. Thus, this framework allows designers to clarify the aim of the interventions whether they are stimulating for intention, or ‘breaking the habit’, or to ensure the changed behaviour through designed artefacts. In 2010, Tang names this framework as ‘Design Behaviour Intervention Model’ (DBIM) in her PhD Thesis (Bhamra *et al.*, 2011; Tang, 2010). It was observed from her thesis that she classifies HPP within ‘eco-information’ approach by describing them as product encouraging users to interact with resource use.

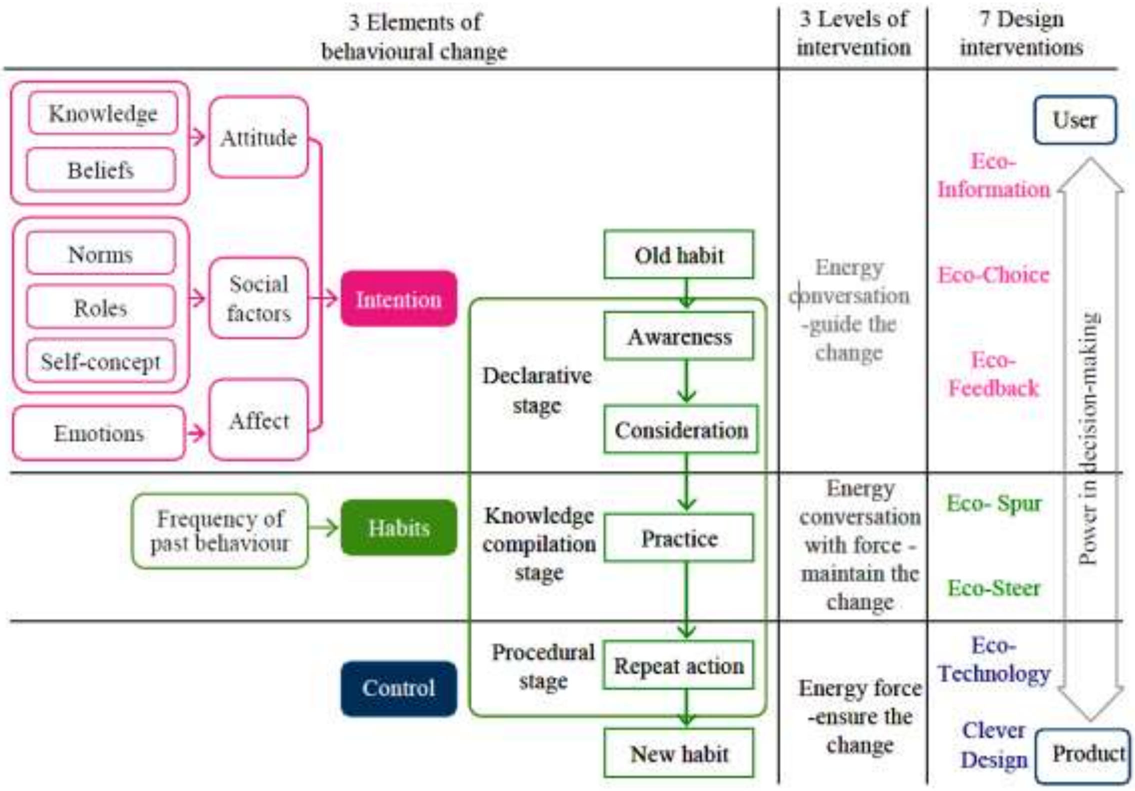

Figure 2.24 Linking antecedents of behavioural habitual change with varying levels of design intervention (Tang and Bhamra, 2008)

At a glance, it is interesting to see how this framework shows the degree of 'decision-making' between product and user. In 2005, Lilley *et al.* (2005) has admitted that these interventions would require a set of empirical and conclusive results to evaluate the effectiveness for each and as yet it is difficult to ascertain. However, the notion of this 'power in decision-making' is somewhat arguably dubious in a sense that most of examples shown within the 'ensure the change' section (i.e. 'Clever Design' or 'Eco-Technology') are technological interventions; not requiring any behavioural change. These interventions require what Gardner and Stern (2008) categorise as 'efficiency behaviour' where adoption of these products will generate a certain incentives without interfering with people's behaviour. For example, Lilley introduces the Honda's IMA (i.e. known as 'eco-mode' that turns the engine off while stopping at traffic lights) and Pavegen[23][24] (i.e. piezoelectric floor system – parasitic harvesting) which can be seen as 'a new mundane artefact' (Latour, 1992), as they bring incentives without user being conscious about. Though, Lilley does touch upon

[23] Lilley introduce these concepts/products through 'design-behaviour' website where she introduces more examples that classifies into seven design approaches for behavioural change (Lilley, 2008).
[24] Both Pavegen and Sustainable Dance Club use basic principle of using piezoelectric floor modules. Detail can be found from www.pavegen.com and www.sustainabledanceclub.com

moral and ethical debates of these intelligent products where the function of bringing sustainable impact can be forced without noticing how (s)he is disciplined. This is similar to what Latour (1992) writes about ‘delegation to machines’; and Norman’s ‘real affordance’, where they argue that undermining forces on behavioural change can be eliminated by complete delegation to all actions to the device in question; also known as ‘black boxed script’ (Jelsma, 1999). However, given the urgency of the environmental problem, Lilley *et al.* (2005) argues that these interventions are necessary and provide a starting path of action which could potentially reduce the impact of current consumption practices. Nevertheless, human actions are not predictable as machine; therefore, materialised inscription for inducing new behaviour may also be resisted by a user who are social agents, and obviously be complied as well (Ingram *et al.*, 2007).

Intelligent products or new technological interventions have been causing debate among scholars about moral/ethical concerns over notion of having lack of ‘autonomous’ control. Jelsma (2006) states that designers are the people who inscribe ‘morality’ in the thing they make and that immorality (e.g. over-consumption of energy) has to be corrected by moral behaviour. Brey (2006) has argued that people’s autonomy may be threatened when their essential everyday actions are ‘trained’ by these types of behaviour steering technologies. To some extent, these technologies instead make goals and plans on behalf of users, whereby humans no-longer become an autonomous decision-maker. However, it has been proven in some cases that these technological interventions do bring about reduction of energy consumption; therefore, it can be done without necessarily interfering with people’s behavioural (Jackson, 2005b; Rodriguez and Boks, 2005). Jager (2003) has argued that the most effective methodology in changing behaviour is by hindering the performance of habit. The same argument can be made towards the ‘intelligent product’ strategies that designers are able to prevent people from performing unsustainable behaviours which in turn may result in ‘cost benefit’ or ‘zero defects’ (Lockton *et al.*, 2008). In this case, these perceived benefits may influence them to practice additional ‘efficiency behaviour’ under certain circumstances (e.g. not leading to rebound effect caused by over-purchasing these products), which may bring an increased reduction of household energy consumption. Nonetheless, most of intelligent products (e.g. parasitic harvesting) may not seem to have the process of ‘de-routinisation’ since its scripted design, rather ‘unscripted’, exists at current behaviour instead requiring a new behaviour. This type of ‘automated’ interventions that bring about reduction of energy use is sometimes called ‘sustainable by stealth’ (Lilley *et al.*, 2005). Therefore, these ‘automated’ devices may fall under category of ‘changing behaviour’ if the solution aims at changing or blocking ‘unsustainable’ behaviour. Tang later support this notion, as she states ‘automated solutions may prove more efficient in altering behaviour without causing conflicts in people’s belief, value, preferences and modifications to existing routines’ (2010, p. 67). However, while most of ‘automated’ interventions are not aimed at ‘changing’ any behaviour, they aim at bringing ‘sustainable behaviour’ without necessarily modifying the existing routines or through a ‘de-routinisation’ process. Also, Tang has discussed concerns over Eco-technology and Clever design that they may have weaknesses in; lack of normative and motivational change, rebound effect, low user acceptance, and ethical/moral issues over being ‘stealth’. However, as illustrated in Figure 2.25, when ‘power in decision-making’ is with the user, the motivational change and user acceptance becomes greater. On the other hand, the product/service/system driven interventions such as piezoelectric floor system may have greater influence in bringing the reduction of environmental impact (Tang, 2010).

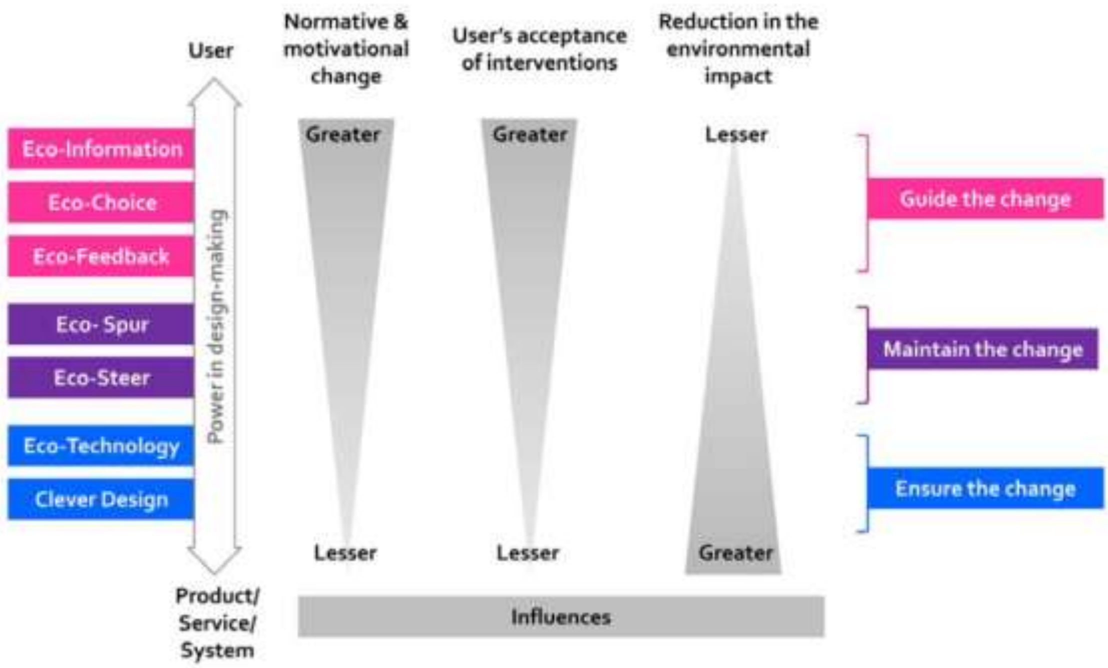

Figure 2.25 Influence exertion through the selection of behaviour intervention (Tang, 2010)

Despite intriguing frameworks and available techniques mentioned in this chapter, it might be difficult to implement a design technique to induce behavioural change without a detail guidance. One of the first attempt was done by Lockton *et al.* (2010), created a toolkit called 'Design with Intent' (DwI) which serves as guidance when designing artefacts to influence behaviour change. He defines it as 'design intended to influence or result in certain user behaviour' which aims to assist designers practicing the process (Lockton *et al.*, 2008, p. 2). The techniques included in this method are derived and can be viewed in parallel with three main classification of *enabling, motivating* or *constraining* behaviour. A total of 101 cards showing ranges of suggestions, questions, and examples are bundled together as a tool kit for intervention designers to utilise in conceptualising process within design practice (Lockton *et al.*, 2009; Lockton *et al.*, 2010).

2.5.5 Encouraging sustainable energy consumption through design

Most of the design interventions, particularly when designing for energy-conservation behaviour (e.g. eco-visualisation), urge to deliver more effective communication to user about how to use energy more efficiently. These design strategies may provide information, choice (empowerment), eco-feedback (consequences of action), behaviour spur (rewarding penalty or incentive), behaviour steer (affordance and constraints), and technical intervention (persuade or control behaviour) (Tang and Bhamra, 2008). However, these design intervention strategies have not been applied widely, although it provides interesting opportunities for designers, but their effectiveness is yet to be validated with sufficient real data.

One of the intriguing examples of 'behaviour steering' and its research is carried by Ramia Mazé. Her research team has focused on the development of design interventions that increase the awareness of how energy is being used and stimulating the changes in behaviour. As a basis for working with energy in design, Mazé's research team explored energy as visible material and experiential in use, diverting the focus within the energy sector from efficiency of energy technology to 'Materialising the Energy' (Backlund *et al.*, 2007; Mazé, 2007; Mazé and Redström, 2008). Most of her project was carried out at the Interactive Institute within the

'Energy Design' research group where they run ranges of projects in developing tools and artefacts to help people become more energy efficient. The Institute's projects (e.g. Power-aware cord, Figure 2.22) mainly consider energy as expressive material for design, where its presentation and use are brought to the forefront in products. The approach focuses on energy as a core aesthetic and functional issue in the early stages of product design (Backlund *et al.*, 2007).

Figure 2.26 Flower Lamp (Backlund *et al.*, 2007).

One of their design examples is a 'Flower Lamp', Figure 2.26, where it explored the design as tool to encourage people to use less energy in their home. It is a feedback display system for electricity consumption, but not as in a display unit that shows quantifiable unit. If the household has a decrease in electricity use at macro-level, the lamp rewards the user by slowly opening up to represent a 'blooming' flower. If, on the other hand, energy use is increased, the lamp closes back to its original shape. This example reflect as a design intervention that is designed to show the consequences of the user's own energy consumption through a system of feedback using 'rewarding' and 'penalties' techniques, attempting to steer new practices/behavior towards lowering energy consumption. Although the form of consequential information in the Flower Lamp is given as 'long-term feedback', the artefact encourages users to have control over their consumption and achieve 'sustainable energy consumption' at macro level. Instead using the reward and penalty technique to show tangible incentives like cost, this design focused at providing psychological factors of 'aesthetically rewarding' symbolic flower to influence on changing energy consumption pattern. This notion of using psychological factors to change behaviour was also shared by Shove (2005), as she comments:

> "The notion that commercial organisations and advertisers have managed to convince people to consume more lends weight to the view that similar techniques might be used to turn evidently fickle desires in other directions". (Shove, 2005, p.2)

The system of feedback not only provides the form of tangible consequences, but it also allows user to interact with intangible side of design such as 'emotion'. The design element in this type of intervention delegates a free space for the inclusion of user's autonomous interaction and increase the relation between product and user that is created through spontaneous occurrences. As Norman (2007) describes;

> 'Emotions are inseparable from and a necessary part of cognition. Everything we do, everything we think is tinged with emotion, much of it sub-conscious. In turn, our emotions change the way we think, and serve as constant guides to appropriate behaviour, steering us away from the bad, guiding us towards the good' (Norman, 2007, p. 7)

However, in some cases, over-programmed narrative experiences inhibit act that serves to hinder meaningful outcomes, turning interaction into another anonymous sequence of pre-planned events (Chapman, 2005), e.g. data based smart-meter. Some argued that presenting sufficient ambiguity or defamiliarising is vital to overcome this mode of interaction; an object that misbehaves sometimes or draws users into thought-provoking engagements (Bell *et al.*, 2005; Chapman, 2005; Gaver *et al.*, 2003). By introducing discursive engagement between subject and object, users can be drawn into discourse that has been created from spontaneous occurrences (Chapman, 2005). The ambiguity and its design implementation on user-product interactions avoid perceiving artefacts through own individual preconceptions or delegated autonomous experiences. Therefore, the spontaneity can be catalysed rather than planned through passive interventions like piezoelectric system or object's limited ability. In other words, the design interventions should move from descriptive to inscriptive (Jelsma, 1999); avoiding from being inconspicuously controlled by another 'a mundane artefact' (Latour, 1992).

The concept of 'behaviour steering' has been widely used as 'persuasive technique' in many HCI studies in relation to sustainability (Blevis, 2007), and for those scholars exploring the alternative forms of eco-feedback such as ambient feedback display (Broms *et al.*, 2010; Kim *et al.*, 2010). It has been proven that graphical displays of eco-feedback increases the consumer comprehension considerably (Egan *et al.*, 1996). By acknowledging this, many design researchers in the domain of HCI and interaction design have been continuously gaining empirical knowledge through user studies exploring the effectiveness of various different persuasive techniques such as; targeted demographic (Jönsson *et al.*, 2010), on water conservation (Arroyo *et al.*, 2005), and persuasive interface that inform consumption patterns throughout the day (Broms *et al.*, 2010), see Figure 2.27. Studies in this domain explore how alternative forms of eco-feedback such as the design of ambient interfaces, sound, light, and other media that can link either the micro and/or macro level of consumption with people's peripheral sense (Broms *et al.*, 2010). In focusing the role of design as an intervention to influence energy saving behaviours, it is observed that most design artefacts developed in the Interactive Institute tend not to delegate any control of energy consumption to the device itself, but to individuals who are autonomous agents.

Figure 2.27 The Energy AWARE Clock in the 24 hour view, showing the electricity consumption for the whole and two days back in time (Broms *et al.*, 2010).

2.6 Maintaining the Sustainable Use

Design strategies that aim at bringing about a behavioural change, and their effectiveness, can only be realised after long-term period. Therefore, it should also take account into how design can help user to maintain the sustainable use of those interventions in the long run. As suggested, studies on intervention should focus at maintaining the stability of changed behaviour (De Young, 1993). For HPP studies, it is assumed that effectiveness of HPP-led intervention will also depend on the process of changing existing habit of using conventional power source, inducing new behaviour of using human-power, and other psychological elements that avails to maintain that behaviour. Below is the relevant research question to be addressed in this sub-chapter:

Q3: Is HPP user-centred?	Q 3.1: If not, What are the factors driving this response?
	Q 4.2: How can HPP be designed in a way that encourages user to use it in longer-term?

2.6.1 User-centeredness

The research question 3, 'Are HPPs user-centred? If not, what are the factors driving this response?' and 'How can HPP be designed in a way that encourages user to use it in longer-term?', questions the necessity of investigating whether the actual users are practicing sustainable use of HPP. If not, there may be several reasons for this cause. However, one of the key aspects for maintaining the sustainable use of such product will be the usability. As it was noted, the effectiveness of any intervention depends on how changed behaviour remains in the longer-term. Thus, current interventions using persuasive techniques to stimulate extrinsic motivations are likely to fail as they become obsolete, so does desired behaviour. This condition is also known as 'Fallback Effect' (Wilhite and Ling, 1995). In previous sub-chapters (2.5.1 ~ 2.5.5), it discussed the comparison of different disciplinary approaches to induce 'decision-making' process in the context of; residential energy use, behavioural change model, technology diffusion, attitude-based behaviour, and social psychology. Although many have a different emphasis, it shares the basic assumption that the autonomous individual plays a central role while dealing with different variables. Therefore, some argue that usability of designed solution plays key role in understanding the human-product relationship (Wever *et al.*, 2008). Obviously, one possible option to minimise the side effect of lacking interaction process between human and product may be an adoption of autonomous energy efficient product, e.g. TV, that has automatic 'blind' mode (Rodriguez and Boks, 2005), also called as 'Functionality Matching' by (Wever *et al.*, 2008).

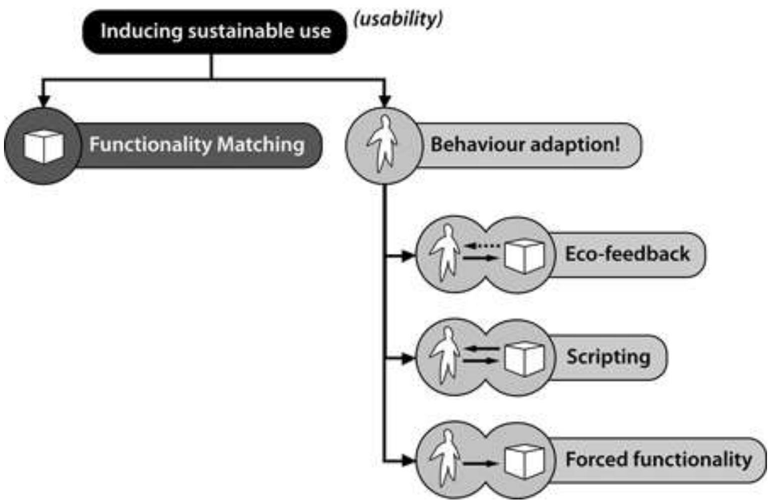

Figure 2.28 A typology of sustainable behaviour-inducing design strategies (Wever *et al.*, 2008)

This notion of emphasising on the usability for sustainable use derived from the lack of cross-fertilisation between sustainable product design research and the user-centred design discipline. Therefore, Wever *et al.* (2008) proposes a typology, Figure 2.28, of 'inducing sustainable use' with divided options of 'functionality matching' with three other sections of; eco-feedback, scripting and forced functionality as categorised in 'behaviour adoption'. The typology is created for designers to refer when designing interventions using different levels of 'intrusiveness' respectively along the line of 'behaviour adoption'. Wever *et al.* (2008) argue that user-centred solutions provide alternative strategies of changing the user-profile into a more sustainable direction. In his work, it suggests using pre-intervention techniques such as 'context mapping' (Visser *et al.*, 2005) within a user-centred design approach to gather user information, then as a team (engineers and psychologist) to decide which behaviour they wish to accommodate (Wever *et al.*, 2008). The sub-sectioned strategies are nearly identical to framework developed by Lilley *et al.* (2005), see Figure 2.23, except the 'forced functionality'. Similar to Jelsma and Knot's (2002) argument of 'more or less forceful way', Wever *et al.* (2008) argue that behaviours can be either induced or forced. Thus, his typology splits the two contrary design intentions, and incorporates the 'forced functionality' which includes either intelligent products (as defined by Lilley *et al.*, 2005) or product-led interventions that prevent unsustainable behaviour. However, it may be argued that this type of strategy is 'another mundane artefact' (Latour, 1992), as Wever (2008, p. 7) describe it as 'performed without thinking about it by the user'.

The issue of designing an interactive usability of product have received increasing attention over the last years. Especially, there is sharp increase in hiring professionals by industry who are working to ensure the easy-use of products such as ergonomist or interaction designers. Not only seeking the potential gain of commercial advantage through production quality or cost saving but design of usability input can differentiate between brands and also increase the preference of product. Therefore, the usability issue can be an important factor in terms of leveraging the commercial success of the product (Jordan, 1998). According to Jordan (1998), the 'usability' is a property of the interaction between a product, a user and the task, or set of tasks, that he or she is trying to complete. As discussed in previous chapters about how new behaviour gets formulated through process of;

awareness, learning and decision-making, and ‘re-routinisation’; Jordan embraces this process through using different terminologies of; guessability, learnability, experienced user performance, system potential and re-usability. One of the principles of usable design that affects the usability is the feedback. According to Jordan (1998, p. 29), feedback is ‘designing a product so that actions taken by the user are acknowledged and a meaningful indication is given about the results of these actions’. However, somewhat contrarily to Chapman’s argument about ambiguity, Jordan depicts that difficult use of products cause the annoyance and frustration which may defeat users’ intended purpose. In addition to the feedback, he also argues that products should be designed in ways that they give as much control as possible over the interactions with the products. In relation to interventions for residential energy use, Jordan’s arguments resemble with Fisher’s argument mentioned on page 57 of this thesis.

> ‘system of feedback on peoples’ energy consumption may give control over their consumption, ‘empowerment’ (Dean, 2008; Hargreaves, 2011), and eventually save energy (Fischer, 2008)’ (from p. 57)

In addition to distinguished strategies suggested by both Lilley *et al.* (2005) and Wever *et al.* (2008), Pettersen *et al.* (2008) suggests a fourth strategy of ‘emotional attachment’ as Design for Sustainable Behaviour (DfSB) includes both physical and psychological interventions. The emotional aspect affecting usability has been discussed by D. Norman through his extensive study on human-product psychology (Norman, 1988; 2002; 2007), also a founder of term ‘user-centred design’. His concept ‘Attractive thing works better’ views the subjective human-product relationship that interweaves together between; visceral, behavioural, and reflective elements in product experience. These three different aspects of design concern the appearance, pleasure and effectiveness of use; rationalisation and intellectualisation of a product which may well play as a key role in maintaining the use of products. In the context of inducing curtailment behaviour or energy saving behaviour through product-led intervention, these arguments suggest exploring design applications that are beyond the traditional understanding of user-centred design, as to make energy-saving activities relatively more attractive and fun. In order to maintain induced or changed behaviour, the C*ompetence* must arise in between the *Materials* and emotions (*Meaning*) related to the activities. As Ingram *et al.* (2007, p. 5) describes this process as ‘Normalisation’ which refers to ‘process of new object and arrangements becomes established, and through which new expectations and forms of competence emerge’. Therefore, the cross-fertilised approach of incorporating ‘theory of practice’ into user-centred design process may seem essential, not only to design intervention that functions well, but also understanding the dynamics of daily life to deliver practice level innovation (Kuijer and de Jong, 2009).

2.6.2 Motivation – the ‘Internalisation’

Maintaining the changed behaviour may not require any external motivations such as incentives or emotional stimulus if intrinsic (psychological) motivations are sufficiently situated at an early decision-making stage. Mechanism of cognitive process through both acquiring and regulating human behaviour has been presented through various different models of behavioural change. Stern’s ABC theory acknowledges the notions that antecedent interventions influencing on single variable motivations (e.g. VBN Theory) have not been so effective in bringing about behavioural change. On the other hand, some theories have argued that ‘self-efficacy’, and ‘perceived behaviour control’ (PBC) can be an accurate predictor or motivator of intention leading to new behaviour (Ajzen, 1991; Bandura, 1994). However, Armitage and Conner (1999) have distinguished two theories that ‘Self-efficacy’ predicts only the intention of behaviour as the individual finds ability and confidence; but for PBC, people perceive behaviour control over both internal and external factors which predicts the behaviour. Nevertheless, these theories mainly argue that intrinsic and/or extrinsic motivations are driving forces for human behaviour and that the later fosters the former motivations to repeat the intended behaviour. However, it has been argued that much attention should also be given to how these behaviours become ‘re-routinised’ and maintained as long-term in daily practice. As De Young (1993) argued, the ‘intrinsic motivation’ can play key role in reducing the side effect of intervention as people discover a behaviour that is worth doing for its own right, as these satisfactions are inherited in direct experience from those intervention.

Current work on design interventions that use persuasive techniques or other forms of extrinsic motivations are likely to fail as they become no longer available (Darby, 2006; Dwyer *et al.*, 1993). For example, Van Houwelingen and Van Raaij (1989) has conducted their field investigation (in Netherlands) into the effectiveness of multiple interventions using feedback and goal-setting on natural gas consumption for a duration of 3 years. Despite its effect of 12.5 % reduction during intervention period (2 years), they found out that the effect did not last during the post-intervention period – and no long-term habit or energy-conscious attitude has occurred.

Scholars also have been underlining the weaknesses of interventions using extrinsic motivations. For example, when behaviours are strongly regulated or reinforced by external factors, eventually people find no link to their attitude with related action or behaviour (Jackson, 2005b). In comparison, intrinsic motivations that are gained by direct experience, perhaps what ‘self-efficacy’ and ‘PBC’ argues, at least, do not merely depend on the effect of interventions using extrinsic motivation or external factors. Deci and Ryan (2000) argue that intrinsically motivated behaviours do not depend on reinforcements since undertaking activities that are interesting in itself are intrinsically rewarding. The Flower Lamp (Figure 2.26) is using this technique. The use of this design intervention may be motivated through the fact that they have consumed less residential electricity (extrinsic motivation), but simultaneously they can be intrinsically motivated for their action affecting on blooming the flower lamp. Similarly, there is Volkswagen’s *The Fun Theory* which uses the ‘fun’ aspect to change people’s behaviour for the better (Volkswagen, 2009). The Fun Theory’ is a campaign coordinated by Volkswagen Company, initiating design projects that aims to get people to change their lazy behaviours. The projects are dedicated to the thought that something simple as ‘fun’ is the easiest way to change people’s behaviour for the better.

Figure 2.29 shows an example of design project called ‘Piano Staircase’ which encourage commuter to use staircase instead of escalator. Their design team transformed the stairs into a giant functioning piano keyboard where applying pressure on each step plays a musical note.

Figure 2.29 Piano Staircase (Volkswagen, 2009)

However, as noted, this strategy may strengthen the effectiveness in changing behaviour, but it may lack in linking the attitude with the actual behaviour as people only engage with the element of 'fun' within the intervention.

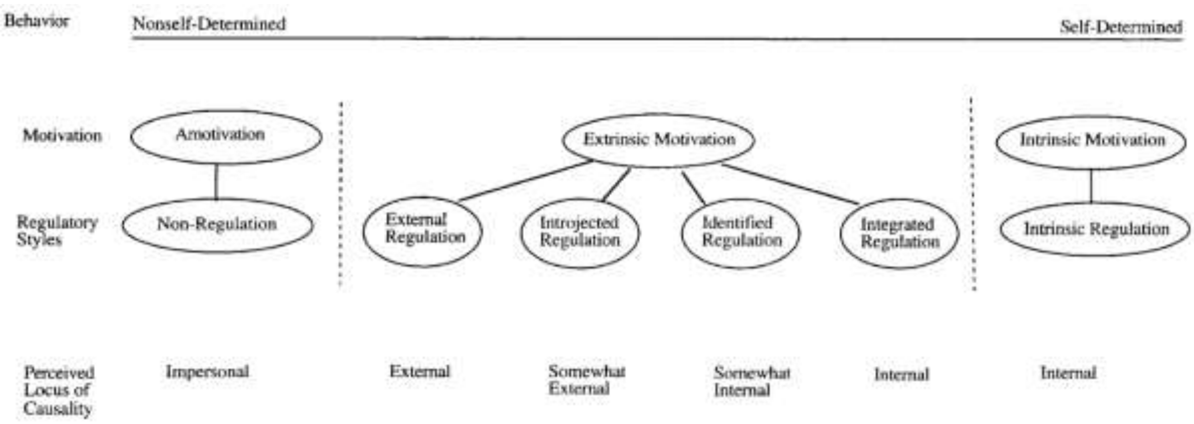

Figure 2.30 Different types of motivation with their regulatory styles and the locus of causality
(Ryan and Deci, 2000)

Deci and Ryan (2000) proposed that intrinsically motivated behaviours are based in people's needs to feel competent, self-determined, and being autonomous. This is due to the fact that people feel subsequently less motivated as they feel controlled by extrinsic motivation. However, Deci and Ryan hypothesised that extrinsic motivations can be controlled invariably to the extent to which they are self-determined as they enact the regulation; known as 'Self-Determination Theory' (SDT). To support this argument, they built the concept of 'Internalisation' where behaviours affected by regulations are internalised through the processes of introjection, identification, or integration (see Figure 2.30). Prior to these extrinsic motivations, 'Amotivation' is the state of lacking the intention to act. When amotivated, behaviours often do not put into action or act without intention. However, extrinsic motivations will vary to the extent in which they are either controlled, sometimes punished or become autonomous through their feelings of social norm. As people show a lack of desire in changing behaviour, it can be controlled by either external regulation (by others) or introjected regulation that is administered by an individual. In contrast, identified regulation refers to people feeling ownership of behaviour, thus be more autonomous. And finally, the integration makes the behaviour to perform in fully volitional mode of action where they are self-determined and its 'internalisation' become most effective (Deci and Ryan, 2000). Therefore, they argue that non-intrinsically motivated behaviours can become truly self-determined. However, Deci and Ryan make clear distinction between the intrinsic and fully 'internalised' extrinsic motivation by separating with a vertical line; although they are volitional, the 'internalisation' is only possible through instrumentality, e.g. design intervention. Presumably, referring back to theories of behavioural change, the regulations within this internalisation process can be realised in which the function of feedback confronts user with consequences of people's actions (Van Houwelingen and Van Raaij, 1989).

2.7 Discussion

In the context of long-term global depletion of energy resources, it is now clear that current patterns of consumption must bring about change and it depends upon the future development of sustainable socio-technical systems and its management. This does not mean to change or persuade individuals one at a time, but bring gradual change through use of socio-technical systems such that the energy consumption arising from ‘normal’ practice is less. It became apparent over recent years that current approaches using information and marketing campaigns towards sustainable consumption have not made significant or sustained changes in people’s practices (Barr, 2003; Burgess *et al.*, 1998). Social theories (e.g. Shove, 2003) presented in this chapter explained the hypothesis behind the inconspicuous pattern of consumption and to some extent this became very normal in our everyday life. Therefore, there is need in (re)designing the everyday products to inform the user about consequences of these consumptions.

Consumer behaviour and their choices of consuming certain products/services – all have direct and indirect impacts on the environment (Jackson, 2005b). It is noted that energy usage is strongly embedded in inconspicuous norms of everyday practice. As noted by academics, it is important that current research should combine and cross reference in between the field of design discipline and psychology on environmentalism, and their strategies to bring behavioural change. This is due to the fact that affordances in HPP require users to change their precedent behaviour of consuming energy from non-renewable to ‘human-powered’ energy. This notion has profound implication for potential impacts of interventions to influence sustainable energy consumption by changing people’s behaviour. Thus, bringing about patterns of sustainable energy consumption should not merely depend upon influencing the attitude to make choices, but instead changing the practices; taking account of complex variables in between *meaning*, *material*, and *competence*. Also, it is vital to understand the product use-phase and consider how intended behaviours are reproduced, maintained, and internalised. In the context of practice theory, especially the *material* element accommodates crucial role as in design discipline which may deliver information to assist individual for formulating new *meaning* towards new behaviour. By processing the information that is delivered through design interventions (e.g. feedback), each individual will volitionally regulate their behaviour to gain *competence*; through ‘internalisation’ process within personalised or social norms. If ‘things’ (artefacts) are required to change in order to bring about a reduction of energy consumption; as well as the opportunities that designers attempts to bring about in doing so, it highlights the need in understanding the practice prior to designing *material* things. As Fisher (2008, p. 235) argues ‘changing things might accompany changing practices’.

Literature from both social theory and disciplines from design research share common views towards the profound role of ‘feedback’ as providing consequential information of intended behaviour. The information become a tool in ‘de-routinising’ the current energy consumption habit and as product-led intervention, it invites users into discursive engagement to help gain ‘delegation of control’ over energy usage. On the other hand, studies have been focusing on the environmental consequences of ever-increasing consumption, therefore introduced ‘energy efficient’ products leading to adoption of ‘efficiency behaviour’ which entails the energy conservation from one-shot purchase. However, the efficiency itself may lead, as it is efficient, to reduce electricity consumption at use-phase; but it can also efficiently make people do more at the same time which in turn may lead to a rebound effect. Additionally, the passive interventions have the potential in bringing effective savings through the concept of ‘sustainable by stealth’. However, some concerns were discussed over these types of interventions for being another mundane socio-technical system where by machine having more control over autonomous human (the user); therefore, people feel less motivated. In order to overcome these concerns, the ‘design’ undertakes an important role in inducing interaction between user and feedback devices, making the individual as an autonomous agent, sometimes using its fulcrum such as ‘emotion’ or ‘fun’. Therefore, an understanding of the human-product relationship and its interaction seems fundamental in promoting sustainable use and maintaining the sustainability of changed behaviour to continue practice energy saving behaviour.

Figure 2.31 shows the summarised illustration of intervention discussed in this chapter. The pie segments in the illustration shows the types of interventions used (shown in grey), disposition of behavioural change, and the emphasis on the importance of maintaining the sustainability of changed behaviour induce by interventions.

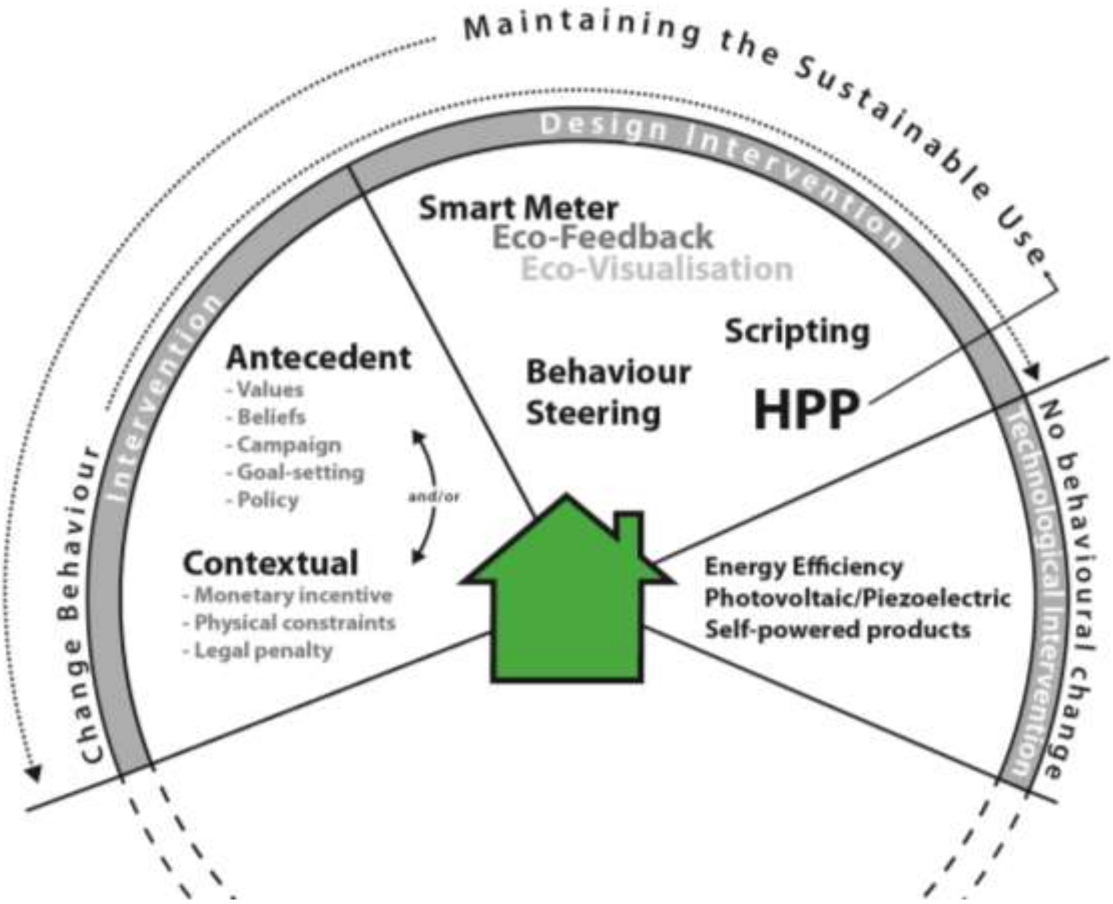

Figure 2.31 Overview of interventions discussed in literature review

2.7.1 Research Proposition

Literature review discussed in this chapter recognises many aspects to reconsider HPP as M*aterial* within practice. Therefore, current research impose new enquiries by drawing further research questions of: What are the missing elements or barriers in design of HPP that prevent people from using it for longer-term or even short-term period? What motivates user to use the HPP? Also, under the assumed premise of the correlation between HPP and energy saving behaviour; How can HPP be designed in a way that encourages user to use it in longer-term?

In pursuit of designing further research enquiry, it was stated that current research investigation will exclude the study in relation to 'parasitic harvesting' HPP. As noted, these type of products scavenge energy source 'indirectly' from people's everyday action which are perceived to be performed in a mind of 'sub-consciousness'.

Justification to this exclusion derived from the notion of these systems being a 'Self-powered products' (Paradiso and Starner, 2005) rather allowing user to perceive a 'possibility' for a certain action through affordances (Norman, 1999). Most of 'parasitic harvesting' HPP mainly focus on the idea of generating 'free energy', which normally requires users to perform an 'efficiency behaviour' – one-shot purchase of 'technological intervention that entails reduction of energy consumption generated by the energy efficiency. However, this research is not intended to view HPP merely as passive object, but as an instrument to discover deeper understanding of value, experiences and attitude involved during HPP usage.

It is argued that interaction in HPP enables critical reflection on energy consumption during its use. The new practice of using HPP and its internalised routine of use may formulate through; 'de-routinising' precedent patterns of energy consuming behaviour; and through 're-materialising' the 'inconspicuous' energy consumption habits; and 're-routinising' that behaviour through an 'internalisation' process; which in turn may establish the 'conspicuous environmentalism' (Hargreaves, 2011). Arguably, HPP should be considered as an intervention that aims for both short and long-term dynamics. Also, it is argued that HPP can be seen as 'product with longevity' by using potentially sufficient resource – non-depletable energy of human-power – and its durability resulting in no further consumption of energy during the use-phase. The external factors of HPP may have a weak impact on maintaining the sustainable use in long-term due to its incentive at a micro-level being so little. However, providing users with an experience of generating their own power to drive functions of EuP, gives users a 'perceivable sense of consciousness' (Chapman, 2005) of energy use in the short-term. The author also argues that the purchase of HPP can be seen as 'efficiency behaviour'. This particular behaviour require adopting an energy efficient product for the sake of increasing the further savings. However, in the scenario of replacing existing portable electronic devices with HPP, the saving may only apply to cost of total ownership that is reduced from not consuming additional batteries. In the context of 'energy saving behaviour', HPP requires a human effort of power generation that contributes towards conserving a corresponding amount of energy to drive the function on demand without relying on the grid power. According to Rogers (1983), a decision concerning the adoption or rejection of such innovation is made when information-seeking activities have reduced the uncertainty about the innovation's expected consequences. In order to find that consequences, the innovation (HPP) must be used by individual through a decision–making process of essentially seeking information and processing this information to later evaluate their dis/advantages; which can be seen as 'perceived behaviour control' (Ajzen, 1991). Later in this thesis provides evidences to prove that current HPP lacks in providing such feedback. While in that process, the designers of HPP should avoid 'command and control' approaches with an intention of empowering individual to cope with the uncertainty they experience (Nieusma, 2004). However, it still raises question whether public perceives the consequence of HPP as positive and enough to influence on maintaining the use. This highlights the necessity of conducting empirical study, to understand the current perception of HPP amongst the public and how potential HPP adopters evaluate the 'actual use'; and further, investigate how actual consequences are influencing their decision to continue use as an everyday product and as everyday energy source.

2.8 Conclusion

The detail and depth of Jansen's literature review and his 15 years of study in the field of HPP is extremely comprehensive. This study gained impetus from reviewing Jansen's extensive amount of research and empirically explored issues on essential part of HPP; the energy systems and power generation. Foremost, his prevailing findings obtained through scientifically driven approaches helped to realise the importance in understanding the 'actual use phase' of HPP that eventually requires qualitative consideration. It provided an opportunity of linking the enquiry to research questions of understanding how design can help sustain the use of HPP and to practice energy saving behaviour through reflection on energy consumption. In this research, the author views designers of HPP as those who intend to design devices that can be viable alternative solutions against the use of, and often over-consumption of non-renewable energy. The literature review included a broad range of academic papers from cross-disciplinary study of; human-powered products, sustainable consumption, practice theory, behavioural change, design interventions, user-centred design and motivational theories. This review has facilitated the process of exploring potential design strategies required for bringing about behavioural change, and discussed deficiencies of various different intervention models. In addition, it underlined the importance of investigating the effectiveness of such interventions, from implementation to inducing a new habitual practice, in bringing new behaviours, i.e. energy saving behaviour.

Chapter 3 Research Methodology

3.1 Introduction

This chapter overview the methodological approaches used in this research with a justification of each approach taken within the research projects. The methodologies are transpired from findings outlined from the literature review.

3.2 Research Paradigm

Paradigm of research is defined as the underlying belief that guides the investigation for choosing the methods for particular discipline to influence what should be studied and how results should be interpreted (Guba and Lincoln, 1994). Traditionally in disciplines of social science, there are two major philosophical paradigms; the ‘Positivism’ and ‘Interpretivism’. The researchers advocate the paradigm of ‘Positivism’ consider the knowledge based on phenomenon that is observed and experienced in order to understand the reality. While qualitative researchers have been adopting and subscribing to a ‘Constructivism/Interpretivism’ paradigm which emphatically understands human actions/behaviours rather emphasising on explanation of human behaviour (Bryman, 2004; Robson, 2002). This type of research paradigm typically view the researchers as one who are influenced by different intellectual traditions, predicating upon the view that study of the social world requires a different logic of respecting the difference between people and the objects; therefore require to grasp the subjective meaning of social action. The strength of qualitative research is that it yields in-depth and detailed data in order to create an understanding of phenomena and lived experiences (Bowen, 2005). The very essence of this study is to develop a conceptual understanding of HPP usage experience, and develop a model that suggests the design strategies required for maintaining its use. It requires understanding of how people interact with those design elements within the strategy; therefore, the approach involves around qualitative enquiries of building a ‘conversation’ between the researcher and the actual users of HPP (the research participants). The behaviour during the use of HPP and psychology involved in performing new practice cannot be understood without *meaning* and purposes attached by human actors. Qualitative data, therefore, can provide rich insight into human behaviour (Guba and Lincoln, 1994).

According to Bryman (2004), the term ‘Interpretivism’ is widely used and describes the epistemological research position that stresses on understanding of human behaviour. Rather approaching it through adoption of a natural scientific model in quantitative research, this type of research paradigm aims to understand the social world through an examination of interpretation of that world by its participants (Bryman, 2004). The main part of this research (see Section 3 of this thesis) involves in understanding of HPP user’s value, attitude, behaviour, and motivation for HPP usage determinants. For this reason, product-in-use case studies were carried with research participants as to co-construct meaning and knowledge, using appropriate methods that allow the investigation to capture multiple perspectives on actual experience with HPP. The participants in this research are viewed as agents to jointly create knowledge with the researcher to understand multiple realities under interpretivist paradigm (Robson, 2002).

3.2.1 Design as research paradigm

As this research project is framed under the context of ‘Design Research’, this field of enquiry and the knowledge resides in three sources: people, processes and products (Cross, 2006). Based on these sources, Cross (2006) argues that ‘design research’ falls into three categories: Design Epistemology – study of designerly ways of knowing; Design Praxiology – study of the practices and processes of design; Design Phenomenology – study of the form and configuration of artefacts. The ‘design research’ discipline seeks to develop domain-independent approaches to theory by drawing upon the research paradigms and methods from art and science as well as contributing to the emerging paradigms and methods of its own field of enquiry. Similar approaches have been applied as an attempt to define this discipline in building its own intellectual and rigorous culture (e.g. Frayling, 1993), one of the approaches widely being used is referred to as ‘research through design’. However, Cross (2006) emphasise that, in order to qualify as research, the activity must be reflection by the work of practitioner; extracting reliable knowledge from the artificial world and making it available to others through communication of re-usable results from that reflection. He argues that the knowledge in design research is of and about the artificial world that is inherent; in the activity of designing (engaging in and reflecting on that activity); in artefacts (gained through using and reflecting upon its usage); and in the processes of manufacturing (reflection upon the making of those artefacts).

> Design as a Discipline, therefore, can mean design studied on its own terms, within its own rigorous culture. It can mean a science of design based on the reflective practice of design: design as a discipline, but not design as a science (Cross, 2001, p. 54).

The most important results in this research were obtained through the use of an artefact that approached the problem in the form of prototype, designing a *Material* (based on practice theory) under user scenario of using human-power as alternative to non-renewable energy source by means of practicing energy saving behaviour. The artefact was developed in a 'research through design' tradition, investigating how intended design of developed artefact (HPP) corresponds to the actual interaction with the HPP users in an everyday life setting. The prototypes should therefore be seen as instruments that draw discourse in understanding the new HPP design space that is aimed at internalising its usage as well as gaining valuable knowledge about how to design future system of HPP. The detail process of making this prototype is discussed in Chapter 8.3.

3.3 Research Purpose

The purpose of research is a motivation to carry a study in the field of enquiry, concerning what type of knowledge to be discovered through the research activity. Robson (2002) classifies 4 different purposes of research enquiry, and they are as shown in below table.

Exploratory	- To find out what is happening, particularly in little-understood situation. - To seek new insight - To ask questions. - To assess phenomena in new light. - To generate ideas and hypotheses for future research - Almost exclusively of flexible design
Descriptive	- To portray an accurate profile of persons, events or situations.

	- Requires extensive previous knowledge of the situation etc. to be researched or described, so that you know appropriate aspects on which to gather information. - May be of flexible and/or fixed design.
Explanatory	- Seeks an explanation of a situation or problem, traditionally but not necessarily in the form of causal relationship. - To explain patterns relating to the phenomenon being researched. - To identify relationships between aspects of the phenomenon. - May be of flexible and/or fixed.
Emancipatory	- To create opportunities and the will to engage in social action. - Almost exclusively of flexible design.

Table 3-1 Classification of the purposes of enquiry (Robson, 2002, p. 59)

Efforts to improve the knowledge on design aspect of HPP and its statistical benefit have been proved, but largely by scientifically driven approaches (Jansen, 2011). However, the understanding of how people use HPP in their daily practice has rarely been studied. It was noted by Jansen (2011), recommending that there are outstanding integral design issues of human-power research which offers numerous opportunities for additional research. Moreover, from a view that HPP requires new or change behaviour, it has yet to be addressed in detail through practical research and by theories of social-psychology. Few HPP studies were found that mainly explored the usability (e.g. discomfort level) information to apply in user-centred design iteration process (Jansen and Slob, 2003; Smit and Sherwin, 2002). This thesis intention grew from the notion argued by many academics that designers should go beyond simply creating environmentally friendly products, but should challenge how people understand the 'functional object' and reframing our conception of products (Walker, 2006). Rather than making HPP as merely as functional machinery that produces alternative electricity, it should be regarded as M*aterial,* which resides in, as Shove and Pantzar (2005) describes, the combination of commodity-and-practice. Therefore, it aims to understand how people interact with HPP and the rationales behind the determinants for adopting HPP (a prototype), or rejection, as an everyday product; and their motivation in doing so.

Study of HPP, particularly from academic perspective, is relatively new area that has not been investigated in detail. Therefore, current study involved in conducting research activities that are under exploratory scheme, ‘to seek new insight, to ask questions, and to generate idea and hypotheses for the future research’ (Robson, 2002, p. 59); and by further systematically developing a theory that is based on data collected through a series of case studies through interplay between inductive and deductive reasoning, seeking to establish generalisation about the studying phenomenon under investigation.

3.4 Research Strategy

Up to now, researchers have been distinguishing between inductive and deductive research methods on the basis of presence or absence of theory. The distinction can be made by the aim of research which is either ‘theory verification’ or ‘theory generation’ (Robson, 2002). A researcher who advocates positivist methodology, which traditionally pre-specifies the research design prior to main data collection stage, uses fixed research design. The procedure is to start with a theory, deduces hypotheses, and designs the study to test the hypotheses. In traditions of flexible research design, known as grounded theory study (Strauss and Corbin, 2007); aims to end-up with a theory (inductive); starting with much less pre-specification and enable the design to evolve, develop and unfold as the research proceed.

Many design researchers and their practices often get influenced by approaches and methods derived from social sciences. Interplay between psychology and semiotic, as an example, they have been applied in areas of ergonomics and emotional design (Ingram *et al.*, 2007). So far, the study on HPP mainly circled around identifying the barriers and suggestions in the design of human-powered energy systems and broadening the knowledge required during the design process of related products based upon a scientific approach (Jansen, 2011). However, it does not mean that the knowledge is yet discovered or investigated by previous scholars in the field of enquiry. There is extensive knowledge already investigated by Jansen (2011) in relation to design of HPP system which generated a theoretical outcome that is deducted from specified hypotheses through an empirical study.

However, no such theoretical framework has been discussed or explored in relation to how people use HPP in their daily practice, more pertinently, how people acquire and organise using human-power as alternative source for powering EuP. Instead exploring the technical process of HPP design or its configuration as an artefact, current research followed an explorative study to identify hypotheses based on factors that influence on behaviour determinants to dis/continue use HPP as everyday product, or at least, exploring its viability as alternative energy source to practice energy saving behaviour.

According to Robson (2002) flexible design evolves during data collection. In flexible research design, based on existing traditions within qualitative research, there are three ranges of approaches: Case Study, Ethnographic Study, and Grounded Theory Study (Robson, 2002). The grounded theory study is particularly useful in new and applied area where there is lack of theory. As a study that aims to develop a theory - data collection, analysis, and theory development, even testing, are arranged throughout the research activities. In current research study, the researcher did not begin with a theory and test the hypothesis through the collection and analysis of data but instead used some existing theories to design questions and to develop the conceptual framework. As this research work is the first attempt in casting a plausible theory of informed subject of enquiry, an explorative investigation of HPP use was carried out through multiple-case studies, along with cross-disciplinary literature review which contributed in building an explanatory conceptual framework. The framework serves as guideline to explain, the abstract, prediction about phenomenon of HPP use; formulating questions to further study; and developing a 'HPP Internalisation Model' which hypothesised the recommendations of design strategy for maintaining the HPP use. The model itself serves as preliminary theoretical concept as to design and further develop rigorous case study. Therefore, the grounded theory approach is appropriate with a flexible research design, aimed at inductively developing a theory that is grounded in data systematically gathered and analysed through the research process (Strauss and Corbin, 2007).

However, it is argued that qualitative findings remain tentative as long as they are untested (Hyde, 2000). According to Robson (2002), similar to deduction process entailing an element of induction, the inductive process is likely to entail the modicum of deductive process. Main focus of grounded theory remain as generating new theory in the subject field, and as much as this research seeks to develop a new theory, the main purpose is to use the hypo-theoretical model to inform the new design strategy for maintaining HPP use. Therefore, the research also follows an evaluation research, as Robson (2002, p. 202) define this strategy as ‘an attempt to assess the worth or value of some innovation, intervention, services or approach’. In order to understand the phenomenon of using new HPP (the prototype), and because it involves interpretation, the research also consider this process to be a deductive process. Data analyses from earlier part of research; ‘Taxonomy and Analysis of Human-power product development’ (Chapter 4), ‘The User: Perception of human-powered products’ (Chapter 6), Home User Study: Stage 1 (Chapter 7) were used to identify the real world problem of HPP and to support the development of hypo-theoretical model, i.e. ‘HPP Internalisation Model’. Emerging concepts identified through main study of this research, ‘At Home: The Internalisation’ (Chapter 8), and its analysis was theorised with reference to literature and dimensions of hypo-theoretical model through deductive reasoning process as a means to evaluate the model. Similar strategy has been suggested as ‘Iterative’ (Bryman, 2004), involves a weaving back and forth between data and theory, and repeatedly referring back to each other. This iterative process ensures that the research is following some exploratory scheme rather merely wandering through the phases. The purpose is to empirically validate (evaluate) the theoretical notion of ‘HPP Internalisation Model’ and as a product-led intervention of using human-power to practice energy saving behaviour.

3.5 Research Methods

After defining the research strategy, the next step is the selection of appropriate research methods. Definition of ‘research methods’ in social research is a technique for collecting data which often involves methods of observation, documentation, interviews, and questionnaires (Bryman, 2004). As indicated in Table 1-1, Thesis Structure Matrix on page 9, the majority of research questions (including the sub-questions) focus on ‘what’ line of queries – for example, Q1: What are the current trends and development of HPPs?; Q2: What are the user benefit of using HPP?. Identifying such ways is more likely to use series of research methods to build understanding about ‘what’ is happening in the field of HPP and the subjects of enquires; an exploratory case studies were chosen that aim to develop appropriate hypotheses and propositions for further enquiry (Yin, 2009).

As indicated through Table 1-1, multi research methods were applied in different phases to meet the research questions posed. Section 2 of this thesis discusses the analysis of existing HPP by using ‘HPP Interaction Matrix’ for classifying types of interaction involved in HPP use (Chapter 4.2) and it includes study findings from minor research projects (Chapter 4.3 – student project and 4.4 – LCA study). The main study of this research has adopted a qualitative case study approach, with a replicative multiple-case design, i.e. (Chapter 6, Chapter 7, Chapter 8). Although dominant results are in qualitative data type, some quantitative results (Chapter 4.4, 8.2, 8.7) were also discussed through small research projects as means of supporting the hypotheses throughout the explorative case studies. According to Yin (2011), in explorative case study, the fieldwork and data collections should be undertaken prior to final definition of study questions and hypotheses. In pursuit of this, pilot study (Chapter 6.2) and ethnographical case study (Chapter 7) were conducted as an objective of understanding user perception of HPP and to understand the problem that becomes an obstacle in HPP use. The results of these preliminary case studies were integrated in the process of developing a conceptual framework, design iteration, and to further develop the final stage of case study which generated new insight into HPP internalisation process.

3.5.1 Scenario Based Research

In contrast to hypotheses used in traditional research, hypotheses discussed in this research must solely rely on a ‘scenario’ of adopting the use of human-power as a way of practicing energy saving behaviour. Now days, the term ‘scenario’ has been widely used in design professions as descriptions of natural, constructed or imagined contexts for user-product interactions (Fulton Suri and Marsh, 2000). As a communication tool, user scenario becomes quiet useful in conveying the observation results to share information, to provide inspiration, and to give freedom of interpretation. It can draw the viewer into a narrative structure that goes beyond artefact to reveal more complex issues (Dunne, 2008). Typical use of scenario in design process mainly support designers to perform action/reflection and to explore problem without making a premature or impulsive design direction.

In this research, especially in the main study phase, the scenario was used to: illustrate the use of HPP system, to evaluate the user-product interaction, and also to evaluate the hypo-theory. Campbell (1992) suggested that use of scenario can make important contribution for testing the case. In illustrating the use of HPP system, the recruitment in pilot study (1 day study) aimed at involving 'real' people, rather than targeted, avoiding research to merely investigate the reasons or cause of specified hypotheses. In order to understand the current perception of HPP among public, the study focused on how people comprehend the use of human-power within its real-life context and their accepted value. It focused on understanding 'product experience', more precisely, all possible affective experiences involved in the interaction of HPP. Rather investigating the phenomenon from depicted user, the pilot study used scenario to invite 'real' people into hypothetical situation for gaining the knowledge of 'real' perception of HPP use. However, it is noted that what people tell is not necessarily what he or she means (Strauss and Corbin, 2007). According to Blomberg (1993), there is a distinction between what people say and what they do, and it is related to behaviours that people believe as 'ideal', and manifested behaviour of what people actually do. User experience consultant Sara Bly has pointed out that if the phenomenon being study is based on infrequent occurrence, like the use of HPP, result from interview may be exaggerated and short-term observation may miss apparent importance (Bly, 1997). Therefore, the identical scenario which is using the human-powered radio, was implemented during post ethnographic field study with a prolonged duration of 1 week. See Chapter 7, HUS (Home User Study) stage 1.

3.5.2 Ethnographic Study

Ethnography is the study of actual practice in context, aiming to find opportunities as well as to counter assumptions. According to Robson (2002), particularly in social research, ethnographic study typically attempts to find the answers to research questions about specific group, organisation or community of interest, and their experiences. While this approach often get used by social scientist in understanding human behaviour, design professions were more interested in designing artefact that supports the activities or behaviour of studying communities. Although this kind of field studies are appropriate for understanding the activity and its relationship to new design or technology (see e.g. Gaver *et al.*, 2004b), it requires thorough planning of when and how to deploy the methods. As mentioned in earlier chapter, understanding how people use HPP in their daily practice has rarely been studied. As this research follows 'research through design' tradition, it used ethnographic study to draw discourse in understanding the problem of HPP, and how potential adopters of HPP correspond to internalisation process that is elicited through newly designed artefact in everyday life setting. The methodology used a theoretical sampling process whereby the research took investigation in different places, people, and sometimes used scenario to maximise the opportunities to discover variations in between data collection (Bryman, 2004). Throughout the main study, this research considered not only the people as object of sampling but also as data gathering to 'making comparison' in between concepts derived from evolving (hypo)theory.

3.5.2.1 Observation

Most important aspect about conducting ethnographic study is developing a descriptive understanding of the group being studied. Therefore, it is grounded in the field work which requires commitment to study the activities of people in real-life setting, more precisely, describing how people actually behave, rather how they ought to behave. From designer's perspective, it provides richer understanding of 'context of use' for the artefacts that they design. According to Blomberg (1993), the emphasis of using the natural setting derives from belief that particular behaviours can only be understood in everyday context in which they occur. The term ethnography was preferred by writers of research methods over 'participant observation' in the 1970s (Bryman, 2004). Because ethnographic study aims to understand the human behaviour, the investigation involves some period of observation. Blomberg (1993) emphasise that the ability to observe and record the activities become key to the success of the endeavour.

Technique of using a 'product' to capture the in-context behaviour is called 'Product-in-use' (Evans *et al.*, 2002). This typical study aims to collect detail account of behaviour surrounding a product or activity through using video equipment which is useful in recognising the problems in life that people have become accustomed to. During the pilot study, ‘Product-in-use’ observation was carried out with an aid of video camera capturing how people use human-powered radio. The result of pilot study gained greater understanding of HPP and re-identified design concerns that were discussed through developing conceptual frameworks. The detail methods and study results are discussed in Chapter 6.2.

3.5.2.2 HUS (Home User Study)

Similar to ‘Product-in-use’ approach, the term IHUT (In Home User Test) is also widely being used in different profession as one of marketing research technique. It is a cost effective way to test commercial driven products with real consumers before commencing to actual market launch. In order to get more realistic outcome on product satisfaction, IHUT approach asks consumers to use the product at home in their own environment rather in a closed room such as focus group. Because current research is not aimed at testing any product satisfactions, the ethnographic case studies were designed to ‘study’ the contemporary phenomenon of HPP use in real-life context. Therefore, the term HUS (Home User Study) was chosen which reflects the investigation of behaviour involved in the use of HPP by real-life practitioners.

It has been noted that more research is required, particularly in the UK domain, to gain more evidence towards intervention measures leading to a long-term behaviour change (Martiskaïnen, 2008). Also, it is argued by Darby (2003) that assessment of intervention was only focused on measuring the inputs and outputs of energy consumption, while failing to account how individual make sense or negotiate with the feedback system. So far, projects has been introduced that took interaction and product design together as a means of design intervention aimed at raising people’s awareness of energy use in everyday life (e.g. Backlund *et al.*, 2007). As mentioned in the literature review, these design intervention strategies have not been applied widely, and their effectiveness in prolonged period has not been validated with sufficient evidence from research data[25]. In order to construct the meaning of behaviour involve in the use of HPP, it is recognised that prolonged investigation

[25] Single paper (Routarinne, 2009) was found that reports a study in which two prototypes from Static! Projects were domesticated in different households in order to collect responses from actual users. The study discusses end user’s comments about their experience of project that may succeed or redeem in upcoming use.

period of ‘actual use’ is vital. The intention of HUS was not to evaluate and assess the HPP per se, but to gain a deeper insight into what it means to use human-power as alternative source of energy and to practice energy saving behaviour. Based on the conceptual framework discussed in previous chapter, multiple case studies of HUS were conducted against number of volunteered households.

Yin (2009) has emphasised that in conducting a multiple case study, it is important to follow replication procedure. The logic behind the replication is analogous to multiple experiments where by it attempts to duplicate the exact conditions of finding (literal replication); or might alter the condition to predict contrasting results under expected reasons (theoretical replication). The first stage of HUS provided evidences that support a theoretical view of HPP use in nature - a study to elicit tacit knowledge about how HPP is used in real world domestic setting. The developed conceptual framework then guided the design of case study for HUS stage 2 where households used a new prototype that is designed to induce internalisation of HPP use. In doing so, the research used method of ‘domestication probe’ (Gaver *et al.*, 2006) to reveal deeper understanding of their value, experiences and attitudes. The new prototype of HPP was domesticated into existing ecology of household-product by challenging their previous routine and users trying to make sense of this new object. The detail process and explanation about this approach is discussed in Chapter 8.4.

3.5.2.3 Semi-structured Interview

Looking back at practice theory, the case studies conducted in this research were designed in congruence to follow the concept of ‘practice-as-entity’ (Røpke, 2009). It aimed at understanding the role of *meaning, material, competence* when using HPP, as it requires user to perform a new practice. The pilot study and HUS stage 1 was designed to understand the *meaning* of behaviour that is involved in the use of HPP. The design development of *material*, following a research through design tradition (Frayling, 1993), was considered as process of designing sustainable socio-technical system to link the subject of activity with its *meaning* (motivation). The last case study, HUS stage 2 was considered as evaluating the hypo-theory of understanding how *competence* has derived from using the new *material* which attempted to elicit people to create new practice. These case studies focused on understanding the *meaning* of particular phenomenon to the participants, where both exploratory and explanatory work was required to understand different types of experiences, and also validating particular measures. Therefore, a qualitative interview was used to collect substantial amount of research data that is derived from direct users of HPP and their perceived casual explanations.

There are several different types of interview introduced by different scholars. Robson (2002) classifies them into fully structured, semi-structured, and unstructured. This parallels with Yin's (2009) classification of; structured, focused, and in-depth. According to Bryman (2004), structured interviews are mostly used in quantitative research where clearly specified set of research questions are structured to maximise the reliability and validity of measurement of key concepts. On the other hand, qualitative research mainly encapsulates two types of interview, i.e. semi-structured and unstructured. In semi-structured interview, researchers or interviewer is more likely to be following a guide which includes set of questions derived from the case study protocol. However, the order of questions can be modified during interview based upon interviewer's decision of asking new question that follow up interviewee's comment. Since there are much greater interests towards understanding interviewee's point of view, the interview may still remain open-ended and undertake a conversation manner. In both HUS, semi-structured interview was used to collect responses from participant who shared their experience of using HPP for the duration of 1 week. The design of interview guide was primarily based on the dimensions suggested in 'HPP Internalisation Model'.

3.6 Quality of research

In qualitative research, the validity and reliability for ensuring the rigour or legitimacy in its research process often gets challenged. This is due to the nature of flexible and qualitative research design where identical circumstances cannot be re-created and this may clash with how independent investigator attempts to replicate the results (Robson, 2002). Criticisms were based on the fact that existing categories used in traditional research were grounded in positivist paradigms which primarily underlie quantitative and experimental research design (Guba and Lincoln, 1994). Since design problems that occurs in real life are often 'wicked' (Buchanan, 1992), there is an indeterminacy where there are no definitive condition to be repeatable and there is not one single answer to explain the phenomena of interest. Therefore, the criteria for evaluating standard of attained rigor and its outcome of qualitative research have been subtly replaced by different concept. Through the work of Guba and Lincoln in 1980s, they suggested the substitution of reliability and validity as concept of “Trustworthiness”, containing four aspects: credibility, transferability, dependability, and conformability (Guba and Lincoln, 1994). However, for Strauss and Corbin (2007), the quality of research in grounded theory approach requires not only about validity, but also a creativity involved during the data analysis. In contrast, Morse *et al.* (2008) has argued that the concept of reliability and validity in qualitative research can be appropriately used in all scientific paradigms since its role is to investigate, to check, to question, and to theorise.

In the present field work case studies, the qualitative approach performs as iterative in order to ensure congruence among question formulation, literature, recruitment, data collection strategies, and analysis. However, ensuring the quality of research heavily depends on the researcher’s ability to put aside possible bias and being reflective rather than solely being objective account (Robson, 2002). Maxwell (1992) argued that observers and researcher are inextricably part of the world; therefore cannot be free from own experience to obtain observer-independent explanation of what people experience. In order for researchers to be aware of the importance of balance to maintain acceptable standard of research enquiry, Maxwell introduces kinds of understanding that are relevant to qualitative research. The main types are *description, interpretation* and *theory* (Maxwell, 1992*).* Typically, many qualitative researchers treat their accounts as one of a number of possible representation rather than being a definitive explanation of social reality. Moreover, since much flexible design keeps close relationship between the researcher and participants, this notion of ‘researcher-as-instrument’ stresses the latent bias (Robson, 2002). Therefore, they support their findings through some of the strategies advocated by scholars to deal with these threats to enhance the validity of research. Padgett (2004) presents six most common strategies used among qualitative researchers: *prolonged involvement, triangulation, peer debriefing and support, member checking, negative case analysis,* and *audit trail*. Other scholars have provided alternatives, but overlapping, by using different terms like *thick descriptions*, *respondent validation exercise* (Lincoln and Guba, 1986).

In order to ensure the quality of current research, a variety of data collection methods were used. Among those strategies mentioned by scholars, many put emphasis on strategy of triangulation which uses the multiple sources to enhance the rigour of the research. To avoid threat in providing a valid description of phenomenon studied, video recording were used during 'product-in-use' observation and all semi-structured interviews were audio recorded. To provide evidence and avoid bias, all semi-structured interviews were transcribed and transferred into computer-assisted analysis program called 'Nvivo'. The triangulation can also be used methodologically by combining the qualitative and quantitative approaches to gather multiple source of data (Robson, 2002). In HUS stage 2, both qualitative and quantitative data were obtained through utilising the prototype which recorded the energy consumption difference during the domestication period.

Possible treats can exist as these data collection methods requires an 'interpretation' of meaning and perspective of HUS participants. Framework accounting the phenomenon observed in the pilot study and HUS stage 1 were modified and applied into development of final version of framework which accounts the dimensions proposed in hypo-theory of 'HPP internalisation model'. These theoretical explanation of behaviour (i.e. internalising the use of human-power) were evaluated through HUS stage 2. This process serves as basis to demonstrating how interpretation in HUS stage 2 was reached and the theory development. The principle behind here is to show how the author traced the route by which the interpretation were made.

To ensure the validity of results the researcher must undertake a transparent methods to collect data and must be mindful to avoid their bias affecting on selection of data and its analysis. However, Robson (2002) also points to the notion that participants comments can also be given as bias. This is due to the fact that what respondent tell the researcher is not necessarily what they mean (Strauss and Corbin, 2007). It was noted in earlier chapter that some criticisms were made against attitude models of behaviour change that there is discrepancy between what people say they do and what they actually do (Darnton, 2004). As this research requires interpretation of participants' *meaning* and perspective based on 'product-in-use' experience, the trial period of using HPP and newly design prototype in stage

2 were engaged at a prolonged period of 1 week. During the trial, the device was deployed to household whereby participants experienced its use in their own environment setting without researcher being present. Therefore, data collected in this field study narrates understanding of how participants actually behaved, experienced or described their value/attitude; rather how they ought to behave or tried to give impressions to which they judged that the researcher wanted.

3.6.1 Ethical Consideration

Due to the nature of case studies conducted in this research several ethical issues arose that required consideration. All the participants were notified of the purpose of the research, what it would entail and their comments would be used as part of a PhD thesis. All the recruitments were based on a voluntarily basis, and that all recorded data were obtained with study participant's permission. Prior to each product-in-use study (Pilot Study, HUS 1 and 2), all participants were assured of their anonymity and all comments used in the analysis would be addressed under participant's code.

During the pilot study, a video recording equipment was set up that captured the each participant's behaviour. All the recordings began by exchanging a verbal consent from each participants. However, no such video clip was publicised neither through this thesis nor by any academic paper. In the later chapter, a collage of video captured screen was used as figure to explain how product-in-use observation was conducted. In this figure (see Figure 6.3), all participants' faces were concealed by overlaying a mosaic effect. For HUS stage 1 and 2, an introduction to the study mainly occurred via an initial email, or through survey flyer (see Appendix H), and more detailed procedure of the study was briefed at each household visit. Upon their consent, all semi-structured interviews were audio recorded and kept safely in hard drive for later use.

The aim of product-in-use study mainly dealt around exploring and understanding the HPP usage; therefore, no particular behaviour was designed, intended nor anticipated. All participants were treated as an 'autonomous' agent to participate, and the scope of investigation was not beyond the realm of behaviour they ought to perform which is to use the HPP.

3.7 Data Analysis

Strauss and Corbin (2007 p. 13) describe the analysis of grounded theory as 'interplay between researchers and data'. With this in mind of researcher, the analysis involved in this research required engagements in an interpretative relationship with not only the text based data of transcribed interview, but also includes images or scene that was observed from scenario based field studies. However, current research has not solely adopted grounded theory. Instead, it followed the approach used in grounded theory to consolidate the development of hypo-theoretical model and identifying the themes from pilot study and through case study HUS stage 1. According to Ryan and Bernard (2003), themes can emerge from; gathered data during inductive process; researcher's prior theoretical understanding of the phenomenon being studied and their characteristics; and from already agreed on professional definitions found in literature reviews. It is important not to view the findings from HUS stage 1, Pilot Study or literature as data, instead, the researcher use the pre-identified dimensions derived from these comparative incidents to examine the data generated at HUS stage 2.

Therefore, the questions that formed the new research objectives towards designing the main study were developed through consolidating existing behavioural change theories (see Chapter 2.5 and 2.6) and from development of conceptual framework (see Chapter 5.3). Findings in this phase of research became the ground basis to form the main category of themes and as a template of codes for analysis conducted for later study.

3.7.1 Thematic Coding

Thematic coding refers to any methods of categorising segments of qualitative data into meaningful themes. In qualitative analysis, terms of 'indexing', 'categorising', 'codes', and 'themes' are being used interchangeably to link pieces of data, i.e. text rather number, as representative of the phenomenon being studied. Rather counting the numbers of appearance of particular codes within the interview data, the qualitative analysis concerns more with interpreting the phenomenon. The analysis taken in HUS was aimed at understanding the complexity involved in the HPP practice rather than purely measuring the frequency of HPP use.

Braun and Clarke (2006) argued that thematic analysis should be considered as a specific method within major analytic tradition such as grounded theory (Charmaz, 2006; Strauss and Corbin, 2007). The benefit of thematic analysis is that it provides a flexibility which can potentially accommodate detailed, yet complex, account of qualitative data. Braun and Clarke (2006) has emphasised that there are a number of ways to determine the themes but it is important to have consistency in ways of conducting this within any particular analysis.

Themes within the data can be identified by either inductive (e.g. Grounded Theory) or deductive (e.g. theoretical approach – 'top down') way (Boyatzis, 1998; Braun and Clarke, 2006); or even as hybrid (Fereday and Muir-Cochrane, 2006). Contrast to inductive approach where the themes emerge directly from the data which is often called 'data-driven' coding, the 'theoretical' approach uses a template in the form of codes and themes that are driven by researcher's theoretical or analytic interest in the area of study. Braun and Clarke (2006) suggest that choice between inductive and theoretical analysis relates to how and why the researcher of study is coding the data.

In preliminary study (Pilot Study and HUS stage 1), data-driven coding was chosen to identify the themes that account the phenomenon of interacting with existing HPP. These themes contributed towards revising the hype-theory of 'HPP Internalisation Model' and identifying the design specification of *material* developed in HUS stage 2 for conducting product-in-use study. The analysis chosen for HUS stage 2 and the coding process maps onto quite specific research question mentioned in Chapter 5.5, which is to validate the theoretical notion of 'HPP Internalisation Model'. In order to evaluate this hypo-theory, deductive thematic analysis was integral in complementing the research question posed. However, the analysis also allowed for new themes to emerge directly from the data using inductive coding which accounted other important aspects identified during HUS stage 2. Therefore, the chosen method of analysis was a hybrid approach which incorporated both the data-driven inductive approach (Boyatzis, 1998) and deductive approach using a priori template of codes outlined by Crabtree and Miller (1992).

According Boyatzis (1998), in using a theory driven approach, there are three steps in developing themes and codes: generating a code, reviewing and revising the code in the context from raw information, and determining the reliability of the code. As the goal of all research is to obtain in-depth understanding and to create fully developed framework which becomes a theory, it is likely for researcher to have hypo-theories in their mind even at the beginning of the research study (Boyatzis, 1998). The first step of coding analysis was identifying the themes generated from contemplating hypo-theory which constitutes the element of dimensions suggested in ‘HPP Internalisation Model’. Next step was to analyse the data using the constant comparative methods (Strauss and Corbin, 2007) whereby transcribed interviews were reviewed thoroughly to generate additional codes which were clustered into segments of code that is guided by pre-identified themes in the first step. As there may be a conflict between the actual phenomenon and the projection on the part of hypo-theory, themes may not be compatible with the code generated from reviewing the raw data. Therefore, based on the absence or presence of themes in the raw information, i.e. validating the code, the interpretation became a direct commentary on the theory whether being confirmed or at least parts of it became refuted. The result of these analyses was the ability to evaluate the effectiveness of each dimensions in the ‘HPP Internalisation Model’.

3.8 Overview of Research Design

Having decided with research methodology as multi-methods, methods and analysis techniques used in each phase of research will be detailed in later sections. Figure 3.1 shows the illustration of research methodology used for current research.

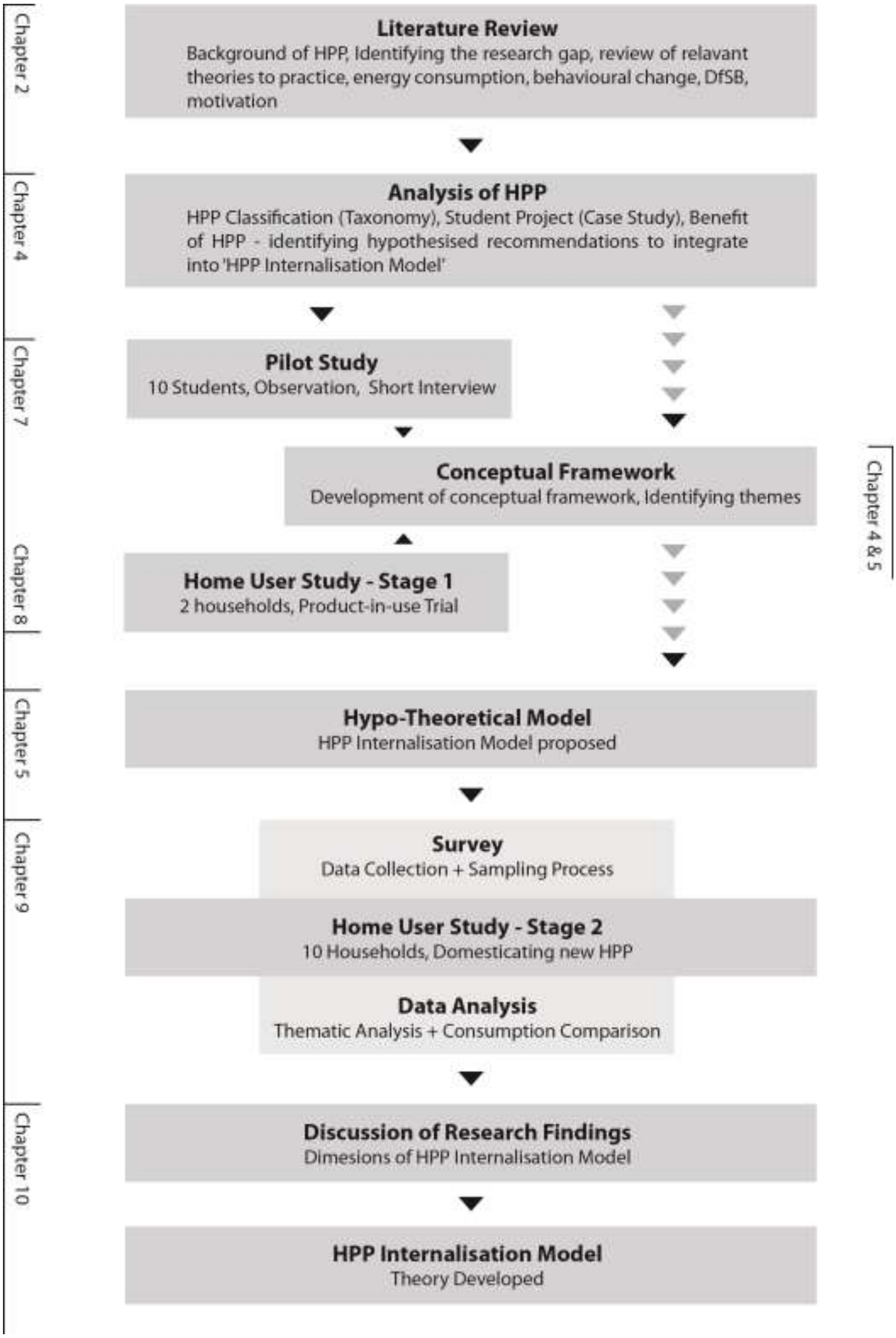

Figure 3.1 Overview of Research Design

Section 2: Analysis of Human-powered Products

Chapter 4 Taxonomy and Analysis of Human-power product development

4.1 Introduction

This chapter discusses the process of developing a prototypic taxonomy of HPP, classifying the types of attributes involved in existing and conceptual designs of HPP. From reviewing publications relating to the development of HPP, difficulties were found in creating a definition or taxonomy that allows designers to contrast disparate use of human-power sources, e.g. wind-up, crank, and parasitic harvesting. To address this issue, this chapter presents the progress of developing a prototypic taxonomy leading to a Matrix ranging from version 1 to 5, which describes the potential design spaces utilising different applications of human-power use. Lastly, it discusses the process of identifying the three dimensions to consider when designing HPP for inducing fed use (HPP Internalisation Model – Hypo-theoretical). All sub-chapters discuss the research investigations in identifying each attributes of HPP, and include a comprehensive analysis of developing this hypo-theoretical model. Following two sub-chapters address the following research questions:

Q 1.2 How can HPP be characterised?
Q 3.2: What motivates users to use the HPP?

4.2 The 'HPP Interaction Matrix'

The method of interaction embedded in HPP communicates directly to users an environmental benefit of harvesting their own energy as an alternative power source - a clean energy (Jansen and Stevels, 2006). One such interactivity, the power generation in HPP, may be interpreted as an educational intervention, rather than parasitic (i.e. generating 'free' energy by stealth), but will always inform and communicate to people what our body can do. From monitoring concepts of HPP from wider sources, the research developed a ‘Human-Power Products Interaction Matrix’ (version 2), as shown in Figure 4.1.

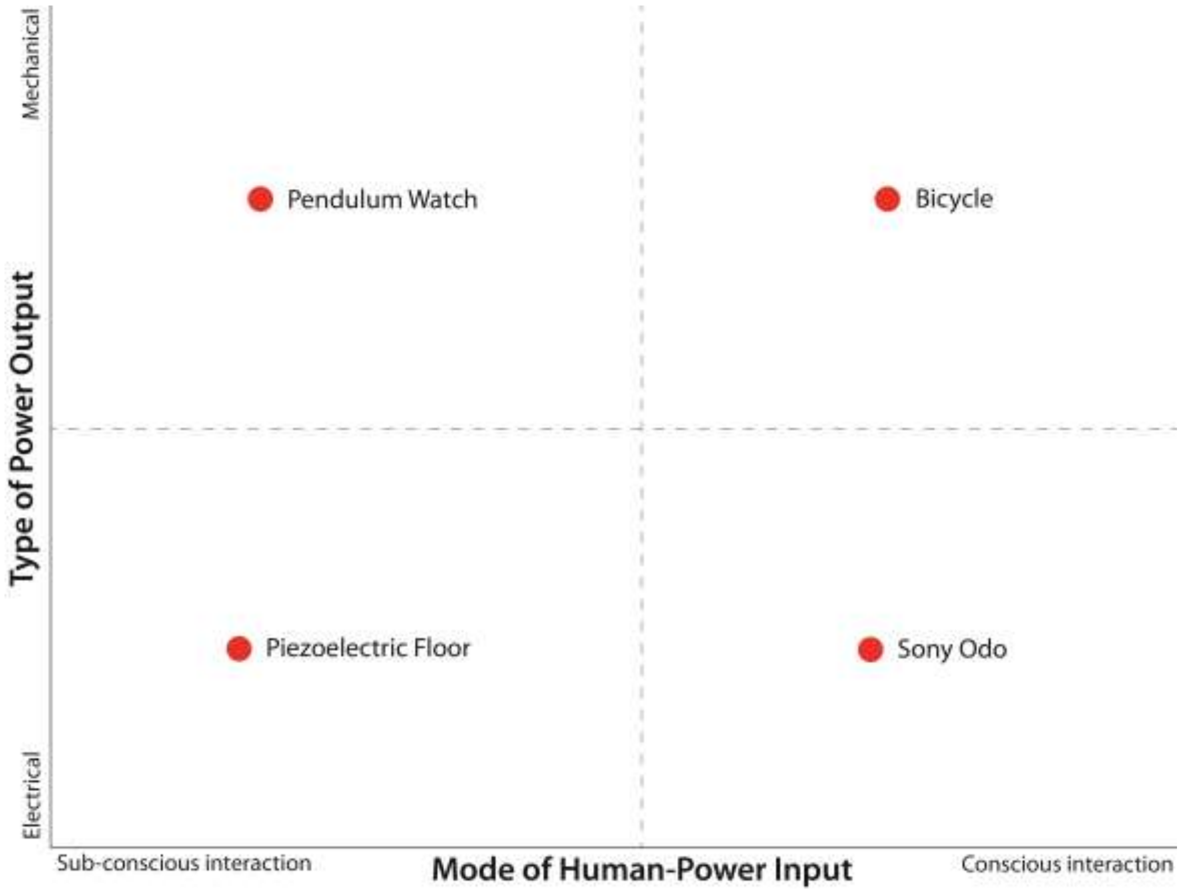

Figure 4.1 Human-Powered Products Interaction Matrix – Version 2

As an attempt, this Matrix is configured around two dimensional axes; the horizontal axis represents the type of cognitive input mode of user interaction between conscious and sub-conscious power generation; the vertical axis shows the type of power output in HPP - either (bio) mechanical and electrical. The Matrix broadens out the definition of HPP compared to other related literatures (Jansen and Stevels, 1999; 2004; 2006) where they are described either as HPP with ‘energy system’ or as ‘parasitic harvesting’ HPP. The purpose of this Matrix is to classify and analyse different attributes of HPP interactions, identifying the possible design spaces. The idea of creating such Matrix spurred from the notion that many concepts monitored from various sources have been showing drastic development beyond introduction of parasitic technology or simple human-power interaction of ‘crank’ or ‘pedal power’. Also, no similar taxonomy for HPP was available or found from literature review. Jansen did, however, created the most recent and detailed analysis focusing around HPP with energy systems. His analysis included the categories of retail price, primary and secondary functions, power generation principle, and marketing strategies (Jansen, 2011).

	Sub-conscious Interaction	**Conscious Interaction**
Mechanical	 **Figure 2.10** Pendulum Watch (TagHeuer, 2010) Mechanical + Sub-conscious interaction: Harvesting energy from sub-conscious mode of user muscle energy, parasitic harvesting, and convert into mechanical power output	 **Figure 2.1** Maya Pedal’s Bicilicuadora (Anon., 2010) Mechanical + Conscious interaction: Harvesting energy from the conscious mode of user muscle energy, direct force exertion, and converted into a mechanical power output, e.g., bicycle.
Electrical	 **Figure 2.9** Sustainable Dance Floor (Anon., 2007) Electrical + Sub-conscious interaction: Harvesting energy from the sub-conscious mode of user muscle energy, parasitic harvesting, and converted into electrical power output	 **Figure 2.8** The first Baygen Freeplay Radio (a) (Baylis, 1999) Electrical + Conscious interaction: Harvesting energy from the conscious mode of user muscle energy, direct force exertion, and converted into electrical power output, e.g., Freeplay Radio

Table 4-1 Examples of HPP for each domain

As a result of classifying HPP through using two dimensional axes, 4 representative domains were identified. As reviewed from Dean's book of 'Human-powered Home' (2008), the range of this Matrix encompasses HPP that have a mechanical output such as a bicycle; in fact it is the oldest and the most iconic HPP. To best explain 4 domains of taxonomy, Table 4-1 shows the example of each domain.

4.2.1 Conscious / Sub-Conscious Interaction

When designing a HPP or its energy system, the vital challenge may reside in reducing the labour around power generating, avoiding real or perceived fatigue to the users. These experience of such fatigue can be regarded as 'perceived behavioural control' (Ajzen, 1991); evaluating the dis/advantages of consequences resulting from exerting human-power. Although the fatigue or stress level is difficult to measure, the motivation of HPP use may be determined by their wider perceived benefits such as price saving, fun, environmentally friendly, no battery, and feel-good factors. These both external and internal factors can be perceived as incentives of using HPP. For first dimension, research was able to define and differentiate types of interactions into two modes of human-power 'input' and they are; conscious user interaction and sub-conscious user interaction. The best examples of such differentiation can be observed from Figure 2.8 and Figure 2.9. The BayGen Freeplay Radio requires a one handed cranking physical motion to wind up the spring which then unwinds to power the motor to supply sufficient electricity (Baylis, 1999). In this interaction, the users utilise their muscle power to apply a kinetic energy 'consciously' by cranking. In other words, the user is in a cognitive and conscious mode of generating energy through a body motion and human muscle exertion. Norman (1990) terms this as 'direct interaction' which refers to a user's direct engagement during the related activity, such as using a tool like hammer or screwdriver. Although this 'consciousness' can fade away as they become a 'real affordance' (Norman, 1999), e.g. cranking without thinking as they became so 'routinised', also known as 'practical consciousness' (as described by Giddens, 1984), but such psychological awareness do exist in prior to this process. On the other hand, the examples characterise as 'sub-conscious interaction' are devices of HPP that utilise energy from human physical movement, arising from sub-consciousness of everyday activities or product-user interactions. For example, parasitic harvesting technologies scavenge energy from people's footsteps, or from an interaction with a third device (e.g. dynamo installed on top of revolving door). In both cases, users are in a ‘practical consciousness’ state of interaction, or often repeatedly performing their daily activities in a sub-conscious mode rather than finding any psychological awareness to generating electricity. According to Norman (2002), two psychological modes are articulated as he explains about behavioural level of design that people can sub-consciously drive an automobile while consciously thinking of something else.

Not all parasitic harvesting technologies are implemented in large-scale and fixed installations. As mentioned in Chapter 2.2.3, scholars have produced a number of parasitic concepts that scavenges human-power in a micro-scale, particularly aiming to power wireless devices like a watch or mobile phones (Kymissis *et al.*, 1998; Paradiso and Starner, 2005). The lab has also introduced PVDF (piezoelectric composite material made in a multilayer) technology that can be applied as a shoe insole (see Figure 4.2); and dynamo mounted onto shoe (Figure 4.3). From energy harvesting perspective, these technologies using the power of daily human movements indeed broaden the HPP applications that can be more practical for wireless devices. Paradiso and Starner (2005) call this concept as ‘Self-powered devices’. For scenario of these technologies penetrating the consumer product market with an aim of bringing about a reduction in energy consumption, it would require people to perform ‘efficiency behaviour’ (Gardner and Stern, 2008) whereby people’s related intentions should lead to the decision of purchasing those products. However, it is noted that the performance of these technologies would require satisfactory results and should always aim to prevent people from performing additional behaviour that causes the rebound effect. For example, over-consumption of these products and their entailing cost savings during use-phase may not justify the total cost invested in the purchase.

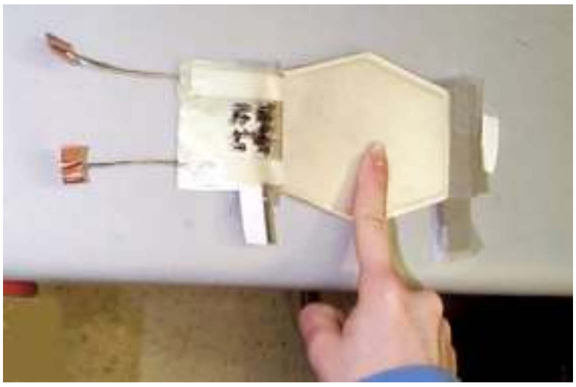

Figure 4.2 PVDF insole stave (left) (Paradiso and Starner, 2005)

Figure 4.3 Shoe-mounted rotary magnetic generator (right) (Paradiso and Starner, 2005)

There has been research carried out in the field between interaction design and HPP, conducted by global companies such as Sony. They have been continuously investing in the development of concept design practices for sustainability purposes. Sony is seeking ways to generate electricity as users 'play' with their concept devices, adding aspects of fun, playfulness, curiosity, ambiguity and unusual practices in use (Sony, 2007). The design team aims to enhance the life value by having a sense of social consciousness and ecological values through developing concepts of HPP. One of Sony's concept products include the 'Spin N' Snap' (Figure 4.4), a digital camera that is charged by placing two fingers in two separate holes and spinning it around a few times to allow a charge. Another example is 'Twirl N' Take' (Figure 4.5) where it uses a one-hand rolling technique to charge enough power to take a digital photo. Both are good examples that demonstrate how interaction design expands its role in providing more intriguing 'perceived behavioural control' (Ajzen, 1991) over their human-power input. People are drawn into an interaction that enables them to experience the consequences of generated power which is derived from a 'fun' interaction. Although the level of consciousness involved in this design application is still immeasurable, the strategy is to induce human-power exertion through interaction design beyond the traditional methods; cranking or winding. This is not to argue that techniques like push button or a simple winding motion does not provide an intriguing experience, but to argue that any applications that delegates control over electricity generation to users and given that empowerment of 'fun' takes such crucial role for instigating motivations to use HPP.

Figure 4.4 Sony Odo Project, Spin N' Snap Digital camera (Sony, 2007)

Figure 4.5 Twirl N' Take (Sony, 2007)

4.2.2 Mechanical (Bio) / Electrical power output

The starting point of configuring a vertical axis onto the Matrix was derived from notion that not all HPP are powered from an 'energy system'[26]. Jansen's definition of HPP is a 'non-conventional power source' focusing on products featuring a conversion of muscular work into *electricity* (Jansen, 2011). This is where the definition may counter against Dean's argument that a 'conventional power source' used to constitute a human-power from historical perspective (Dean, 2008), e.g. gramophone. Therefore, HPP can be defined as any products powered by human physical interaction which either has an output of (bio) mechanical or electrical functions. The best example to explain the vertical axis of the Matrix will be the

[26] 'a technical artefact designed for converting the efforts of human muscular work into electricity' (Jansen, 2011, p. 3).

'bicycle'. It amplifies human muscle energy into mechanical work to produce a velocity which then enables a user to travel a distance. A bicycle is likely to be plotted at top range of vertical line for having mechanical output - not incorporating any electrical storage unit. These types of non-electrical HPP are still favoured by many people. HPP such as Coffee Grinders, Can openers and hand whisks are conventional examples that are still widely used by household whilst electrical versions are available in the market.

Within the domain of 'mechanical + sub-conscious' interaction (A), the only example found was the pendulum watch (TagHeuer, 2010), see Figure 2.10, pg. 22. As mentioned in the earlier chapter, the most popularly known human-powered watch is 'Seiko' quarts wristwatch introduced in 1988. This type of watch captures the vibration of walker's movement (pedometer) which rotates the pendulum connected to a pinion driving a force to wind-up the spring – a mechanical system. However, in recent development of pendulum watch it also uses a miniature generator (Matsuzawa and Saka, 1997, cited in Jansen, 2011). In this case, the example can be included in the domain of 'electrical + sub-conscious'.

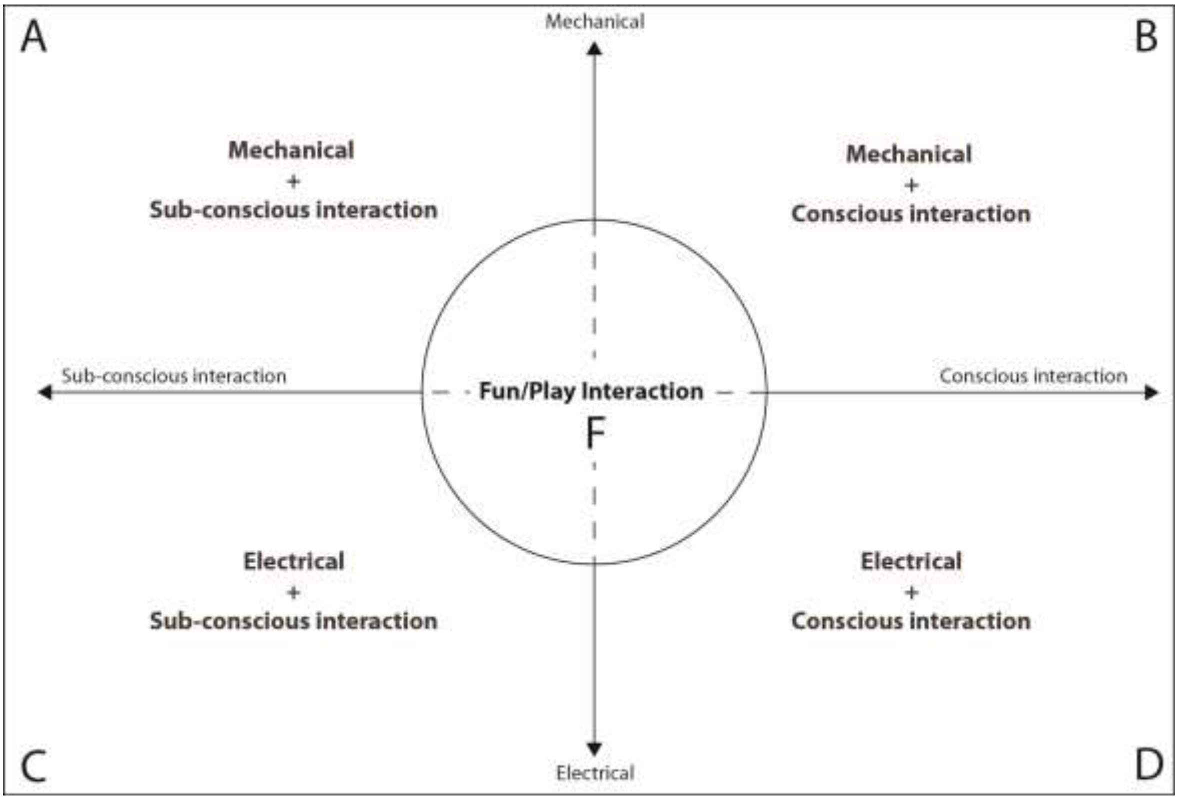

Figure 4.6 HPP Interaction Matrix - Version 1

4.2.3 'Fun' Interaction

Figure 4.6 HPP Interaction Matrix - Version 1 is the first version of Matrix developed during an early stage of current research. As illustrated, the progress of classification resulted in developing 5 different domains (A~F) that explains each attributes of HPP. In addition to two axes, a 'fun interaction' domain had been inserted in the central zone of the Matrix. An example of this domain is the Soccket, shown in Figure 4.7. It is a soccer ball (football) that captures energy during game play; generating electricity from the movement of cylinder magnet traveling between the coiled copper that is located in the centre of soccer ball. After some period of playing with the device, the user can return home and use the ball to connect to a LED lamp to read, study, or use it as an indoor lighting. According to the manufacturer, 15 minutes of play can light 3 hours of LED (Uncharted-Play, 2010). The 'fun' feature of playing a soccer game is encouraging users to create kinetic energy from its physical interaction. From this description, the Soccket can be plotted in the central 'Fun Interaction' area but below the horizontal axis due to having electrical output from a power storage unit. However, for the Playpump (Figure 2.11, on pg. 23), it can be plotted within the domain of 'fun interaction' but will be placed above the horizontal axis due to this system not amplifying any electrical output.

Figure 4.7 Soccket (Uncharted-Play, 2010)

Whilst many parasitic harvesting technologies are concentrating on scavenging human-power from a 'sub-conscious' mode of power input, most HPP in the domain of 'F' attempt to draw motivation for applying human-power in discrete mode of interaction. The 'fun' activities involved in two examples of HPP are themselves intrinsically rewarding during at 'play' and arguably they are in 'conscious' mode. It is argued that when positive feedback shows the effect of a certain activity, it enhances the intrinsic motivations (Deci and Ryan, 2000). In the same context, it can be seen that availability of incentives (free electricity) that are conserved while at 'play' may enhance such intrinsically motivated behaviours. Also, it can be observed that the examples of Playpump and Sockket are particularly targeted at demographics who suffer from shortage of 'resource' such as water or electricity. Therefore, the 'need' factor may prevent the obsolescence of such motivation as they are indispensable resources rather than inconspicuously desired. In this case, an individual's decision in using HPP may become greater as both internal (energy scarcity) and external factors (fun) merge together. The discrete nature of interacting with the device arises when the user consciously plays with the 'fun' feature (e.g. playing football), but the method of transforming the human-power into another form of energy such as a pump or electrical light is scavenged in a sub-conscious mode

(Stealth mode). Therefore, the first version of the Matrix plotted the domain of ‘fun interaction’ (F) in the central area as they both include interaction of ‘consciousness’ and ‘sub-consciousness’; and sometimes having output energy of either ‘electrical’ or ‘mechanical’.

4.3 Student Project as case study, Project ‘Off the Grid’

The initial research work began as a case study involving first year product design undergraduate students at Nottingham Trent University. The main objective of the study was to collect HPP concepts generated by students, based on the first version of HPP Interaction Matrix, and plotting them onto each domain. The first version of the Matrix attempted to propose a set of design dimensions that constitute the axes of taxonomy; then, HPP designers can select the method of utilising human-power during the design process. However, it required an exploration of identifying the feasibility of this Matrix.

In doing so, more subsequent questions were generated, as reviewing the first version of HPP Interaction Matrix. However, these questions still fall under the scope of research question of; ‘How can HPP be characterised?’. The questions are:

- Could existing or newly developed HPP concepts be classified by using ‘HPP Interaction Matrix’?

- What are the most common electrical products that students use? And can they be transformed into HPP?

From December 2010 to November 2011, total duration of 8 weeks long student project was designed for this case study. The project addressed the over-consumption of energy issue resulting from increased use of everyday electronics. Students were briefed to select an electronic product and (re)design it into an interactive ‘off the grid product’ - meaning its functional power should not be supplied by neither the power grid nor any kind of new technologies such as photovoltaic power cells. The results of the project produced number of speculative concepts that are design driven, proposed as alternative solutions to problem addressed in the brief. The result also produced a comparative analysis between plotting of student project concepts and plotting results from real time HPP monitoring onto an 'HPP Interaction Matrix', see Figure 4.11 on page 123.

4.3.1 Probe

One important objective of the case study was to collect quantitative data of identifying the range of the most common electronics products being used in a students' daily life. This type of method is often called 'Cultural Probe' developed by (Gaver *et al.*, 1999), intended to provide insight and inspiration for the design process. The methodology originally require a set of tools such as disposable camera to keep the image diary of people's daily life with given instruction from the researcher.

The student project was designed into two parts. The first part of the project was a one day observation, producing an observational sheet comprising photos of 25 products (called as 'bingo sheet') that students interact the most in their daily routine, shown in Figure 4.8. See also Appendix A for the first part of project brief. At this stage, students were not briefed about the second part which required choosing one electrical product among 25 observed and (re)designing it into HPP. The rationale behind the first part of the project was aimed at raising awareness to electricity consumption of chosen products, and bringing up the subject of 'inconspicuousness' of energy use while they interact with those product/services. The tasks set in the project aimed to direct students to perform a thorough observation on a particular electronic product, at same time, helping them to realise how a designed product is specified against a range of complex parameters other than simply performance and aesthetics. This enabled students to critically explore a single product, approaching the potential design transformation and embodiment in more diverse and conceptual way.

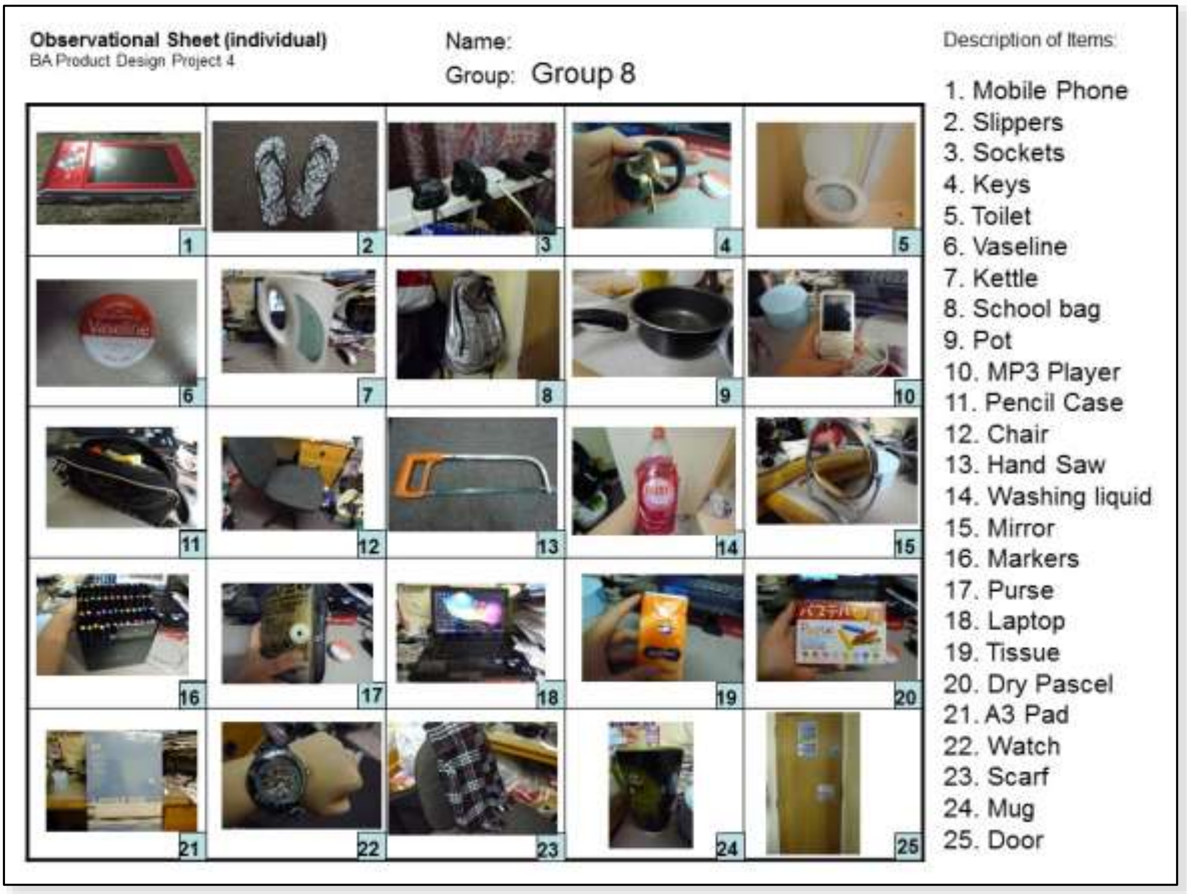

Figure 4.8 Student project part 1 – Example of observational sheet

In order to prevent student from listing the product items with having pre-conceived idea for designing HPP, the second part of the project was later revealed after the delivery of submitting the observational sheet. A Total of 656 product items were observed from submitted observation sheets, and number of 60 common items were identified through synthesising process; developing 10 final observation sheets from groups of 6~7 students. As an initial synthesising process, students played a ‘bingo’ game, calling out an item listed in their observational sheet. First three individuals who made 5 consecutive lines were given small winning prizes, i.e. human-powered radio. The game exercise was aimed at students to realise and share the kinds of everyday items that are commonly being used among students. Second stage of the exercise was to list out in a sheet, as a group, the common and non-common items from reviewing individual team member’s sheet. Final stage of group exercise was repeating the ‘bingo’ game from a collaged group version of observational sheet. See Figure 4.9.

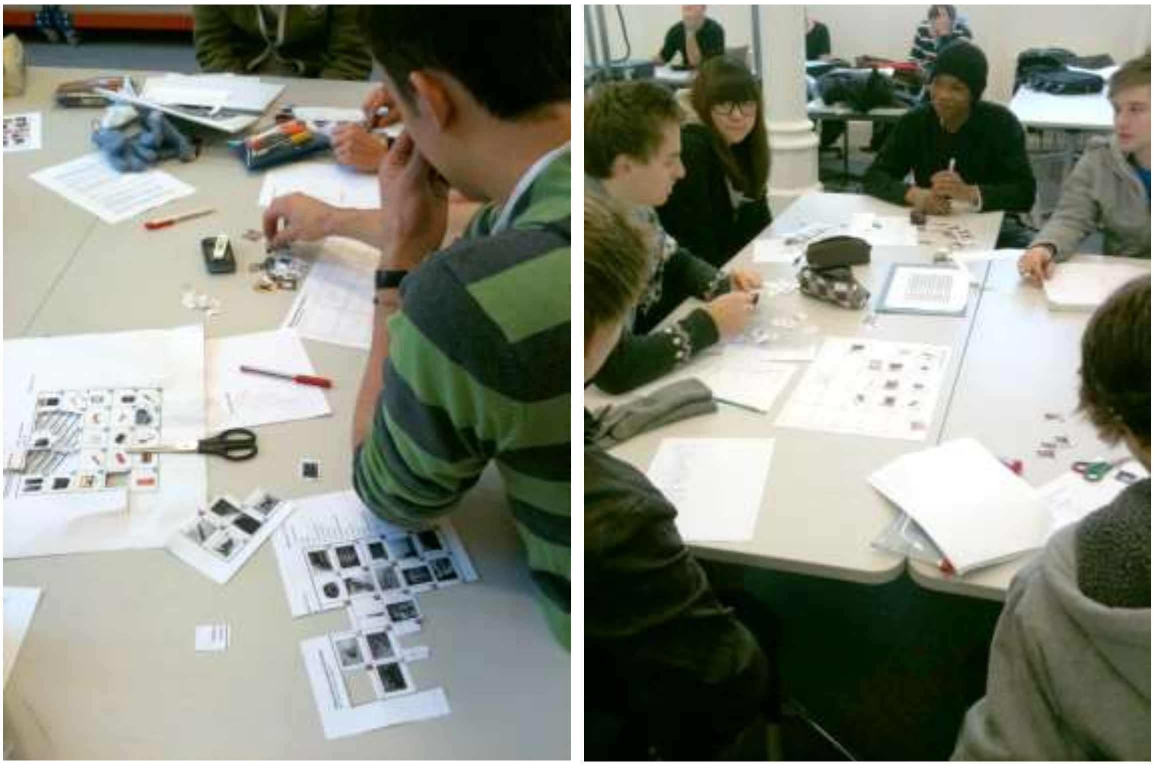

Figure 4.9 Picture taken during 'Bingo' game, a synthesising process of identifying common items being used by students.

The result showed that, 44 % of all items were electronics, of which 35 % were classified as 'portable' electronic devices - which potentially have a higher possibility of transforming into HPP. The most common electronic items were mobile phone, laptop and MP3 (Ipod), and additionally, products like electric toothbrush, alarm clock, shaver, mouse, remote, and camera were listed as portable products. The project which incorporates a method of retrieving common items/products data from this type of probe exercise seemed a justifiable method. The process helped in identifying the list of such products for consideration of (re)designing into HPP. As Gaver (2004a, p.7) expressed concern over this methodology being used in a purely scientific fashion, the result of part 1 exercise was not merely designed for finding hard numbers, but to encourage students to engage with the subject and to use 'a pervasive sense of uncertainty as positive value for design'. It was deemed crucial as a research objective to deploy methodologies to select and conceptualise such products into HPP which can ideally be acceptable to future users; in some cases enabling the potential creation of new market scenarios. In other words, they must be products that are commonly being used, and will be used to greatly effect on future products. Interestingly, Jansen has presented a table showing average power consumption of portable consumer electronics in year 1999. His paper identifies the opportunities for HPP by combining levels of human-power output from push, squeeze, and crank with the list of product items including their power consumption. (See Table 2-1 on page 19 and Figure 4.10). It was observed that top items selected from student project in year 2011 shows some overlapping with Jansen's list. However, items like the Walkman or portable FM radio are now converged into single device such as IPods or IPhones. These products' power consumption has been fluctuating over the past 12 years. For instance, due to having multiple features and services, products like IPod require higher capacity of battery which then requires higher power supply in average of 2~5 Watt (i.e. IPhone charger consumes 5 Watt). Presumably, as these product/services play such crucial role in accomplishing today's daily tasks, the usage time of these everyday electronics have been increasing.

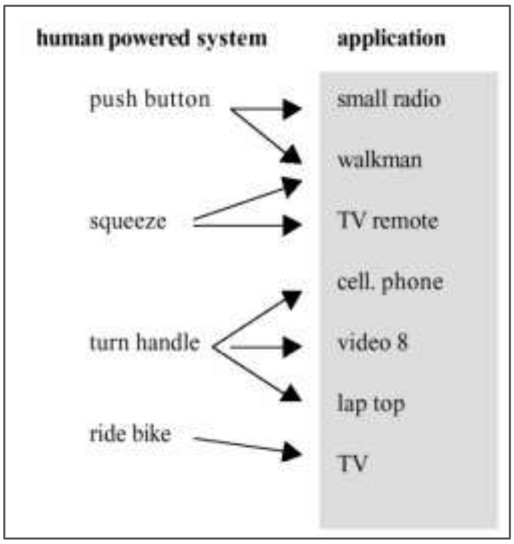

Figure 4.10 Combination of human-power movements and application (Jansen and Stevels, 1999)

4.3.2 Plotting

After the first part of the project, students were briefed to select an electronic product from their observational sheet and (re)design it into an interactive 'off the grid' product[27]. All of the students' final concepts were characterised and plotted onto the 'HPP Interaction Matrix', on version 1. Figure 4.11 shows the overlay plotting of real-time HPP concepts (Thumbnail pictures) and the plotting result of the student project

[27] See Appendix B for student project part 2.

(red dots). It can be observed that the results from both cases showed similar plotting characteristics. The HPP monitoring process has only found one example that best describes the domain 'A' which was a Pendulum Watch. However, this case study exercise was not able to identify any concepts or innovative idea arising from students' concepts that could be characterised within this domain (A) of 'Mechanical (output) + Sub-conscious interaction (input mode). The examples of student project concepts and full list of student projects can be found in Appendix D of this thesis.

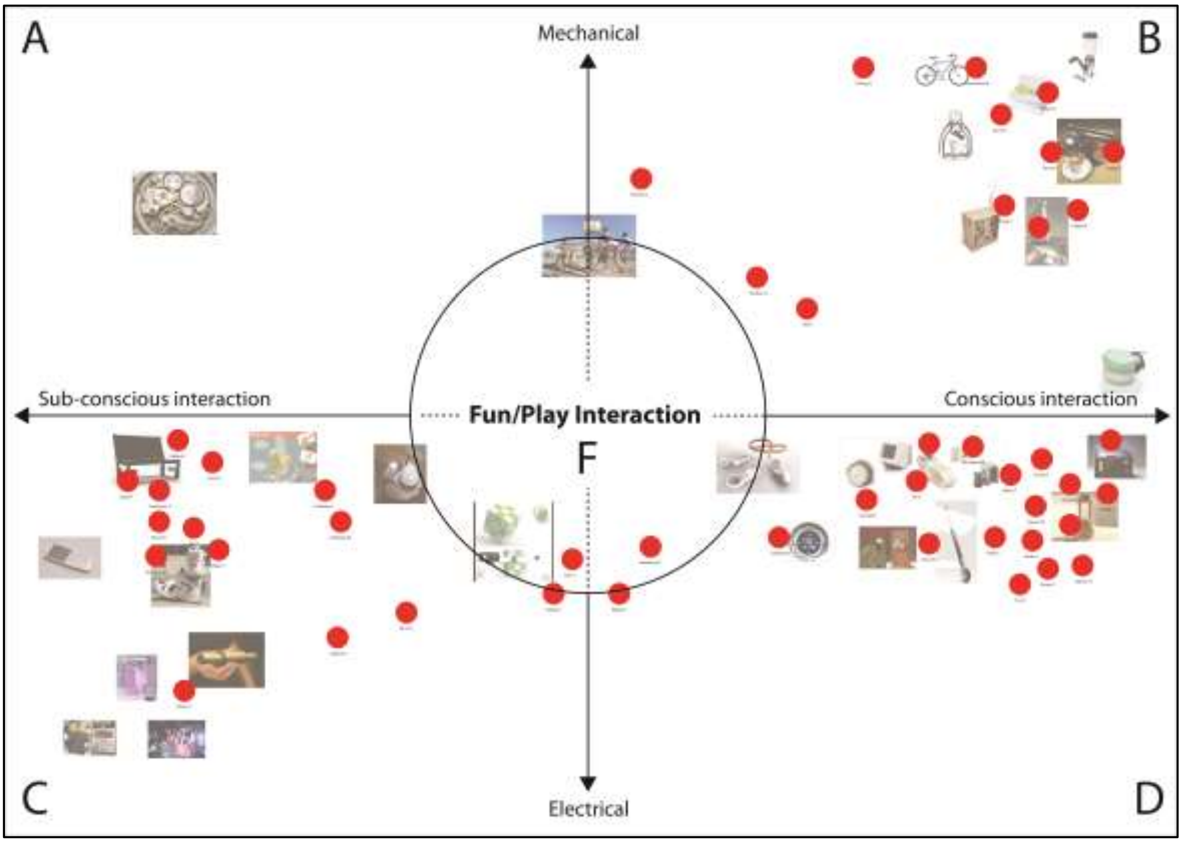

Figure 4.11 Overlay plotting (Red dot shows the plotting of the student project)

4.4 Benefit of using HPP

It has been argued by many scholars that the 'use-phase' of the electrical product's life cycle is the most significant impact in the context of energy consumption (Bhamra *et al.*, 2011; Lilley, 2009; Wever *et al.*, 2008). The energy consumption is mostly regulated and they are determined by users' behaviour. While HPP concepts are known as product using alternative energy source or by means of generating 'free-energy', it is crucial to examine their actual size of potential incentives arising during the 'use-phase'. This enquiry leads to research questions of:

Q2: What are the user benefits of using HPP?	Q.2.1: What benefit has been discussed in the past research or publication?
	Q. 2.2: Can sustainable usage of HPPs reduce energy (electricity) consumption?

Jansen conducted a study (1997), an environmental impact analysis by comparing a human-powered radio with three battery powered products (non-HPP), measuring their life cycle value through SIMAPRO Life Cycle Assessment (LCA) tool, see Figure 4.12. His analysis was based on assumption that all radios will be used and transported into country of Netherlands. The major factor that influences on the yearly increment value (mPts) of non-HPP (D&S[28], Grundig, Philips) is based on consumption of battery over the five-year life cycle.

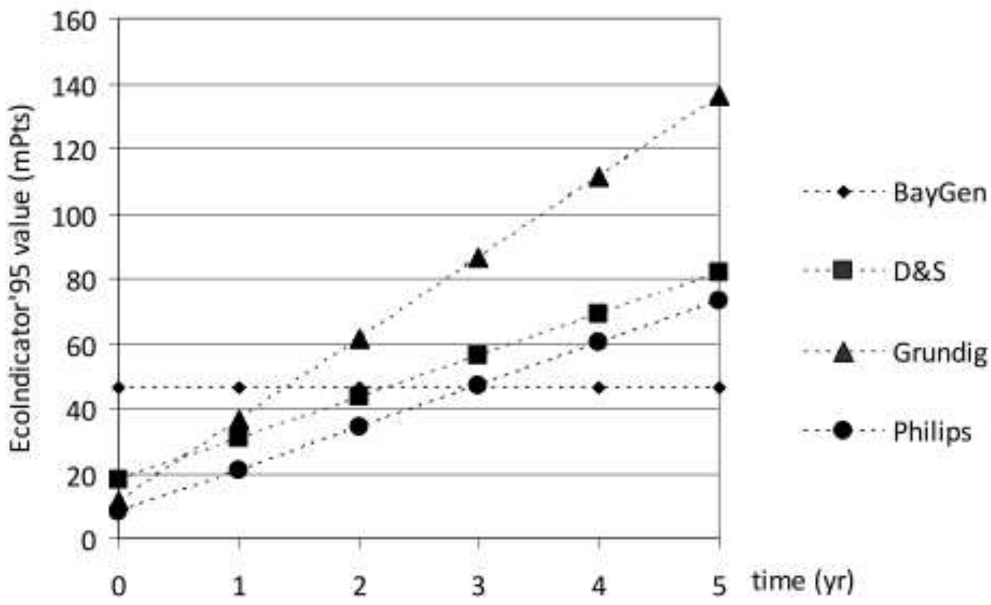

Figure 4.12 Ecoindicator '95 value during life time, showing increase over 5 year consist of the sum of production, transport and EOL (end of life) value (Jansen, 1997)

[28] D&S had a solar panel connected to built-in NiCd battery)

As shown in Figure 4.12, most HPP would normally have higher value due to containing more components for dynamo (energy system), also affecting on total weight during transportation. His study concluded that in between 1.4 ~ 2.9 years, the environmental impact of the battery powered radios will equal the value of BayGen Freeplay radio; as known as 'break-even point' (Jansen, 2011, p. 129). This is not to argue that the environmental benefit is always present as anyone continues to use the HPP. However, as these types of devices no longer require any further consumption of batteries, the 'reduction of life-cycle environmental impact is a possible benefit of HPP' (Jansen, 2011, p. 130). In addition to demonstrating this possible advantage, Jansen also presented the analysis for cost of ownership comparing 3 battery powered flashlight against human-powered flashlight. The end values, the 'eco-value', were calculated by dividing *cost of ownership* over value of *life cycle environmental impact*. The evidences were presented that possible reduction up to 86 % efficiency can be retrieved, for period of 2 years, by using human-powered flashlight. Reduction in the cost of ownership and perceived reduction of environmental impact is proved, and as Jansen concludes, as the real benefit of using HPP (Jansen, 2011).

Although Jansen only compared HPP against battery consuming products, current research found necessity of further investigating and comparing LCA value of HPP against plug-in powered EuP. There were several reasons for this investigation. First, the initial research questions were originated from setting scenario of whether HPP can bring any reduction in electricity consumption as its usage maintained over period along with its increase number of HPP used by households. The LCA study conducted in this study originally concentrated on measuring the environmental impact value that is based on the scenario proposed in Chapter 2.4.4 (pg. 41). The scenario was based on assumption that the increased use of HPP in household, by substituting existing EuP with HPP, will entail reduction of energy consumption as they no longer consume electricity from the power grid. Jansen and Stevels (2004) call this benefit as 'Material Benefit' – do not consume energy from non-renewable sources during the use-phase of the life cycle. Building on from Jansen's results, this study aimed at finding the new time value; data that shows the duration of usage time required to meet this new 'break-even point'; comparing the end value arising from using energy to power plug-in EuP against value occurred during production of HPP.

Secondly, the house size (outer case) of HPP that Jansen has used in his LCA study had much higher mass volume which affects on the total environmental value (mPts). In order to redeem these mass variables, Power Plus Rhino Radio (Figure 4.13) was chosen for this LCA study. This radio can be powered by battery, hand crank (human-powered application), or plug-in power adapter. Therefore, the housing unit and supplementary components (Speaker, PCB, antenna, etc) can be excluded from inventory list as they are being shared while in use.

In order to find the new ‘break-even point’, the radio was disassembled to separate and categorised components into either ‘HPP’ or ‘plug-in power’ system. The energy system (Figure 4.14) represents the added impact value for manufacturing as human-powered radio which includes the component of dynamo and rechargeable battery. The power adapter (Figure 4.15) considers being the only additional component for plug-in (electricity consuming) system. In the beginning, it was anticipated that the study process was planned at conducting LCA on both of these assemblies. However, it was decided to only measure the value arising from the ‘production’ instead of including the value arising from other variables like transportation. This data were to be compared by the electricity consumption rate (kWh) of radio including its accumulating consumption value over time period, reaching to new ‘break-even point’. In this case, this ‘break-even point’ is referring to the time required to meet at the point where HP radio begin to use ‘less energy’ during overall life cycle. However, it is important to point out that information needed to find the accurate electricity consumption at production stage were very limited. One of the main drawbacks on using LCA software such as SIMPRO is the inconsistency between LCA studies. The issue appears to be caused from researchers selecting subjective choices, therefore, impossible to relate new LCA calculations to existing studies (Andrae and Andersen, 2010). In the same context, the objective of this LCA study was not to cross examine any results with Jansen’s LCA study. It should be also clearly stated that the data coverage (input information on material selection and manufacturing process) on current LCA study is based on information gathered from consultation with product design experts within the University. Thus, the results were to be perceived in the manner of projecting and quantifying the incentives incurring under the set scenario.

Figure 4.13 Power Plus Rhino Radio

Figure 4.14 Energy system (Crank Handle, Motor, Rechargeable Battery) disassembled from radio (left)
Figure 4.15 Photo of Power Adapter (right)

Figure 4.14, shows the components of energy system disassembled from the radio. Each component and sub-parts in the energy system were disassembled and measured on a scale. Each data set (material, mass and processes of manufacture) were entered into LCA software called SIMAPRO version 7, using the calculation method version of Ecoindicator ’99 (H).

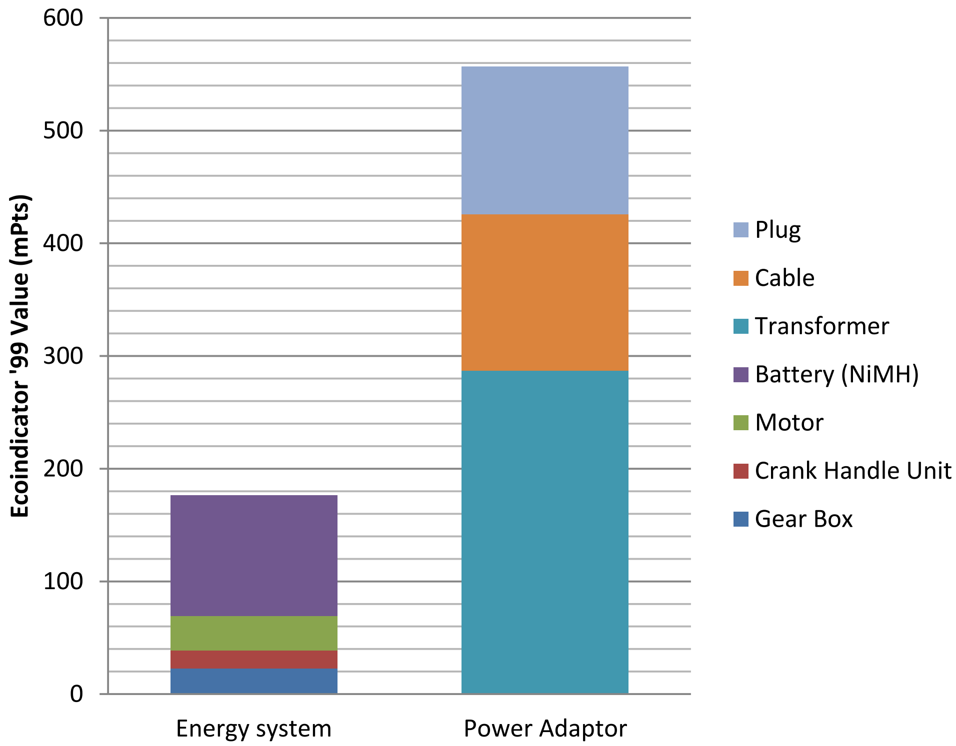

Figure 4.16 Ecoindicator '99 values for production of Energy System and Power Adapter.

Figure 4.16, shows the Ecoindicator '99 value of Energy system and Power Adapter at production stage, with sub-assemblies shown in coloured stack bar. As visualised in the figure, the EI (Environmental Impact) value of Energy System is 176 mPts and the Power Adapter has much higher value of 557 mPts. Although the data selection was speculative and subjective, meaning that the data is not reviewed by any third party expert, the result shows that the total EI value of Energy system is 68 % less than the Power Adapter. Therefore, it can be argued that the environmental impact of HP Radio is already lower than plug-in radio at production stage and that the 'break-even point' could not be retrieved. Moreover, the mass of Power Adapter (170 g) was much higher than total weight measured for Energy system (104.16 g), which would add additional value to plug-in radio at transportation stage.

Figure 4.17 shows the incremental rate for EI value of energy consumption (electricity) of the Radio. The data set for this rate is based on assumption that the radio will be used in the European Region at consumption rate of 0.00035 kW (measured directly from the radio). According to RAJAR (Radio Joint Audience

Research), average weekly listening hours per listener is 22.6 hours (RAJAR, 2012). This figure was multiplied by 52 (weeks in year) to get total hours of use and multiplying to 0.00035 kWh which equals to 0.4 kWh of consumption per year. The EI value of this electricity consumption from power grid is estimated as 18.3 mPts per year. It can be seen that the new ‘break-even point’, defines as the time where the EI value of consumption (plug-in radio) will equal to value of added impact (Energy system) in HP Radio, measures at year 9.6. In other words, the increasing mPts rate of plug-in radio will meet with ‘value of HPP energy system during production’ at 9.6 years, meaning it will require that amount of year to become a product that begins to ‘save the energy consumption’ within a life cycle scenario.

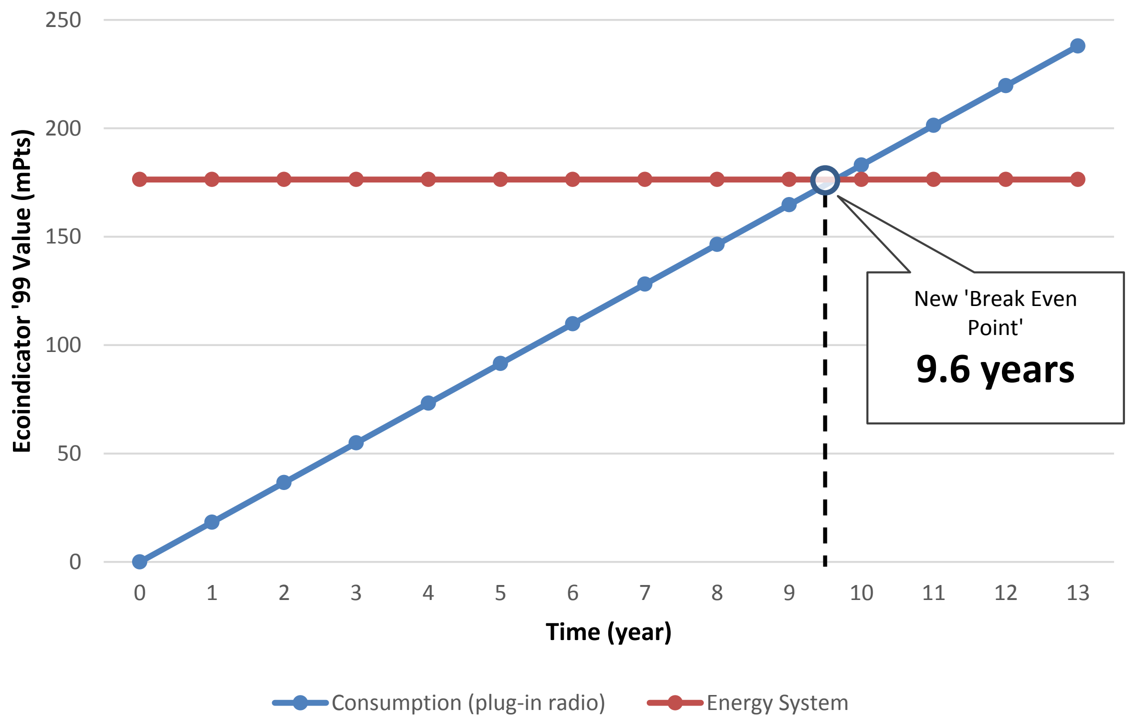

Figure 4.17 Ecoindicator ’99 value for life cycle of radio consumption

4.4.1 Cost

The average electricity cost in UK domestic sector is £0.145 per kWh (DECC, 2013). The Power Plus Rhino Radio’s electricity consumption, using plug-in power adaptor, was measured at 0.00035 kW. So, 0.00035 (kW of radio) x 22.6 (average hours per week) x 52 (weeks in year) x £0.145 (average cost per kWh) is equal to £0.06. Therefore, it can be stated that the incentive of using HP Radio over the plug-in power radio is compensated at rate of saving £0.06 per year. If these figures are used in total life cycle cost, the average cost of radio is approximately £25 (price shown on eBay), when this is divided by £0.06, it will require 417 years of consistent use of HP Radio to meet the 'break-even point' for the cost of ownership. The speculated cost in this calculation may not imply as significant motivator to bring any change of behaviour in practice.

4.4.2 LCA Result and discussion

The figure of £0.06 is very ambiguous, as well as 417 years. This result may be sufficient to motivate user to purchase HPP for replacement to plug-in radio; especially for the purpose of saving electricity consumption and to gain any perceived benefit. The amount of actual electricity consumption verses a user's amount of time and effort require to generate such saving may seem incomprehensible. Therefore, purchasing or using such HPP cannot be seen as efficient when attempting to adopt a product for the sole purpose of reducing electricity consumption. Jansen's result of 1.4~2.9 year may perceive to be long or short period. Looking from cost saving perspective, the HPP is proven to be efficient against battery power products. However, LCA study undertaken in this chapter shows quite unsatisfactory results against the scenario of using HPP as replacement to grid powered products, e.g. EuP. Nevertheless, it still brings the attention to the emphasis on the element of 'design' which can potentially influence to bring longer demand-of-use or motivation towards sustaining the use of HPP. This doubtful query led to the research question 2.2: 'Can sustainable usage of HPP reduce energy (electricity) consumption?' Although the figures presented in this chapter is derived from assumption and speculative knowledge on HPP input data, the results show that, based on scenarios, some incentives are present. In spite of its low and somewhat disappointing result, it is yet known about how actual users of HPP would value these incentives. Therefore, this notion also builds on to the necessity of conducting empirical study that aims to understand how actual consequences of using existing HPP are influencing on consumer decisions, and their determinants.

Not all users will purchase such HPP for the purpose of saving electricity consumption nor for the cost benefit; it is also argued that not all cyclists are doing so to save fuel consumption for transportation. Rather, application of certain aspects like communication, feedback, or other types of moral empathy between product and user is perhaps more relevant issue for users of kind. This notion was shared by Jansen's study on consumer perception of HPP. 52% of randomly selected respondents preferred the HPP package saying 'environmentally friendly' over two other packages of 'no need for battery' and 'fun while zapping (winding)' (Jansen, 2011; Jansen and Stevels, 2004). Thus, it can be concluded that public's view on HPP primarily relates to 'altruistic value' (Stern, 2000), rather being reliant to individual's forthcoming incentives arising from its use. In defining 'Altruistic Behaviour' for example, it is a performance of an unselfish act. According to Morris (1977), it is a pattern of behaviour that must benefit someone else, not merely a matter of being helpful but being helpfulness at a cost to yourself. In the case of HPP, it is a cost of effort that is applying human-muscular energy as alternative to reduce the environmental impact caused by either battery or grid power. However, it is still vital to understand what rationales, as in qualitative response, are affecting on the motivational determinants of 'using' HPP.

Also, the result highlights the need for improvement of HPP technologies that enable human-power conversion into functional power, along with its reduction of EI value at production level for shortening the time to reach the 'break-even point'. Borrowing from Cooper's (2005) model of sustainable consumption, *efficiency* of HPP technology that increases the output and 'design' that allows the *sufficiency* by extending the life time of HPP may have some potential as object of *Material* (Røpke, 2009) in everyday practice; enabling user to perform an energy saving behaviour through product longevity. Especially, as efficiency of battery capability and dynamo output increases, the incentives speculated in this study may increase in parallel. Contrastingly, this result may cause live debate on how people perceive this as affirmative or essential value for maintaining the use of HPP. From cost perspective, a figure of 6 pence may not be perceived as dominant benefit or motivator for HPP users. Nevertheless, this value of cost can arguably be defined as a potential benefit. From individual perspective, this value may not be significant to maintain the use of HPP; but on the other hand, the value may appear as much greater when number of HPP increases and as more people begin to use HPP. The benefit and its value may not give much impact to egoistic individual but it may do so for whom values the need of altruistic activity.

4.5 Developing a Hypo-Theoretical Model

The case study work carried up to this stage provided a model of prototypic taxonomy, HPP Interaction Matrix – Version 1 & 2, which availed to characterise HPP concepts and their analysis through plotting them into domains of identified attributes. It can also be used as a tool to forecast the potential design spaces, identifying type of power-generating interaction and the functional output for future scenarios/idea of HPP. However, each definition of domains still required further justification due to some uncertainty involved in different measures of psychological interaction. This unclearness became more prominent as author discussed the matter with Jansen in person at a conference held in Delft, Netherlands, where he is currently based. As he commented, he has also spent reasonable amount of time trying to identify any indicators to characterise different ranges of HPP by power interactions (e.g. cranking), consciousness or sub-consciousness (‘passive’ on his term). Jansen admitted that he was not able to create a measuring tool to find mutual and exclusive method that can draw/plot these concepts in a single axis. Similar conclusions were made to his study (Jansen and Slob, 2003), attempted to measure the level of ‘comfortable/sustainable force exertion’ during cranking. He concludes by posing a new challenge in the field of HPP research that any level of discomfort, comfort, fatigue, or (sub) consciousness is difficult to measure. Whether they are extrinsic or intrinsic, it will vary upon individuals’ motivations and in different situations. This discussion led to serious consideration of re-assessing the plotting of case study result and real-time monitored HPP which were classified and mapped through using the earlier version of Matrix. It was realised that plotting, identifying the levels of interaction mode, were performed solely upon author’s knowledge. Therefore, as it can be observed from Figure 4.1 (Matrix Version 2) and Figure 4.6 (Matrix Version 1), one projected change was the ‘arrows’ indicating the levels of attributes, both vertical and horizontal axis, were changed to a ‘line’ which classifies the domains instead of different levels involved. Moreover, this research did not succeed in obtaining such tool or indicator in measuring different levels of psychological attributes involved during the interaction of HPP and for the justifications of plotting each concepts at designated location within each domain. The Matrix version 2 (Figure 4.1), therefore, became a taxonomy which helps to classify HPP into different domains; it can be used as a tool to forecast future HPP concepts and avail designers in deciding different types of input mode and output power of HPP.

4.5.1 Motivation

In discussion of HPP using the ‘fun’ aspect, it was observed that such technique do generate ‘playful’ feature that stimulates certain motivations to continue use the HPP system, e.g. Playpump. However, it can be seen from the Sony Odo and Playpump projects that they have two distinct interactions as to enable physical interaction for inducing ‘fun’ experience. For Sony Odo projects, the design applications enable user to have more ‘fun’ while exerting human-power, and transfers that mechanical energy into a dynamo system (or energy system). On the other hand, the Playpump engages the user into a ‘fun’ interaction via a third device; the merry-and-go. However, the research found challenges in classifying these kinds of concept into attributes for ‘Mode of Human-Power Input’ – the horizontal line on Matrix version 2 (see Figure 4.1, on pg. 109). From motivational perspective, both examples draw users into a ‘fun’ interaction and it induces a ‘play’ activity; however, it is challenging to make any firm argument whether the mode of interaction is conscious or sub-conscious. Arguably, the challenge lies in how a system of feedback communicates with the user. For instance, the output of ‘Spin N’ Snap’ (Figure 4.4) provides consequential feedback by applying human-power in relatively short period of time by allowing them take a photo using the charged electricity. For the Playpump, the system of feedback provides the user with a velocity when riding the merry-and-go, and the users are drawn into an activity of ‘play’, but the device does not provide any consequential feedback of how much water is being pumped. However, it provides the feedback of how ‘fun’ the related activity can be. Also, the application of HPP like Playpump and Soccket can also be used and played as a ‘standalone’ device in addition to its role as a device for generating energy resource. In other words, the motivation for using such device may not be around the notion of generating resource but based on its user-centeredness, i.e. designed around ‘fun’ and ‘play’ interactions. As argued by Jackson (2005b), when behaviours are strongly regulated or reinforced by external factors; in this case the ‘fun’ aspect, it may show a weakness in linking the related attitude of ‘power generation’. Therefore, it can be argued that these types of HPP application may derive motivation to use the system of HPP, but it may not link the attitude of ‘power generation’ to their intended activity.

Moreover, as these 'fun' aspects are always exposed to risk of becoming obsolete, so it may no longer be perceived as desired behaviour. However, these 'free energy generating' devices may give stronger motivation for further use as scarcity of energy resource do exists in some demographics. In this case, individuals' decisions are constructed through relationship between social and technological systems rather simply as autonomous agents (Shove, 2003; Wilhite and Lutzenhiser, 1999). Considering this complexity, the 'fun applications (Domain F in version 1)' were considered to be extended into the third dimensional axis which describes other qualitative measure (see Figure 4.18), leading to question 3.2 of this thesis; What motivates user to use the HPP?. It was projected at this stage of research that all of the identified attributes were to be re-examined and revised into more concise and distinctive definitions, including the third dimensional attribute – the motivation aspect.

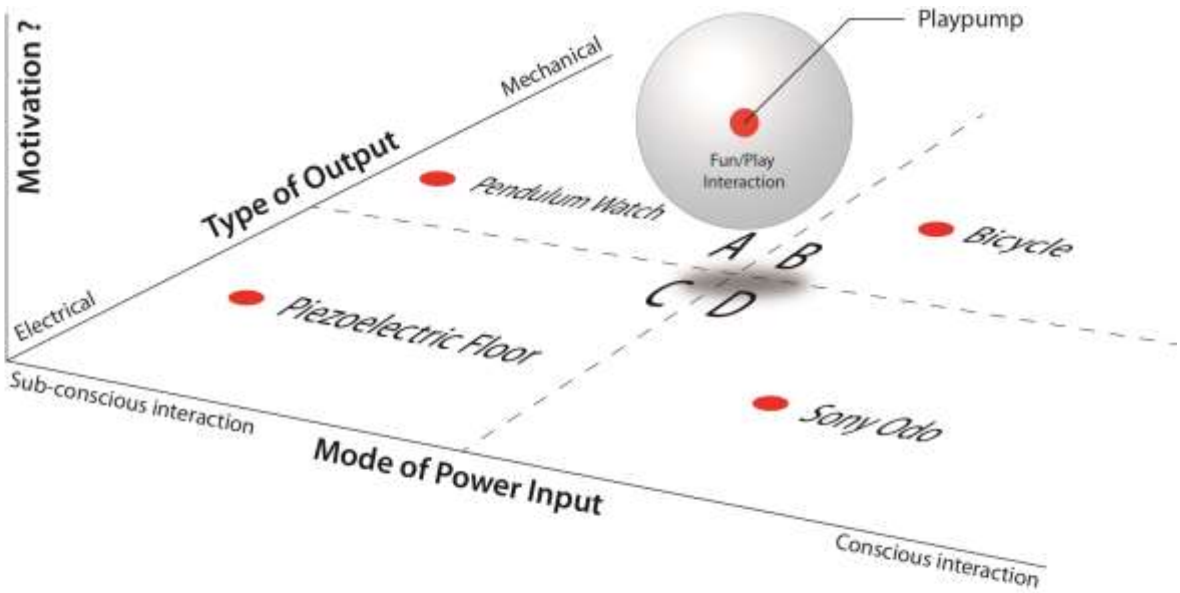

Figure 4.18 HPP Interaction Matrix (Version 3) with indication of 'fun' aspect (motivation) extending to third dimension

4.5.2 Delegation of Control

As indicated, current research had also found some challenges in further exploring the input mode of 'sub-conscious'. This is due to the notion of taking this study into more depth of understanding how HPP can be a *Material* (Røpke, 2009) within a 'practice' that interconnects with attitude towards notion of sustainable energy consumption. Interventions using sub-consciously interacting HPP (i.e. technological intervention), and presumably, are not the types of products originally designed for the purpose of changing user behaviour or influencing new daily practice. Again, this research focuses on exploring the demand nature of energy consumption by re-materialising the energy use and how design of HPP can induce an 'energy saving behaviour'. It can be seen that most of the parasitic harvesting or sub-consciously interacting HPP deal with increasing the efficiency of power output in order to bring a greater outcome - rather placing the users in a central position by 'delegating' control of power consumption and generation. In other words, they are 'Self-powered devices' (Paradiso and Starner, 2005). Interestingly, this shows some relevance with what Tang and Bhamra (2008) presented in their framework for behavioural change, see Figure 2.24, on page 67. They have classified design interventions by the degree of 'power in decision-making' between the user and product. Among their example of interventions, the piezoelectric floor system is one example where the power in decision-making is upon the product/service/system. In contrast, examples like Energy Aware Clock (Figure 2.27) and other design artefacts from the work of Interactive Institute shows attempt of 'materialising the energy' (Backlund *et al.*, 2007; Mazé and Redström, 2008), helping 'user' (autonomous agent) to become more energy efficient rather delegating the control purely over to automated devices. As argued by Tang (2010), when the power in decision-making lie upon the user, the motivational change and acceptance of intervention may have greater effect.

In a similar manner, 'Self-powered devices' can be seen as devices where the control over energy generation is delegated towards the system of HPP. This notion of 'delegating' control over energy generation makes one step clear interpretation towards the complexity involved in 'Fun' application of HPP. First, it can be seen that the Sony Odo delegates control of human-power generation merely to the user who makes a conscious decision via exerting muscle energy through the 'design' element which avails that activity to be compensated by 'fun'. For the Playpump, the 'fun' interaction arise when the users are consciously 'playing' with the merry-and-go, but the delegation of control for water pumping lies upon the parasitic system. In other words, users may have delegation of control over 'fun' but 'perceived behaviour control' (Ajzen, 1991) may only exist at reinforced external factor of having 'fun' with merry-and-go. Therefore, it can be argued that interaction involved in parasitic harvesting methods rely on the 'hidden' technology which transforms the generated energy through external 'design' applications that are embedded in the system of HPP. If the 'design' element enables user to link the subject of using human-power to their activity and provides its consequential feedback, there may be a greater effect in bringing the spontaneous motivation for using such device. So, it is upon the design intervention to make the interaction either passive; or as 'perceived affordance' (Norman, 1999) which allow users to perceive the 'possibility' for certain action, i.e. the 'self-efficacy' (Ajzen, 1991). According to Ajzen (1991), opportunities available to a person must to some extent dictate the likelihood of behavioural achievement. In other words, the design of intervention should move from being descriptive (e.g. technological intervention) to inscriptive (Jelsma, 1999); avoiding from being inconspicuously controlled by another conceivable 'a mundane artefact' (Latour, 1992).

4.5.3 Feedback

However, this does not mean that people are always in a sub-conscious mode or unaware about the generated energy. By having such system of feedback, it may be insufficient in bringing the behavioural change, but rather it can invite them into what Backlund *et al.* (2007) says the 'thoughtful engagement'. Arguably, this engagement may stimulate the attitude which lead people in practicing more 'efficiency behaviour' (e.g. buying more parasitic harvesting technology), as this behaviour can be more effective in producing energy saving (Gardner and Stern, 2008). Whether the designed application in HPP utilises conscious or sub-conscious interaction, it becomes more apparent that the system of feedback will play an increasingly important role in engaging user into discourse of generating alternative energy. It is argued by scholars that frequency of feedback plays imperative role and as well as the design factor for instigating behavioural change (Backlund *et al.*, 2007; He and Greenberg, 2009; Jordan, 1998). For this reason, the researcher created HPP Interaction Matrix - version 4 that includes consideration of both 'delegation of control' over energy generation and the frequency of 'feedback', as shown in Figure 4.19. In this version, 4 domains of HPP types are identified in letter A, B, C and D. It is requested to all readers of this thesis to carefully review the explanation of each coloured lines (located at right-top corner of the Matrix).

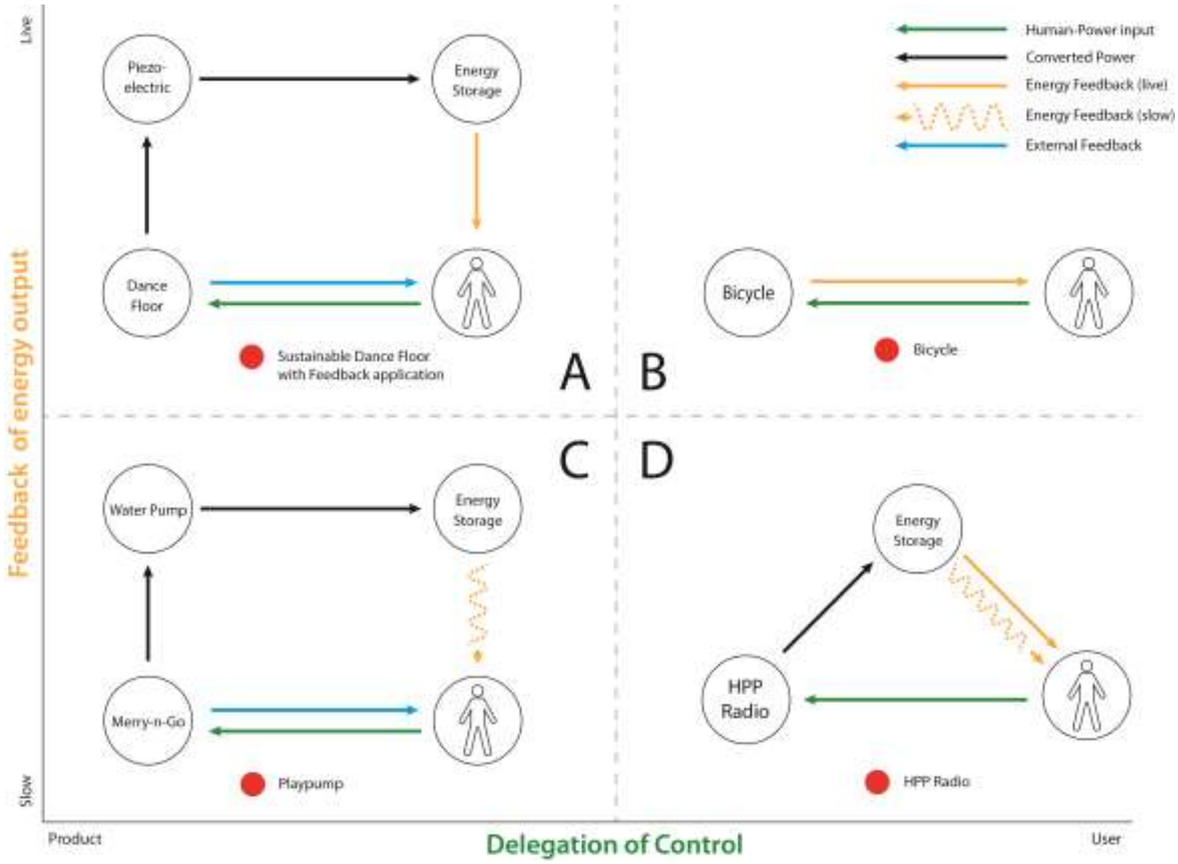

Figure 4.19 HPP Interaction Matrix – Version 4

In domain A, the ‘Sustainable Dance Floor’ uses human-power that is scavenged from people’s dance movement. However, by having such system of feedback application[29] which delivers data of conserving energy in real-time (live), it ‘makes people dancing on the floor understand that they are the ones powering the floor’ (Anon., 2007). In this case, the HPP and its design application allow user to find the link to energy-conscious attitude by providing real-time (live) feedback information of transformed energy and the ‘fun’ motivation is given to user at the same time. Nonetheless, the method of retrieving human-power into alternative form of energy source still remains at precedent behaviour of ‘Dancing’ rather than instigating people to practice new behaviour. Although the behaviour is not changed, it can be defined as ‘sustainable behaviour’ where it reduces the environmental impact without necessarily modifying the existing routine (Tang, 2010).

[29] See Figure 2.20, pg. 58 for example of feedback application in Sustainable Dance Floor system.

In domain C, the Playpump utilises human-power that is generated from the ‘fun’ activity of playing on the merry-and-go. In this case, the HPP and its design application scavenges the human-power in a stealth mode. Whether the psychological interaction with merry-and-go is in either mode, the source of energy generation becomes dependent upon its design application within the system of HPP. Also, the frequency of feedback on conserved energy is provided at slow range (demonstrated with curvy arrow line in yellow – expressing the longer-term of feedback). For instance, although the users of Playpump receive live (real-time) feedback that is ‘fun’ as they kinetically interact with merry-and-go; however, the feedback of conserved energy (water) is non-communicable to users during the activity. For ‘Sustainable Dance Floor’, the feedback line (yellow) would have been in ‘curvy’ line if a feedback display (i.e. real-time) was not present at the activity. As highlighted in previous chapter, these types of HPP using reinforcement of external factors may show weakness in linking the activity with the attitude of being energy-conscious. This suspects to be the cause of having no such feedback system that delivers the consequences of energy related behaviour and the ‘delegation’ of control over human-power generation belongs to external devices rather at user's own control. Users may be in conscious mode of interacting with the external device that gives ‘fun’ while ‘playing’ but the system of HPP becomes ‘Self-powered’ as it utilises the generated power from behaviour of energy-sub-conscious attitude. These external feedbacks of ‘fun’ or ‘playing’ are shown as lines (live) coloured in sky-blue.

In domain B and D, there are examples of HPP that delegates free space for the inclusion of the user’s autonomous interaction. First, the bicycle provides live (real-time) feedback that shows how human-power (pedalling) amplifies the energy into velocity as travelling a distance. HPP in this category typically provides direct experience of learning how human-power transforms into functional power output. Also, the control of functional output, including the conserving energy, sorely depends on the intention of users who are ‘autonomous decision-maker’ (Brey, 2006). However, as users become routinised with the related activity, these actions can be performed with ‘practical consciousness’ (Giddens, 1984) like driving an automobile. With regards to this psychological notion, the dimension of ‘delegation of control’ helps in classifying whether the functional output of HPP is driven by the system of HPP (product) or merely by the intention of HPP user who are capable of controlling the power generation.

As highlighted in Chapter 2.5.3, the feedback and its design application are considered important element when designing as an intervention. It is argued that the longevity of changed behaviour be dependent on how well feedback system is designed; therefore, it requires thorough consideration in order to avoid people from returning to old behaviour even after feedback is removed or they become accustomed to (Martiskaïnen, 2008). In the same context, the system of feedback in many HPP radios (plotted at Domain D) shows some obscure degree of interactivity in providing the consequential information. For instance, when HPP users are consciously applying the human-energy (e.g. cranking or winding), the device directly allow user to know that the device is being charged (shown as straight line in yellow). In many cases, HPP uses a single LED that lights up with indication of ‘charge’ while cranking. However, during this kinetic interaction, users are not aware about how much of equivalent energy is being conserved. The consequential information, available time length of radio use from charged electricity, is unrecognisable until the function stops to operate. Therefore, it can be viewed that the radio provides feedback of ‘charging’ instantly; however, the feedback on conserved amount of energy is given at slow or in longer-term rate (shown as curvy line in yellow). As shown in Figure 4.19, this indefiniteness of feedback in HPP radio is demonstrated as having both curvy and direct line in yellow.

Figure 4.20 Charging indicator (LED) on HPP radio

4.6 Conclusion

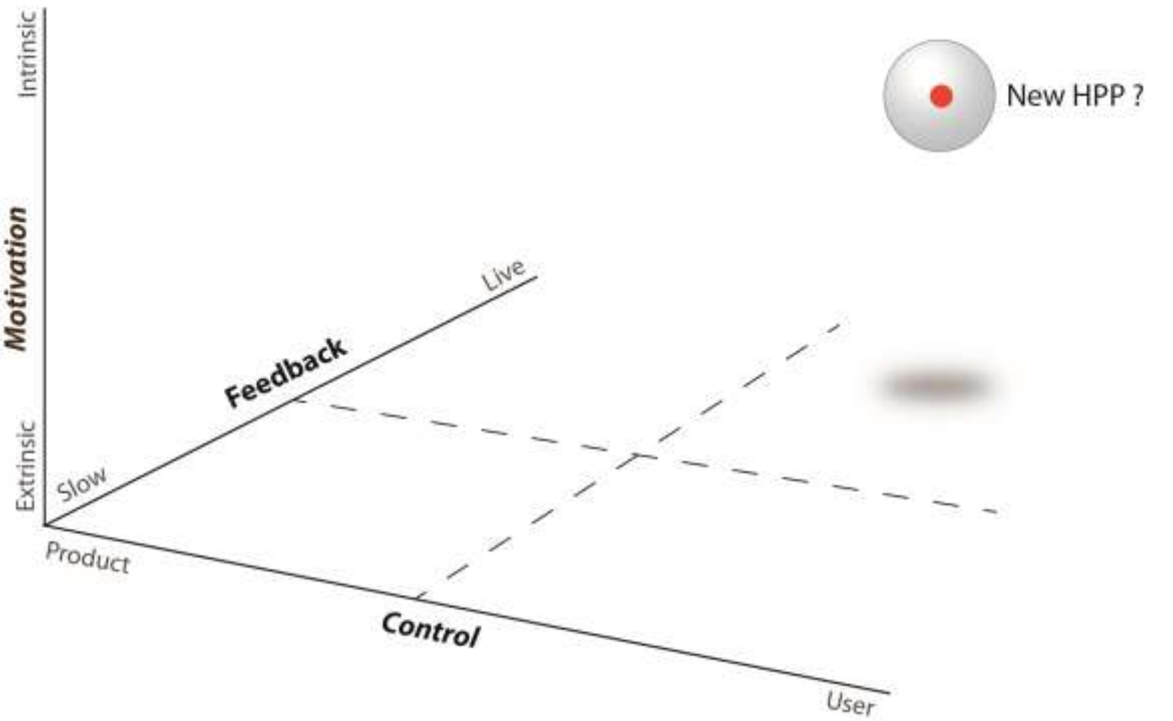

Figure 4.21 HPP Interaction Matrix version 5

At the start of developing these Matrix, the original aim was to approach the investigation by classifying previously published examples of HPP, and how they can be analysed under attributes identified. The purpose of creating an early version of Matrix was concentrated on classifying the clearer definition on both conceptual and existing HPP. Also, some drastic changes in designing different applications of HPP have been noticed. It was observed that recent monitored concepts and idea were centred around instigating motivations towards applying human-power or methods of sustaining the use of such system which makes them to become ‘off the grid’ products. There are more other ways to describe HPP design spaces beyond the parameter identified and discussed through 5 versions of Matrix. The research could have proceeded to detail exploration of evaluating more or less intriguing HPP design idea and identifying the indicator to help classified them into different levels. However, the purpose of developing final version of Matrix was not considered for further analysing the HPP concepts. Rather, the direction was headed towards building a hypo-theoretical model describing the required imperative elements within the design of HPP for instigating sustainable use; and therefore bring internalisation process to practice energy saving behaviour. By the end of its process, it was required to identify dimensions that represent a rational aggregation of instigating new and sustainable behaviour through HPP, and reflecting as strategies for sustaining the HPP use. It made an effort to contrast attitudinal factors discussed in other disciplines’ model of behavioural change to the dimensions explored in developing different and evolving versions of ‘HPP Interaction Matrix’. As a final version, HPP Interaction Matrix version 5 was developed (see Figure 4.21), which shows three dimensions of; Motivation, Feedback, and Control. Each dimension in the Matrix shows different methods to be utilised when designing the HPP. For example, designer can choose to delegate the control of power generation to either product (parasitic) or user (direct experience); design feedback system that either provides live (short-term) or slow (long-term) frequency; and designing the interaction that can gain an impetus to HPP user by drawing either intrinsic motivation or utilising external device to draw extrinsic motivation.

4.6.1 Next step

The complexity involved in psychological mode of ‘Fun’ interaction led this research to consider how motivation plays a crucial role in internalising the HPP use. Based on a literature review in diverse disciplinary fields, it suggests that the system of feedback could allow such behaviour to be sustained and maintained over a period (Wood and Newborough, 2003) and be controlled by the autonomous individual (Brey, 2006) - the 'user'. By linking all three dimensions (axes) with respect to social-psychological aspect in behavioural model, a 'HPP Internalisation Model' is proposed (Figure 4.22).

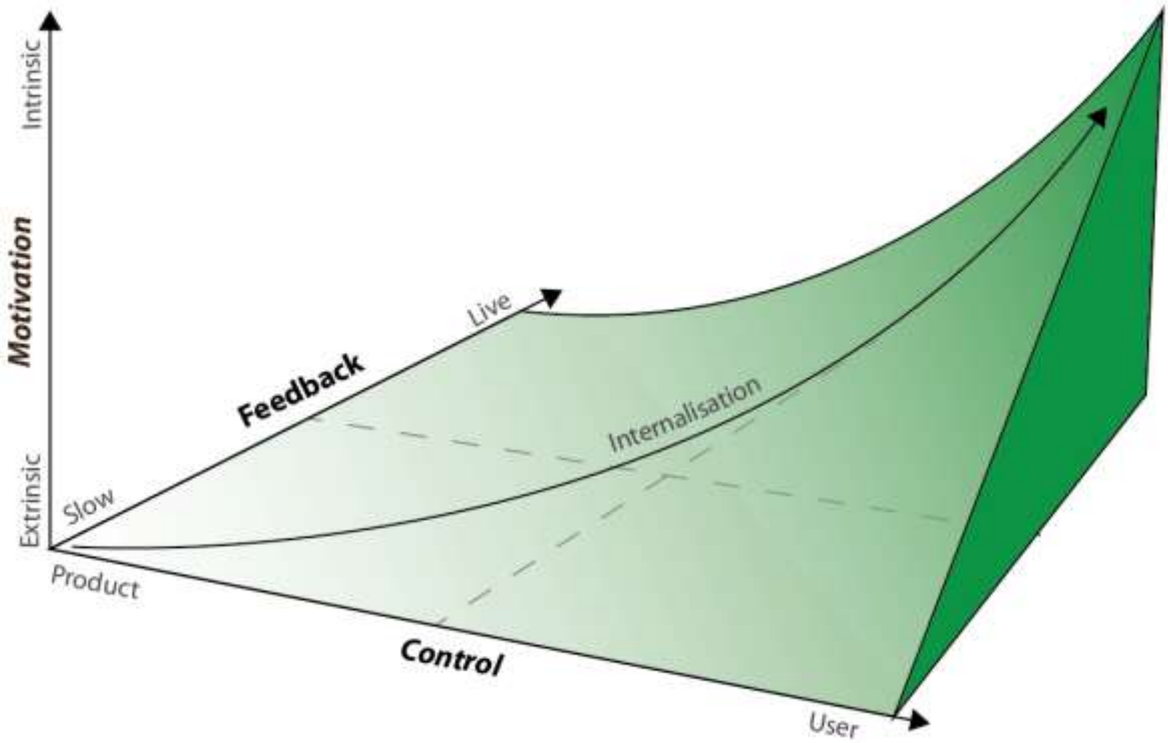

Figure 4.22 HPP Internalisation Model (Hypo-theoretical Model)

The three dimensions, whilst discussing interesting consideration when designing HPP for the aim of internalising its use and to induce practice of energy saving behaviour, the model did not have any real data to support its effectiveness in both theoretical and practical aspect as yet. It is this reason that empirical research was conducted to understand how public perceives these design elements of HPP in respect to 'design for sustainable behaviour (DfSB)'. Through investigating the meaning of HPP use and its consequence, series of case study was designed and analysed to demonstrate the process of building a new prototype that reflect these theoretical dimensions. In between, the results of these case studies generated great insight to actual use of existing HPP that helped in iterating and enhancing the definition of each dimension.

Chapter 5 Conceptual Framework and Research Objectives

5.1 Introduction

Human-powered products, as this thesis argues, is considered as an intervention aiming to induce energy saving behaviour under concept of 'curtailment behaviour' (Gardner and Stern, 2008) which involves the effort of reducing energy consumption. Arguably, the new behaviour of using HPP can be considered as behaviour derived from 'de-routinising' the precedent patterns of energy consuming behaviour. Therefore, theoretical notions presented in literature review (Chapter 2) discussed many different types of interventions in means of instigating user to practice energy saving behaviour or motivations that influence on those determinants. It has also discussed the complex system of practice which requires both behaviour patterns and form of mental activities to carry and reproduce new practices. Reviews on models of behaviour change (Chapter 2.5.1), design strategies using both antecedent and consequential intervention techniques (Chapter 2.5.4), and descriptive analysis on HPP (Chapter 4) serves as a basis for building a hypothesis of 'HPP Internalisation Model' presented in the previous page.

It has been discussed that strategies of design intervention in the field of DfSB[30] uses socio-psychological techniques to influence on behavioural determinants either by coercive or persuasive way through stimulating internal factors (antecedent interventions) and, sometimes, reinforcing through external (consequential intervention) factors. However, it was highlighted and suggested that when behaviours are limited by consequential interventions, essentially people find no link between attitude and behaviour (Jackson, 2005b; Wilson and Dowlatabadi, 2007). In order for people to access the outcome of implemented behaviour, the system of feedback plays crucial role where users learn the energy consequences of specific behaviour through presented information (Abrahamse *et al.*, 2005; Van Houwelingen and Van Raaij, 1989). This process of influencing the behavioural change is often called 'decision-making process' (Fischer, 2008), 'cognitive script' (Jackson, 2005b) or 'perceived behaviour control' (Ajzen, 1991). Techniques such

[30] Design for Sustainable Behaviour

as 'persuasive technology' or 'behaviour steering technology' has been widely used in means of preventing people from performing unsustainable behaviour (Lockton *et al.*, 2008), sometimes by stealth (Lilley *et al.*, 2005) and therefore most effective in changing behaviour (Jager, 2003). However, some concerns were discussed over these techniques where user may no-longer be an autonomous decision-maker (Brey, 2006). It was suggested that when power of 'decision-making' is delegated to user, the normative and motivational change will increase which in turn leads to greater user acceptance of implemented intervention (Tang, 2010). Nonetheless, the question still remains how these behaviours can be 're-routinised' and perpetuated as long-term in daily practice.

5.2 Integrating Socio-psychological Findings

This chapter presents representative interventions discussed in previous chapters and their deficiencies in visual illustrations. The rationale behind this work is to establish a theoretical framework which can describe and explain how key elements; feedback and motivation, are interrelated to current study of HPP. In building the guideline for demonstrating the behavioural change processes, Stern's framework of value-belief-norm (VBN) theory serves as basis to describe each intervention since the model provides 'the best explanatory account to date of a variety of behavioural indicators of non-activist environmentalism' (Stern, 2000, p. 412).

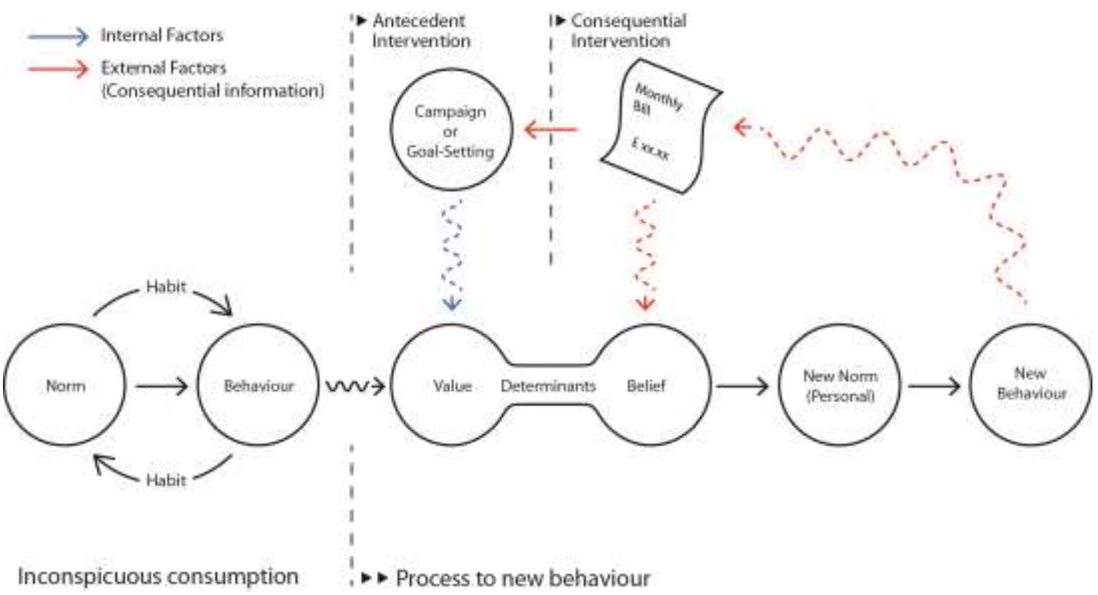

Figure 5.1 Process of behavioural change using 'Antecedent Intervention'

Figure 5.1 shows the process of behavioural change using ‘Antecedent Intervention’ to bring about reduction in residential energy consumption. Moving from left to right, it shows a path diagram demonstrating how intervention attempts to instigate behavioural change through process of influencing on behaviour determinants, developing into personal norm and engaging into new behaviour. On the left, it shows two circles (norm and behaviour) that represent the precedent behaviour, routinised habit of behaviours or patterns that causes inconspicuous consumption. Moving from left to right starting at the first dotted line, it indicates the triggering moments of ‘de-routinisation’ process (Spaargaren, 1997) using antecedent intervention; a process to new behaviour. The second dotted line demonstrates how consequential interventions are affecting on behavioural determinants, either on their value or the belief. When antecedent intervention is implemented (e.g. information campaign or goal-setting), mainly large-scale information and knowledge dissemination which becomes a stimuli of internal factors, the process of influencing on these determinants is demonstrated in blue curvy line as it is provided in indirect manner. As Stern (2000) underlines, these moral and antecedent interventions have not been so effective; however, when feedback is used as combined intervention with antecedent intervention, the effectiveness of such intervention achieves improved end result (Abrahamse *et al.*, 2005; McCalley, 2006). Consider the case where one attempted to change their behaviour through influenced value-based attitude such as personal achievement, but the process of knowing the behaviour consequence (feedback) is through paper-based bill which has long-term frequency; not in a real-time feedback. For example, if one individual decide to change a habit or certain behaviour to bring about reduction in residential energy consumption, the consequence of these new behaviours is presented depending on how frequent the paper-based energy bill is delivered to household. In this case, even the external factors such as monetary incentives are in place, the consequences of changed behaviour can only be realised in long-term perspective, therefore demonstrated with curvy (slow) line in red. Moreover, households have only few options to choose other than using this conventional and long-term feedback methods for tracking the consumption where, most of times, they find difficulties in correlating the units of consumption to their actual habit (Darnton, 2004). The effectiveness of such intervention may vary depending on how feedback information is interacting with the household practitioners. However, if the changed behaviours are implemented and mediated by personal motives such as altruistic belief (e.g. need to do the right thing), the behaviour is likely to be maintained since intrinsic motivations are sufficiently situated (Deci and Ryan, 2000). Behavioural changes in this case can be seen as reactions to attitudinal change where individual has adopted a personal satisfaction which guides behaviour through self-efficacy (Bandura, 1994), rather than an outside influence.

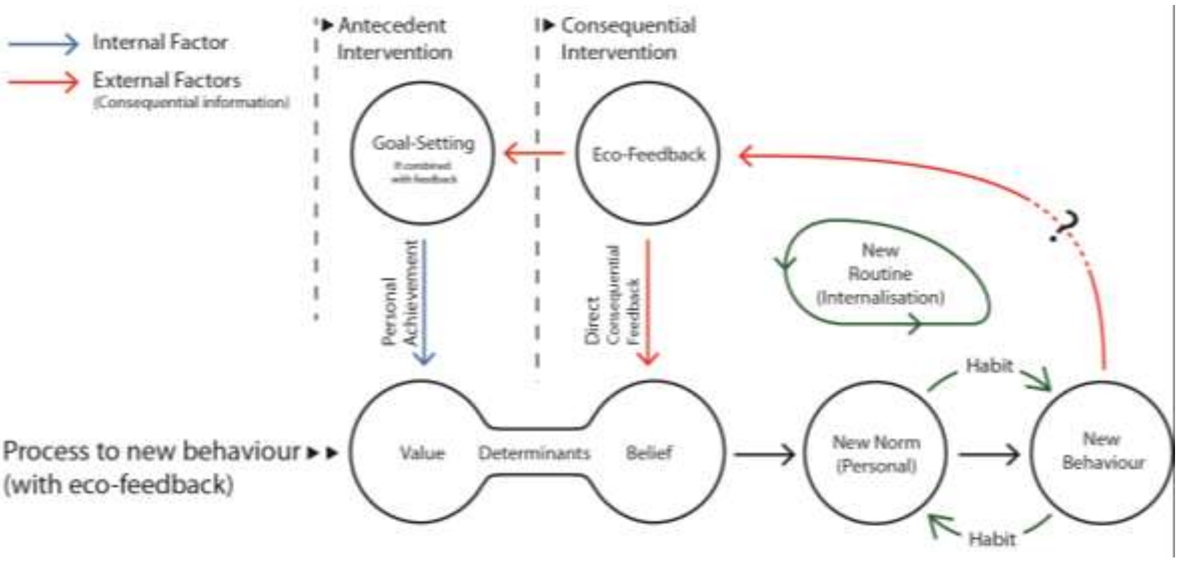

Figure 5.2 Process of behavioural change using ‘Eco-Feedback Intervention’

Figure 5.2 shows the process of behaviour change using ‘Eco-Feedback intervention’. Instead showing the flow of feedback in curvy line as shown in Figure 5.1, the Eco-Feedback (e.g. Smart Meter displaying electricity use in cent per hour) makes individuals to be aware about the available incentives or the behaviour consequences in real-time (live), therefore, demonstrated as direct line in red. Also, the real-time feedback will directly allow user to link the behaviour consequence to the goals set by household. The effectiveness of bringing new behaviour, for example the curtailment behaviour, measures high as feedback frequency are provided in continuous (instant) manner (Abrahamse *et al.*, 2005). A study has proved that continuous feedback in conjunction with goal-setting reduced the residential gas consumption by 12.3 % (Van Houwelingen and Van Raaij, 1989). The system of feedback, in this case allow user to experience the positive (or negative) reinforcement to carry out the behaviour, and possibly into routine pattern.

However, Darby (2006) has argued that there are downsides to these reinforcements of consequential interventions where once incentives are taken away, the changes are likely to fade away. The question mark over dotted line in red demonstrates this deficiency of feedback system. Nevertheless, when appropriate information makes individuals to access the outcome of consequences (e.g. perceiving possibilities of money saving), the intervention will eventually make individual into a belief as to how easy or difficult the behaviour is. This process is called 'perceived behaviour control', defined by (Ajzen, 1991). As households realises the possibility to influence and change their behaviour, and as they successfully perform the same behaviour in routine, the behaviour becomes internalised (shown in green line) as they regulate both internal and external factors into their practice.

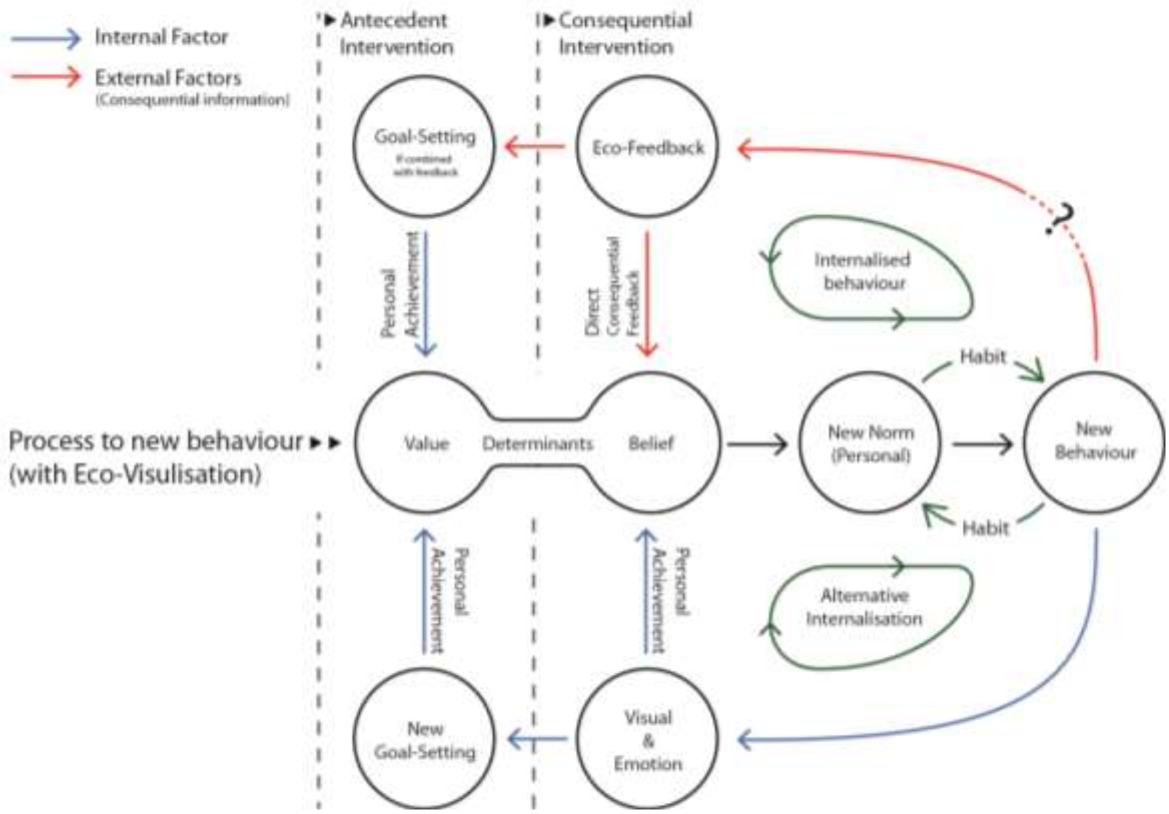

Figure 5.3 Process of behavioural change using 'Eco-Visualisation Intervention'

The best example of describing the 'Eco-Visualisation Intervention' (Figure 5.3) is the Flower Lamp presented in Chapter 2.5.5, pg. 70. Disciplines such as HCI and interaction design seem to have promising opportunities as to increase the effectiveness of intervention by making the feedback system into more interactive and frequently communicating device compare to conventional methods (e.g. paper-based), to bring reduction of energy consumption and behavioural change. However, the idea of visualising the feedback information spurs from the notion that data-based feedback devices have some ineffectiveness in maintaining the changed behaviour due to disconnection between consumption data and the actual habits (Pierce *et al.*, 2010a). Therefore, designers in related disciplines have explored in making the alternative form of feedback system such as ambient display which focuses on influencing psychological motives to sustain the changed behaviour. The design element in interventions of ‘eco-visualisation’ uses both extrinsic (e.g. cost saving) and additional intrinsic (e.g. emotional factor – feeling good as flower blooms) motivation to make individual be free from merely relying on single consequential intervention. In the case of Flower Lamp, design intervention provides alternative psychological motives (personal), i.e. aesthetically rewarding flower, which reinforces the choices to maintain or sustain the new behaviour (shown in blue line). In such a case, under circumstance of tangible incentives becoming obsolete, an alternative stimuli using emotional factor will avail household to sustain the intended behaviour. However, this is not to argue that all feedback devices should be designed in some kind of symbolic form. A field study has reported that participants did not appreciate the ambient display, finding them as ‘ambiguous’ (Fitzpatrick and Smith, 2009). In some cases, over-programmed displays and their experience may inhibit the actions that serve to change the outcome (Chapman, 2005). As mentioned before, the feedback of ‘blooming’ effect on Flower Lamp is delivered in long-term frequency. However, this framework emphasise on the notion that using additional psychological motives, in addition to conventional interventions, can potentially provide ‘double dividend’ (Jackson, 2005a) stimuli as user maintain the behaviour that is intended by designer.

5.3 Conceptual Framework of HPP use behaviour

A conceptual framework explains the main things to be studied - indicating key factors, constructs and possible variable – and presuming the relationship among them (Miles and Huberman, 1994). According to Robson (2002), it uses a diagrammatic form of expression of theory about what is going on, what is happening and why. In this sub-chapter, process of behavioural change when using HPP is demonstrated in consideration of design approaches that uses socio-psychological theories of behavioural change; that is particularly aimed at inducing energy saving behaviour. As this research started from setting a scenario of using HPP as intervention to practice sustainable energy consumption, in means of de-routinising the precedent behaviour and re-routinised into new practice, this section shows the suspected deficiencies and the possible cause of its ineffectiveness when urging for internalisation of HPP use.

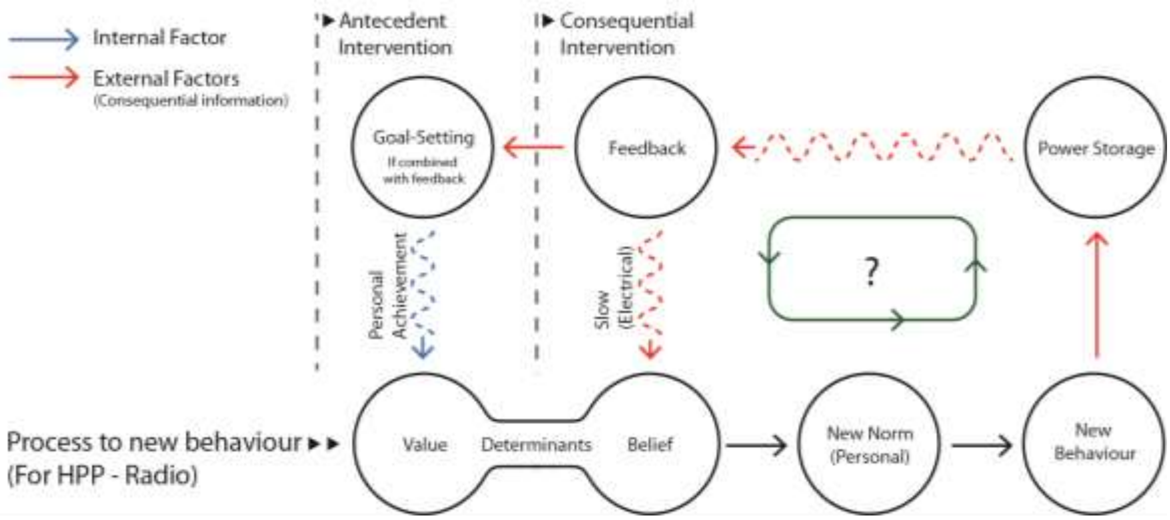

Figure 5.4 Process of behavioural change when using 'HPP'

It has been discussed about the obscurity of feedback frequency of HPP radio in Chapter 4.5.3. As Jordan (1998) argues, the interfaces of product should provide clear feedback so that actions taken by the user are acknowledged and some meaningful indication is given in accordance with its consequences. In consideration of this imperative role, some of HPP lacks in providing appropriate feedback that allow user to know the exact size of consequences. At early stage of its interaction, the system of feedback on HPP do signifies how activity of applying human-power and electricity generation is interrelated to drive the function of device. However, it was observed that in most of portable size HPP people find difficulties in accessing the outcome (available functioning time) over effort put in to exert the human-power, see Chapter 6 and Chapter 7. According to Van Houwelingen and Van Raaij (1989), the function of feedback is formation of habit, going through process of routine actions being set and reinforced; and internalising the behaviour. This deficiency of feedback system on HPP is demonstrated in Figure 5.4, using the same framework used in the discussion of socio-psychology based interventions. Red lines indicate the frequency and flow of feedback on existing HPP and they are demonstrated with curvy and dotted for being malleable. This malleability of frequency and lack of consequential information also affects when the user has a set of goal to achieve. For instance with HPP radio, users would have to be reminded about the equivalent ratio of power output against required charging time. Even with this information, user would need to count every seconds and minutes of charging time (or revolution of cranking) in order to set a goal of powering the device for certain period. However, it should be noted that the experience of interacting with the feedback information is a subjective matter. People will eventually go through the process of 'perceived behaviour control' (Ajzen, 1991), finding out the consequence against effort put in, though, it will require a certain length of time to be familiarised and internalising the related activity. Under this premise, it can be argued that the feedback of HPP draws some doubts (shown as question mark) about its effectiveness in bringing internalisation and long-term use of HPP.

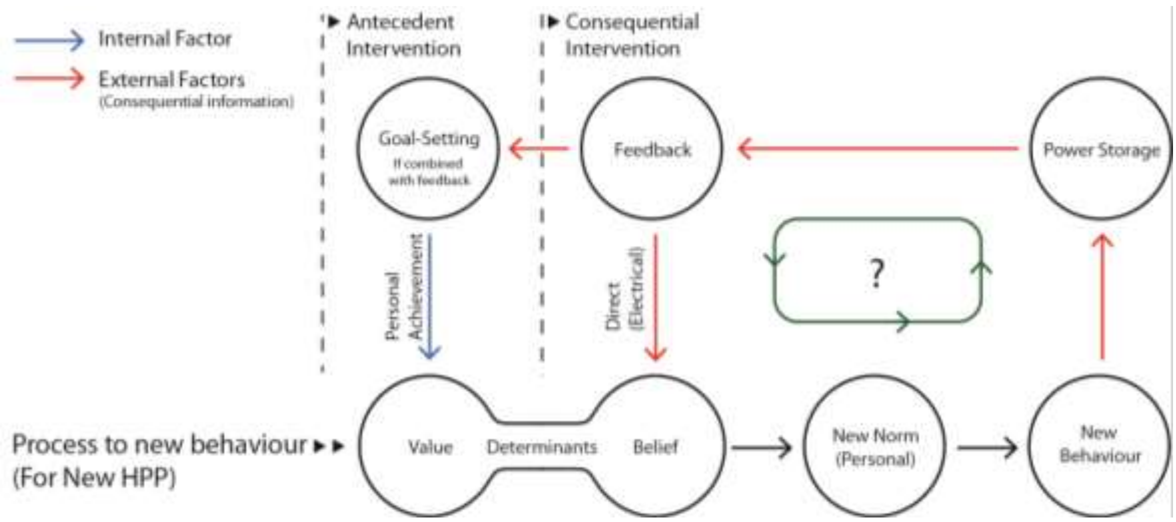

Figure 5.5 Process of behavioural change using 'HPP with direct feedback system'

From theoretical perspective, it can be seen that current interface of feedback system on HPP needs some modification towards providing more specific 'perceived behaviour control' (Ajzen, 1991) which in turn may increase the interactivity between the action of applying human-power and its expected outcome; e.g. making the feedback system into real-time, indicating the time left till complete discharge of energy system, see Figure 5.5 showing direct line in red. However, Jansen shows some contrast view towards this aspect by suggesting that design of HPP must be adapted to the use and resource of human-power. In order to maximise the value of consequence (e.g. longer functioning time) HPP should be designed in a way that fit to the human-powered source by reducing the power consumption of the functionality, avoiding stand-by or sleep mode, avoiding energy consuming graphical user interfaces (screens) (Jansen, 2011). However, the issue may only exist around portable sized HPP where the power consumption of modified feedback system (e.g. graphical user interface), although they can be tiny, reduces the available functioning time as the capacity of battery or stored energy unit containing small capacity.

5.4 Conclusion

The design intervention strategies and their deficiencies has been discussed through development of diagrammatic frameworks shown in this chapter. These assumptions serve as basis and supports the development of each constituent elements suggested in the final conceptual framework. Figure 5.6 offers an explanatory framework for conceptualising the process of behavioural change using preferred state of HPP, and internalisation process derived by designed intervention. As recommended, the system of feedback or its interface must provide the real-time consequence (shown in direct red line), linking the behavioural determinants with the possible goal set by household or user. This framework also suggest to implement a ‘double dividend’ (Jackson, 2005a) strategy by using additional psychological motives which alternatively influences on determinants to internalise the use and possibly into routine practice (shown in curvy blue line).

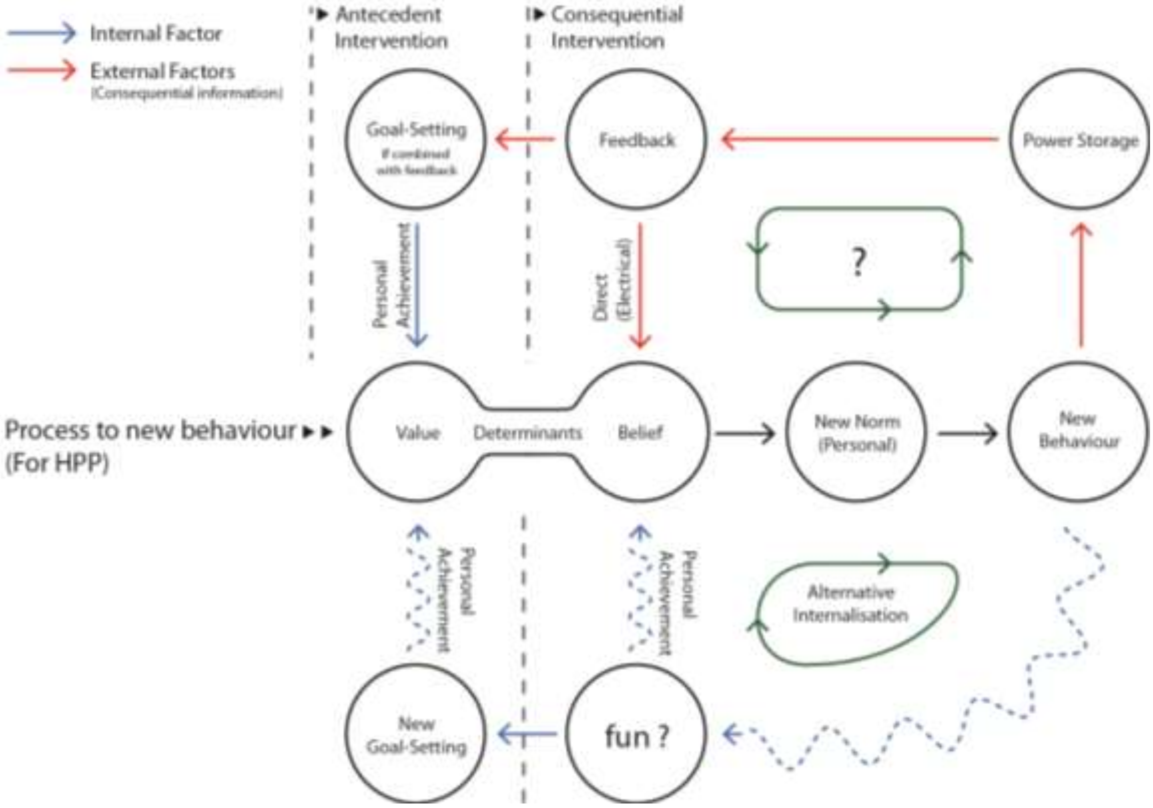

Figure 5.6 Conceptual framework (diagrammatic) for behavioural change of HPP and internalisation process

To identify its potential competency as intervention for instigating energy saving behaviour, an exploratory investigation of HPP use was carried out through case study using this framework (see Chapter from 7 to 9). From the analysis of using 'HPP interaction Matrix', it was highlighted that psychological mode of 'fun' interaction in HPP influences on motivational factor which can be seen as 'double dividend' stimuli that is beyond the objective incentives arising from generating 'free power'.

However, in making argument of internalising the HPP use, each element indicated in 'HPP Internalisation Model' (Figure 4.22 on page 142) must be supported by research evidences, hypothesising recommendations to improve the use patterns. Therefore, an empirical study was required to understand how actual consequences of existing HPP are influencing on behaviour determinants to continue carry out as everyday product and become routinised as a new practice. Moreover, it is crucial to understand which motivation, either intrinsic or extrinsic, influences on behaviour determinants. Therefore, the proposed diagrammatic framework serves as basis to methodological approaches used for the rest of research studies.

5.5 Research Objectives

As stated in the introduction, the general aim of this thesis is to investigate how the ‘use of human-power’ and designed interactions in HPP could lead to interventions for instigating changes in attitude and behaviour in regards to energy use and consumption. Specifically, the focus is on designing new interactivity of HPP – as a means of de-routinising the current habitual energy consumption, and making individual to make conscious choices of using HPP with the goal of reducing energy consumption – practicing energy saving behaviour. Based on the scenario of using HPP as replacement to EuP, the research generated a conceptual framework which contributes towards hypothesising the recommendations as design intervention. In relation to the main aim of the thesis and proposed ‘HPP Internalisation Model’, the following research objectives were formulated for the rest of study.

a. To investigate current perception of HPP among public and how they comprehend its consequence over applying human-power (Pilot Study).

b. To investigate how potential early adopter of HPP evaluate the ‘actual use’, and how actual consequences are influencing on determinants to carry as everyday product; routinising into practice (Home User Study: Stage 1).

c. Develop a prototype of HPP reflecting as ‘HPP Internalisation Model’ with evidence supported by findings from pilot study (Research through design - The material: “White Box”).

d. To evaluate and theorise the ‘HPP Internalisation Model’ with publics in interest of HPP - recruitment through appropriate sampling process (At Home: The Internalisation - HUS Stage 2)

The research work carried in previous chapter, Taxonomy and Analysis of HPP, serves as basis to the process of ‘theorising’ the current research, entailing to conceive and being intuitive towards building a hypothesis of ‘HPP Internalisation Model’. However, each dimensions of the model require further justification in terms of its hypothesis of internalising the HPP use. Later part of research work is considered as process of formulating the theory into a logical and explanatory scheme. Therefore, the current research is not intended to verify or falsify the hypo-theory, but rather stated as epistemological proposition of understanding how the actual user of HPP responded to hypothesised recommendations (each dimensions) in ‘HPP Internalisation Model’.

Section 3: The Use-phase

Chapter 6 The User: Perception of human-powered products

6.1 Introduction

In order to gain deeper understanding on the 'use of HPP', it is critical to view the user as operator in practice rather as a consumer of new product launch. It has been noted that Jansen (2011) has extensively covered the literatures in relation to HPP and comprehensively analysed its technical applications. However, a single literature have not been found nor attempted in understanding how households use HPP in their home. Studies related to HPP shows that there are opportunities in adopting this application as alternative source for battery running products, or as mobile power for wireless computing devices. Whilst these academics have contributed towards gaining the knowledge about wider HPP applications, this research had an enquiry of understanding how publics perceive these opportunities. Below are the relevant research question to be addressed through this chapter.

	Q 1.3 What is public's perception about HPP?
Q3: Are HPPs user-centred?	Q 3.1: If not, What are the factors driving this response? (What type of feedback is available in HPPs?)
	Q 3.2: What motivates user to use the HPP?
	Q 3.2: What are the missing elements or barriers in design of HPP that prevent people from using it for longer-term or even short-term period?

6.2 Pilot Study

According to Robson (2002, p. 185), pilot study is a 'small-scale version of the real thing, a try-out of what you propose so its feasibility can be checked'. Understanding a real world do carry some complicated cases; therefore, pilot study aims to encounter any issues that are relevant in data collection for main study. However, Yin (2009) distinguishes between ‘pilot tests’ and ‘pre-tests’. The former one refers to pilot case study that assists researcher to develop relevant line of questions and essentially functions as exploratory study to gain some conceptual clarification for research design. In contrast, the ‘pre-test’ is closer to the usual meaning of a pilot study in which the intended data collection plan is used as faithfully as possible – like a ‘dress rehearsal’ (Yin, 2009).

A pilot case study was conducted in order to generate the documentary evidence of understanding public perception towards using HPP. Especially, it was crucial to understand how actual user or publics comprehend the use of HPP and their accepted value as alternative energy source. The aim of this study also focused on obtaining the evidences to support the frameworks developed in Chapter 5.3. While the process of developing a ‘HPP Internalisation Model’ emphasised on the notion of how feedback can play a significant role in bringing a behavioural change, and as HPP requires a new set of behaviour to be performed by its user, it is under speculated and yet investigated whether publics accept current methods of feedback on HPP as positive or negative. The data collected from this pilot study provided interesting evidences to support the design of remaining stages of ‘Home-User-Study’ and also evidences to support the conceptual framework discussed in previous chapter.

The identified themes in the analysis accounted the phenomenon of interacting with existing HPP – the human-powered radio. These themes contributed towards revising the hype-theory of ‘HPP Internalisation Model’ and identifying the design specification of *material* developed in HUS stage 2 for conducting product-in-use study.

6.2.1 Methodology for Pilot Study

On December, 8th, 2011, a pilot study was organised which aimed to understand in detail about general perceptions of HPP and its usage experience[31]. 10 University students were randomly recruited around campus and from various different backgrounds. This type of recruiting strategy is also known as ‘probability sampling’

[31] On 2nd of December 2011, ‘pre-test’ of this pilot study was conducted with 6 undergraduate students.

(Bryman, 2004) where the selected participants become representatives of segment of population. The invitation to the pilot study was advertised through online social network service, i.e. facebook. Participants did not receive any prior information nor their role in the pilot study other than about complimentary refreshments for required participating time, i.e. 30 minutes. However, before receiving their consent, they were only briefed that the study was a qualitative research based on a product evaluation.

Figure 6.1 Pilot Study Set-up

Figure 6.1 shows the picture of the pilot study set-up. As each participants entered the room, they were briefed in detail about the procedure. The study comprised with 4 different phases. First, students were asked to fill out a 1st questionnaire[32] short after when a portable size human-powered (cranking) radio (HPR) was given to them. Figure 6.2 shows two images of the HPR named 'Uni-com Windup radio'

[32] See Appendix E

purchased at a cost of £ 12 from local electronic store. This hand-held sized device can function as a radio and also as a torch, having a foldable wind up handle. The author measured its running time from winding up for 1 minute at a normal pace[33] which gave an average of 8~10 minutes of radio listening time.

The research could have introduced different kinds of HPP for pilot study, e.g. phone charger. However, as name 'windup radio', or 'Baylis' Radio' has dominantly became an iconic figure when introducing the HPP, HPR was selected through a discussion with the supervisory team. Another reason in choosing the HPR was supported by Ofcom's[34] research document which reports that 90.3 % of the UK adult population tuned into radio each week (Ofcom, 2013). Therefore, the activity of listening to radio is not a completely a new behaviour for participants, at least they all had few experience and can speak based on their experience or even as comparative evaluation.

Figure 6.2 Uni-com Windup Radio

Questions listed on the 1st questionnaire was based on understanding their first impression of the product, skill to operate, expected run-time, and their perception about HPP as commodity of interest. This was done as self-completion questionnaire where it has advantage of minimising the interviewer effect. It has been suggested that people tends to exhibit certain desirability bias when an interviewer is present (Bryman, 2004). Therefore, all questionnaires used in this pilot study were designed for participants to comment about themselves and their own

[33] Researcher weights 80 kg with 180 cm tall.
[34] Independent regulator and competition authority for the UK communications industries.

experience. However, on a usual self-completion questionnaire, it comprises a series of questions with a limited set of response categories that can provide some countable measures. In this pilot study, both questionnaires were designed to draw participant’s comment that are more qualitatively driven, rather having a selection of answers to choose from. As the pilot study aimed at understanding how each participants accepts the value of using HPP and explaining their experience in-context, the majority of the questions required a commentary response with a few mixture of fixed answers.

As they finished filling out the questionnaire, participants were left alone in the room with given mission which was to listen to radio for 30 min. All 10 participants consented for video recording while they participate in this ‘product-in-use’ (Evans *et al.*, 2002) observation. The video recording observation enabled the researcher to capture the in-context behaviour and learn what people actually do rather than what they tell you (Evans *et al.*, 2002). All participants were briefed to do other free activity like reading or talking on the phone while they listen to the radio. Obviously, the radio’s battery was completely discharged prior to each study. The rationale behind the closed-room observation was to avoid ‘reactivity’ where presence of researcher may interfere in some way with the study setting, and in particular with the behaviour of people involved (Robson, 2002). While reviewing all recorded scenes, the objective was to capture any gaps of current HPP design problems, common or unusual behaviours, exemplar case of product misuse, and to encounter any user frustrations that may arise while interacting with this new device. Most importantly, it is a method of uncovering how HPP is really used and whether actual users are performing the behaviour as intended by HPP designers. Figure 6.3 shows the collage photo of 5 participants involved in the ‘product-in-use’ observation.

Figure 6.3 Collage of video captured screen from product-in-use observation

Questionnaire 2[35] was designed to be filled out by participants after they experience the device for the duration of 30 minutes. Through these phases, the research aimed to obtain some comparative analysis between their preconceived perceptions about HPP prior to experiencing the actual intervention (radio) and their after-use responses. Both questionnaires were limited to 7~8 questions, giving relatively short period of time to finish. This was due to reducing the risk of 'respondent fatigue' where people tend to inadvertently answer in a typical long questionnaires.

[35] See Appendix F

Figure 6.4 4 images of HPP shown during the semi-structure interview

The last phase of the pilot study was a semi-structured interview with the aid of images that represents 3 different types of HPP. Figure 6.4 shows the 3 types of images that were presented one at a time to draw discussions on their perceptions for each photo shown. These images were selected with a notion of understanding how people view different kinds of HPP that were discussed in the HPP Matrix. For example, bicycle image (1) was presented to draw discussion on mechanical HPP; to draw discussion on how people feel about using mechanical human-power over electrical devices (for Coffee Grinder [2]); and how people view HPP devices that induces 'fun' interaction (3)[36]. Table 7-1 shows the overall approach to the pilot study.

[36] Two images were shown for 'fun' HPP which included an images of Twirl N' Take (Sony, 2007), and images of HPP concept called 'YOYO Phone' which charges the power of phone as user play the device as YOYO.

Phase	**Research Enquiries**	**Approach**
5 min – 1st Questionnaire	- What is the general perception about HPP? - Do people know what HP radio is? - What is their expectation of HP Radio runtime?	Questionnaire was design according to research questions.
30 min- Product-in-use	- Do people know how to use HPP? - What are people's behaviours when listening to radio? (e.g. occurrence of cranking, etc)	Participants were given a mission of listening to radio for 30 min. Video equipment was set up, recording their behaviour.
5 min – 2nd Questionnaire	- What is the first encounter after they experience using HPP? - Any change of perception before and after use of HPP?	Questionnaire was design according to research questions.
Short Interview	- What do they think of other HPP concepts?	Discussion on 3 photos of HPP

Table 6-1 Overview of Pilot Study approach

6.2.2 Initial finding and discussion

The questionnaires were particularly useful in understanding the user's perception, experience, and expectation on the HPP run-time. 3 images shown during the semi-structured interview helped in drawing more discussion on the topic of HPP which gave interesting insights to how people perceive such idea of generating electricity.

6.2.2.1 Questionnaire 1

Below are the important bullets points of findings from the 1st questionnaire:

- 

  2 out of 10 participants recognised it as 'Human-powered Radio' as they first encountered the product. Rest of answers were as 'Radio' (4) and/or 'Torch (4)'

- 

  6 participants had no previous experience with HPP. Other responses were: *'I've seen similar one from toy'*, *'Yes, about 2 years ago'*, and *'only briefly, not in on going use'*.

- 

  5 participants expected that it will last for 1 hours from full charge, but the value was varying from 15 min ~ 8 hours, meaning that some people have lack of knowledge or low prediction about the performance (run-time) of the HP radio.

- 

  Half of participants responded 'No' against question asking for their intention of use/purchase of HPR in the future. Reasons for this responses varied, e.g. *'I don't listen to radio'* and *'no reason'*. Response of 'Yes' comprised relatively subjective reasons of; *'If travel', 'just to show off', 'I like it',* and *'if it doesn't affect my day life activities and time'.*

- 

  Responses for questions asking potential location or time-of-use were varied: e.g. *'Camping', 'Picnic', 'Outdoors in general', 'Mountain Shelter', 'Hiking', 'Day to day life', 'Educational Product', ' Emergency', 'Travelling',* and *'In my room'*.

These responses show that most of the participants' view towards the idea of using human-power to drive the radio function deemed around its benefit that were mentioned by Dean (2008, p. 76), 'human power is best suited to applications that require small amounts of power, that benefit from portability or exist in remote locations, and that need to be available on demand and that are relatively inexpensive'.

The expectations on run-time were also varied among participants, though, half of participants responded that it will last 1 hour from the full charge. It is assumed that this figure did not come from any of their profession knowledge, but perceived as an average expected run-time in order to accept its future use. From the 1st questionnaire, it was found that many had imagined the use of HPR in a location where there is no access to electricity grid, and only two participants had responded for adopting it as 'everyday' item.

6.2.2.2 Product-in-use Observation

Total of 8 sessions of product-in-use observation was carried where 2 of the sessions had 2 participants in a single group. The observation lasted between minimum of 23 minutes and 30 minutes maximum. All video recording was kept safely in hard drive for researcher to do multiple replays of their interaction with HPR. Below are the important bullet point of findings from the observation.

- The majority of participants did not seem to have any usability issue. All of the participants spent not more than a minute to fully understand the function of HPR.

- The frequency of the charging attempt and the duration of windup actions varied among all participants. Highest frequency of charging attempt was observed as maximum of 5 times to lowest of 1. The shortest winding up duration last 20 seconds to maximum of 4 continuous minutes of charging (winding).

- Observed 8 Participants not being able to detect while HPR stopped due to low battery level. They've realised it after a period of maximum of 5 minutes to minimum of 1 minute. However, as participants were free to do their own activity such as reading or mobile texting, this may have caused the distraction on its awareness. Other 2 participants who constantly winded up the HPR at an interval of every 5 minutes were not involved in any other activity but regularly holding or interacting with the HPR functions.

Most intriguing finding from the observation was the duration of windup action, i.e. length of time applying human-power into HPR energy system. Majority participants spent enough time, average of 1~2 minutes of windup action which resulted in having only few charging attempts within 30 minutes of trial. One participant charged HPR for 5 times that each last about 20 seconds of winding. The same participant (PSP-8), who was reading a book while listening, spent 5 minutes until detecting the power outage of the HPR. He described this situation during the short interview: *"I had high expectation before use, but after use… I came to know that it takes more than 70 % of my focus to making it work. The concept of generating the power works well, but that come in the account of your time…. Listening to radio and reading book is okay, but going to radio to generate again and coming back to reading, it just make me get lost in between."* (PSP-8).

Overall, it was observed that all participants' number of charging attempts and the duration of applying windup action were wide-ranged. After reviewing the observed data, the result brought to attention of how feedback can be a viable feature in delegating the control over power generation, giving an empowerment to control their usage. The consequential information, the available time length of radio use from charged electricity was not present other than a single LED that shows green light while winding up. It was observed that all participants were unaware about the size of electricity being generated and how much of equivalent run-time was available. It seemed that duration of wind-up actions are more likely be affected by the level of 'physical fatigue' rather than each user planning out the available run-time as they apply human-power. Beyond understanding the available run-time, the HPR device also lacked in providing the required time to reach 'fully charged' level. One of the session, where there were 2 participants, described this product-in-use difficulties during their conversation: *'How would you know that is fully charged?'* (PSP-5) *'I don't know'* (PSP-6).

6.2.2.3 Questionnaire 2

Questions listed on the second questionnaire was based on their experience of HPR. In order to reduce the 'respondent fatigue', number of questions were limited again and no more than 5 minutes were consumed for all participants to fill out the questionnaire.

In describing their first impression after experiencing the HPR, various comments were received. These comments dealt with issues like usability, functionality, run-time expectation, rejection of further use, and suggestion of new potential location of use. Below are breakdown of 10 responses:

Positive responses

- *'Doesn't require as much winding as I thought'*
- *'The battery last longer than I thought'*
- *'It is quiet as it wasn't charged after cranking, the volume was fine'*

Negative responses

- *'It takes my focus and cannot do anything else alongside with it'*
- *'It's run-time is low'*
- *'I had to keep winding it up to keep it loud. There is no indication of charging'*
- *'The crank lever is very difficult to use, and run time is very short'*
- *'It is unique, but I don't think I can use this for long time'*
- *'It is so annoying when cranking'*

Neutral responses

- *'It could be used during War time. Good for exercise'*

Beside the usability issues mentioned by few participants, the majority of the responses dealt around the issue of low power capacity that required constant attention to the device which in turn demanded for a longer duration of run-time. Increasing the power output of HPP along with higher capacity of energy system has been noticed and suggested as a key element for future HPP development

(Jansen, 2011). Especially, the technological improvement of HPP seems to have promising opportunity in inducing greater motivations towards HPP use.

Reponses related to recalling on the number of charging attempts and the duration of wind-up actions had some obscureness. Majority of participants (7 of them) did recall the number of charging attempts, but the actual duration of charging time did not correspond to their actual time spent. In question of asking for expected run-time for one minute of charging, the responses were varied and ranged from 2 minutes to 3 hours. It is important to notice that this responses were collected after they experienced the HPR with at least having few attempts in charging its energy system. Still, only 2 participants had responses that were closer to the actual HPR power performance[37]. However, the functioning time and the radio performance can vary depending on the velocity and the density of applying human-power into energy system, i.e. wind-up or cranking. However, it is notable to discern closely that other 8 participants were not able to predict on the actual power performance of HPR.

Questions probing for their motivation in terms of carrying the device as ‘everyday’ item had diverse responses that were related to anthropometric usability, power output, and reasons of one’s own perception, see Table 6-2.

[37] HPR’s power performance were measured as: one minutes of windup gives average of 8~10 minutes of radio functioning time.

Would you replace this product with plug-in powered radio? yes/no Why?	**What changes/development would you suggest to make it a better product?**
- Yes, if it had more functions like MP3, internet search. And it is too big to carry. - Yes, if I was inside or close to home (garden) - Yes, I like the mobility. In 50 years time, it will be useful when there is limited resource. Fun to wind up, saving energy! - Yes, it radio last for 4 hours - Yes, when I'm travelling.	- Longer Runtime (6 responses) - Better control (ergonomics) - Make it as home use. - Make it possible to plug-in. - Need charging indicator. - Use solar power. - Easier cranking methods. - Smaller in scale. - To be generated by foot power as well. - Use body heat for generating power - Have the TV function. - Weight, design, price, functions, colour - Better tuning dial.
- No, I got tired of cranking. The plug-in radio would be more convenient. - No, if I was near a power source - No, I don't need mobile radio. - No, it is so annoying to charge, and there isn't much function. - No, sometimes I just want to stop doing anything.	

Table 6-2 List of responses from Questionnaire 2

Among the positive/negative responses, it was reported that some participants prefer the use of conventional energy source (grid power) over idea of using human-power, and the lifestyles that is dependent upon cheap energy source. It was also notable to realise that multiple functions offered by current mobile technology such as 'smart phone' has significantly raised the standard of demandable functions in mobile electronics. In fact, people listening to radio via a mobile phone has risen from 13 % to 20 % in last 12 months, and the share of digital listening (e.g. internet, TV) equates 34.3 % of all radio listening (Ofcom, 2013). This points to the notion that future market opportunity for HPR will be narrow, and it is suspected that the trend of HPP will inevitably aim around 'emergency' use or at the locations where there is limited electricity access. In other words, access to radio content will no longer solely rely on portable radio set but expands out to other ICT and mobile devices. However, as pointed earlier, the future technology will potentially drift the increase of efficiency of power consumption on these mobile devices which may in turn give opportunity for HPP to be seen as another viable solution when supplying additional functional power.

6.2.3 Semi-structured Interview analysis

Approximately 5 minutes long semi-structured interview was conducted with each participants subsequent to finishing the questionnaire 2. The aim of semi-structured interview was to draw discussion on their perceived value and understanding about different types of HPP. Since the duration of interview was limited to 5 minutes, the unit of analysis and the data size was not deemed to be sufficient to generate a generalised view. Nevertheless, all interview were transcribed and transferred into coding software called 'Nvivo'. The major themes were identified which corresponds to the images shown during the interview. Line-by-Line coding was performed that generated 3~4 codes (sub-themes) that each falls under the major themes.

6.2.3.1 Bicycle

The discussions using an image of 'bicycle' began by raising a question of this product being still favoured by many publics, see Figure 6.4. Three sub-themes emerged in describing their opinions, and they were; 'convenient', 'environmental friendly' and 'exercising'. Participants have exemplified the bicycle as a product that utilises a human-power through relatively 'convenient' method which assists people traveling a distance. *"Because it is more efficient than walking."* (PSP-7), "*If you think of it from historic wise, it was about transportation, moving from point A to B. That was a good solution"'* (PSP-8). However, there was a comment which described how the activity of listening to HPR can differ to riding a bicycle: *"But for radio, me putting human-power into, it takes more effort than putting batteries in. By hand cranking it, it takes me longer to listen to the radio. But if there was no battery, it is much efficient than going out to buy another battery"* (PSP-7). Again, this brings to a view that using human-power still faces challenging aspects in terms of regarding it as everyday energy source when in fact people consider it as useful source in emergency situation. Other notions to 'convenient' were discussed in relation to cost and easy-access compared to other transportation such as automobile. Small number of comments were received in relation to bicycle being a product to reduce the pollution. However, dominant comments were gathered around the notion of 'exercising' and health related where people perceive the activity as leisure. For example: *"this has become an exercising device. People are enjoying that fact"* (PSP-2), *"people see it as exercise. Good for your health"* (PSP-4). More importantly, interesting comments were shared by participants in terms of describing the possible motivations, especially the intrinsic motivations: *"...and exercise and it is fun. You enjoy the speed"* (PSP-3), *"people think of it with health issue, exercising, and for some people riding a bike is enjoyable thing to do"* (PSP-8). Though, one participant has raised an interesting assumption that can be described from aspect of 'adaptability': *"we are used to looking at the bike. But HPR is a surprise. If people are more used to electrical bike, it would be a different story. Electric bicycle can be more comfortable. But there is something that people like about bike. Maybe it is fun"* (PSP-10).

The comments above bring attention to the notion of 'motivation' where the psychological awareness of related behaviour and its outcome of consequences increase the higher acceptance of product use. Although these behaviours are exposed to being a 'real affordance' (Norman, 1999) as they become so routinised and that people view them as normal, but the processes for maintaining the use are influenced through different form of intrinsic motivations. In retrospect, it can be viewed that many parasitic harvesting HPP utilises the interaction derived from activities which exists persistently around people. These activities are perceived to be so 'routinised' and that people view them as normal, using 'real affordance' to minimise the repulsion, e.g. revolving door, rocking chair, Soccket. However, in between the interaction of HPR, it is assumed that people hardly find any intrinsic motivation and the outcome of consequences rarely increase the adaptability of further use or subject to certain condition, e.g. emergency.

6.2.3.2 Coffee Grinder

The second image theme was shown to continue the discussion on HPP which had two images of coffee grinders; one that had crank handle to grind the beans (A), and an electrical grinder (B). See Figure 6.4 on page 161. Participants were asked to make a preference of choice between two products and describe their reasons. The preference of choice between two product images were equally balanced. The comments describing the reason for choosing ‘A’ (the hand-crank grinder) were varied. These comments dealt with issue such as cheaper cost, being an activity that brings ‘reminiscence’, and how they value the activity of grinding. For example; *“we used to grind the coffee beans back home. I think it is very efficient way to drink coffee… in cost wise too. The manual grinder one gives you deeper perception about coffee as well”* (PSP-8), *“If I was going to grind the coffee, I want to do it myself. Because I want to play. I don’t’ see the point of buying electric one if there is already grinded coffee available in the market”* (PSP-6), *“I’m a very energy conscious person. I’m a fine artist who enjoy from this that I physically develop. This is the same case.”* (PSP-1). In linking with the comments from ‘bicycle’ theme, it is assumed that people seek the ‘nostalgia’ of human-power use, and the activities they imagine from looking at ‘A’ type of grinder and bicycle gives them less repulsion towards its use since many would have experienced the similar mechanism before. However, for HPR, the repulsion seems higher since the activity around listening to radio never began from using a human-power. Although the activity of listening to music may have begun from using a gramophone which is human-powered, but people reminisce the radio as a device which has been relying on the use of electricity. Therefore, this points to the challenging aspect for those HPP classified in the domain of ‘D’ from HPP Matrix version 3 (page 134); where they require high level of motivation to overcome this barrier in order to maintain the prolonged use.

In contrast, participants’ comments in choosing a ‘B’ (electric grinder) dealt with the actual practice of drinking a coffee. In this case, it was recognised that the use of electricity inevitably became an ‘inconspicuous’ as the activity of drinking a coffee sometimes derive from a routine of what people take to be the normal ways of life. Especially considering the prolific pace of modern lifestyle, the electric coffee grinder becomes a socio-technical system in which the pattern of these activity make people to involuntarily consume the electricity in a relatively ‘inconspicuous’ manner. *“…but I would rather buy the electric on. Because I have to drink the coffee right away”* (PSP-2)

"...but for the coffee drinkers, they drink coffee because they are tired. And I don't think they will like the idea to spend more effort and time making a coffee. So presumably, they want something quicker" (PSP-7)

"I will use 'B', because it is convenient. You drink coffee every day. 'A' will be annoying""(PSP-3)

6.2.3.3 HPP with 'fun' interaction

Discussions on 'fun' HPP (Figure 6.4 on page 161) did generate some interesting comments. As the author reviewed the transcribed interviews, three sub-themes emerged: 'gimmicky', 'hybrid', and 'parasitic'. Number of participants favoured the idea of 'fun' interaction; however, it soon followed with some negative comments or concerns over issues being a 'gimmicky' product. For example: *"Today, time is very important, so I don't want to get bothered. I would rather just charge the device beforehand (before phone reaching low battery level)"* (PSP-9), and *"Problem is when you have to do extra thing. I think this will be good for teenagers. If you have free time, it will be a good time killer. But for busy people, they cannot do this"* (PSP-10). These negative comments also led to a suggestion of making HPP using 'parasitic harvesting' methods. As participant (PSP-10) commented in regards to how such idea of 'fun' can be challenged: "*I don't think it is about 'fun', it is about sub-consciousness. I prefer something like you charge while you walk. But these idea still require you to stop and do something. I still like the idea about human-power but I don't think it can get into daily life… if it was solar, it will be okay… solar power is much more convenient"*.

The theme 'hybrid' emerged as a number of participants found the idea of 'fun' application as useful 'back-up' energy source in case of emergency. However, the condition of this emergency situation were describing the consequences of using current touch screen or smart phone when in many cases people demands for longer and higher battery capacity. For example, "*I would like to have one of these, because I always have problem with my smart phone battery"* (PSP-2). With regards to this condition, number of participants have commented towards the demand of using human-power application as 'hybrid' feature, integrating a concept of 'available on demand' as one of the key benefit of using HPP.

"I think it will be nice to have this alongside the traditional charger. Because… problem with modern phone like smart phones… the battery power… you are lucky to get a day or two from full charge. But soon as you use internet, it drains quicker" (PSP-7).

6.2.4 Conclusion

The pilot study discussed in this chapter produced results that availed in designing the rest of case studies. This study can be seen as a 'single-case-study' in which the study is a pilot and first case within multiple-case study designed in this research. However, it is guided that, in this instances, the case study cannot be regarded as a complete study on its own (Yin, 2009). However, as the cases set in this research rely on a scenario of using HPP, it should be regarded as either 'unique' or 'revelatory' case where both can justify the study as 'single-case' for being rare and previously have not been studied.

Inducing a motivation to apply human-power is most challenging part in any design development of HPP. Thus, there have been a number of proposals designing interaction of applying power generating labour to perceive as ancillary element such as utilising human movement while doing other activity (e.g. Playpump). When HPP users are faced with choices of using HPP and other products, perhaps they will choose the one that gives more convenience to accomplish any given tasks. From eco-design perspective, Jegou has argued the necessity of making both the efficiency of product and the sufficiency of user interaction are complementary to each other, exploring how to 'do nearly the same with less' (Jégou *et al.*, 2009). However, from research findings from this pilot study, it shows that HPR does not perform nearly the same as plug-in radio, and the 'less' part of using human-power is hardly acceptable. No participants raised any issue with the quality of function (sound), but many regarded the use of human-power as 'more' required labour rather than as 'less' harmful energy source. Jansen and Stevels (2006) noted that users of HPP are required to apply certain 'added discomfort' to generate an electrical power and certain level of motivation is required to support the intention. Comments from participants support this notion as the consequential outcome of HPR that rarely increases the adaptability of further use, and it is evident that people hardly find any intrinsic motivations which would in turn overcome those barriers. In contrast, riding a bicycle has been perceived as activity that performs from many different form of ‘intrinsic motivations’ such as ‘fun’. De Young (1993) argues that ‘intrinsic motivation’ may reduce the side effects of intervention by making individuals discover a behaviour that is worth doing for its own right. During the semi-structure interview, many had the view that riding a bicycle produces this type of intrinsic motivations. From ‘practice’ point of view, these motivations can be seen as how people perceived the *meaning* of related behaviour; as explains ‘…can be generic, in the sense that they are shared by many practices, such as idea that doing something is healthy’ (Røpke, 2009 , p.2492)

However, in the case of HPR, many had difficulties in receiving sufficient consequential feedback for user to go through a ‘perceived behaviour control’ (Ajzen, 1991). As argued before, users need to go through learning process of perceiving feedback such as; power required to drive the product, absolute time of charging, and interaction of product interface. Feedback in HPP can be an essential component in learning through interacting with power generating; knowing how much is generating and how much power is left in the energy system, i.e. ‘live feedback’. The live feedback defines as interface of designed object and its interaction giving instant learning as to understand how much of power input in being converted. Deci and Ryan (2000) argued that intrinsic motivation get enhanced as positive feedback signifies the effect and spurs the satisfaction of the need for *competence*. The task during the 30 minutes of ‘product-in-use’ was only requested to listen to radio which considered as ‘goal-setting’, and no fixed number of power generating interactions was required. However, it was observed that no participant spent equivalent amount of charging time to produce the full power that correspond to radio run-time of 30 minutes[38]. From this observation, it can be argued that no sufficient feedback was delivered during the interaction of HPR. All participants had difficulties in gaining the *competences* which required skills and knowledge to carry out the intended behaviour and possibly establishing a routinised behaviour. This deficiency was visualised during the process of developing a conceptual framework of HPP use in Chapter 5.3, referenced in Figure 5.4

[38] A single user was observed, spending 4 minutes of charging which would have given approximately 40 minutes of charging. However, she was not in any consciousness of knowing the consequential feedback in return of her human-power exertion.

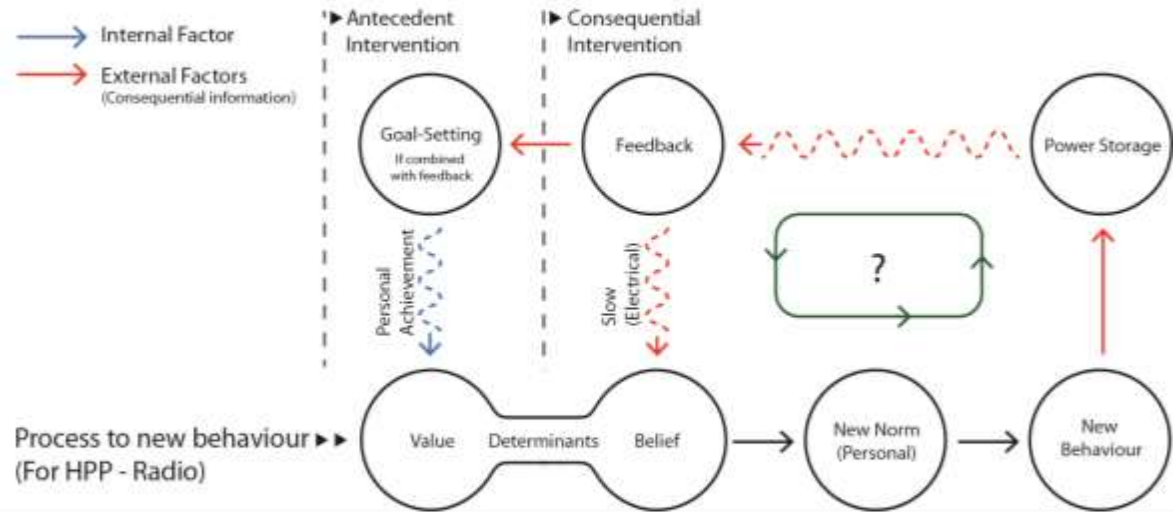

Figure 5.4 Process of behavioural change when using 'HPP'

Therefore, the observational result brings to the attention of how feedback can be a viable feature in delegating the control over power generation, giving an empowerment to control their usage. Moreover, this points out to the opportunity of improving the interface or design element that enable user to understand about consequential information in more immediate form - beyond presenting through a single LED that shows green light while winding up. This obscurity of feedback frequency was discussed through developing 'HPP Interaction Matrix – Version 4' (Figure 4.19, on page 137), and in Chapter 5.3 with illustration of framework (Figure 5.4) which demonstrated above mentioned deficiencies.

In discussing such issue from the context of product longevity, it sorely depends on how consumers would value the product and design intention that was inscribed by designer. Products with attached personal value are often more respectfully handled and lead to a better care which may increase the product lifespan (Lilley *et al.*, 2005). From interviewing all pilot study participants, many had the notion of how HPP can impact on electricity consumption. Despite this interest, the outcome of consequence (e.g. available run-time) did not fulfil the user to increase their motivation towards using the device as permanent domestic electronics but rather as outdoor or emergency purposes. In other words, the value or design element attached in HPP lack in providing sufficient extrinsic motivation for users to practice prolonged use of HPP. However, the technological improvement of HPP which expands the run-time seems to have promising opportunity in inducing motivations towards HPP use.

Chapter 7 Home User Study: Stage 1

7.1 Introduction

After the completion of pilot study, the research recognised the need of collecting richer data in understanding how household use HPP in their home. The data collected in the pilot study were considered as ‘preliminary’ since all the responses from the study participants were derived from their experiences occurred in an artificial setting. In order to carry the research into more depth, the research planned a Home-User-Study for duration of 1 week with recruitment of local residents in Nottinghamshire, UK. The aim was to gain more evidences in understanding the use of HPP and identifying the real world problems in a prolonged setting.

It can be argued that new establishment of ‘practice’ is required for internalising the use of HPP. Since the new practice is regarded as routinised type of behaviour which consists of several elements, it is an entity configured with set of bodily-mental activity held together by *material, meaning* and *competence* (Reckwitz, 2002). The result of pilot study brought up a subject of HPP deficiency in terms of how feedback can play crucial role in spurring the satisfaction of the need for *competence*. However, it is noted that pilot study responses represent how people encounter the HPP that is based on a relatively short experience and the motivational intention was never pre-existed. Therefore, it was necessary to evaluate this finding in the form of replication which extended the case study duration up to 1 week with participants with a higher motivation towards the use of HPP, adding more validity to the data by understanding the studying phenomenon using a practice oriented approach.

7.2 The user

While this longer-term HUS is aimed to find in-depth understanding of *competence* element, it alone is not sufficient to fully establish this new behaviour into a ‘practice’. The key investigation in this stage still remained as to focus on understanding the *meaning* and *competence*; however, certain eligible condition was required in order to carry out an intended or required practice. First, it was vital to find ‘actual users’ who are ecologically motivated and are well aware of the *meaning* aspect in the context of establishing a new practice that may arise from using HPP. These individuals are considered as practitioners who have willingness to adopt and purchase such device like HPP or have experience of adopting technological interventions to practice lowering their household electricity consumption. In other words, they are considered as people who are well aware of the *meaning* of future practices arising from the use of HPP, and individuals who are willing to consume the *material*, i.e. the HPP. This type of consuming behaviour can be seen as 'consumer innovation adoption behaviour', defined as the degree to which an individual adopts a new product, in this case HPP *(Material*), relatively earlier than other members in a given social system, e.g. early adopters (Rogers, 1983).

This notion of situating the *meaning* element as to explore how practice could arise through using HPP was derived from recent study result which investigated the effectiveness of 'eco-feedback' system, also known as In-Home-Display. The result reports that eco-feedback is likely to appeal only to those who are environmentally motivated whereas the other participant's usage behaviour were languished over a period of time (Strengers, 2011). Wilson *et al.* also highlights that specific types of energy efficiency intervention correspond more effectively with early adopters and vice versa for the mainstream market (Wilson and Dowlatabadi, 2007). In addition, Stern's VBN theory suggest that variable of values (motives) can directly affect the variable that activates pro-environmental actions (Stern, 2000). In order to design an intervention that can bring an impact, it was important to understand what level of chasm may have exist between these early adopters and subsequent majority of potential HPP users.

Another reason for recruiting a specific type of individual also derived from reviewing previous HPP related literature. For example, Jansen (1999) has ran a workshop with 17 participants from various background including persons specialised in the field of environmental design. It aimed at exploring the insight, from both ecological and economical aspects, in the subject of human-powered energy system as consumer product. It showed the analysis of opinions, bias, or roadblocks towards acceptance of HPP. The conclusion of his study showed similar characteristics in terms of creating a categories or themes of how people perceive the use of HPP, although the result were again based on assumptions from ecological and economical aspects. In order for this research to take into further depth beyond

Jansen's result and the pilot study, more specific recruitment of participant was necessary. Especially, it was necessary to gather information and understanding the HPP usage based on the experiences of 'actual user' who are willing to adopt such material to establish new practice.

7.2.1 The Recruitment

The research began with searching for local residents who are eco-motivated, additionally who are frequent radio listeners. For recruitment process, the research used a 'snowball sampling' technique where the researcher makes initial contact with an individual who are relevant to the research topic and then establishes further contact with others (Bryman, 2004). The recruitment process began by contacting locally famed consultant who were interviewed for author's bachelor project. This consultant runs a local community project which aims to retrofit eco-home in the east-midlands region. Two households in Nottinghamshire County were recommended through email forwarding who have participated in the community project and also widely known for owning a low emission emitting eco-house. These people are members of local community group called 'Eco-Team'. As an Eco Team, they discuss ways to reduce their use of electricity, gas and water and as well as decreasing the amount of rubbish they throw away. The consent of participation and detail visit schedule were arranged through email swapping along with verifying the eligibility for being a frequent 'radio listener'. Total of three visits to the participants' residents were made beginning with leaving an energy meter device onto their plug-in radio, measuring their average electricity consumption prior to using HPR. The participant code (HUS1-1) and (HUS1-2) will be used in this thesis to refer to these two participants.

All the visits and the product-in-use trial was conducted in between January and February of 2012. The first visit began with a house tour hosted by participants showing various implements in making their 'eco-house'. HUS1-1 resident owned a number of solar panels (PV) on the roof with an energy monitor that shows the reading of power conservation unit linked with household electricity consumption. She had several other equipment installed as an attempt of reducing the total energy use, such as dehumidifier heat pipe which helps to keep the hot air in the house during winter time. HUS1-1 was also a very highly motivated and exemplary figure of 'energy conscious' individual and who constantly practice energy saving behaviour. For example, she is not a frequent TV watcher, watching maximum of 1~2 hours a day and mostly relying on the radio to listen to the news. From viewing her practice from HPP perspective, she can also be seen as the 'actual HPP user'. Figure 7.1 shows the collage of images taken during the house tour at HUS1-1 resident. During the tour, she showed various kinds of kitchen utensils that uses non-electrical kinetic power such as hand-crank whisk, hand-crank tomato grinders, and cheese grinders. She also owned earliest model of Trevor Baylis's freeplay radio which powers the radio from winded up spring coil and also owned a bespoke fruit squeezer (bottom right).

Figure 7.1 Photos of equipment shown during house tour

HUS1-2's resident was introduced as first 'carbon net-zero' house in UK through various news media. The owner, participant HUS1-2, calls this resident as 'Peveril Solar House' installed with custom-built solar collectors which provides favourable balance between PV[39] generation and heating system consumption, see Figure 7.2. The equipment includes installation such as sunboxes[40], solar heat pump, PV and storing these heat energy underneath the ground of borehole. The house still relies on the use of grid for lighting and cooking appliances. But for the building emission, this house now achieves credit balance of the regulated quantities, as recorded by the meter[41]. While HUS1-1 is characterised as a practitioner of 'energy saving behaviour', HUS1-2 can be seen as who ideally uses 'inadvertent' feedback as described by Darby (2001) as household having an advent of solar water heaters and other PV systems to become a place for 'generation' as well as consumption of power. According to Darby (2001) it is highly likely that this behaviour of understanding the input and output energy causes increased observation of energy use and a shift in thinking. Although HUS1-1 also had a display unit of monitoring the real-time energy input from her solar systems, HUS1-2 is seen as a character who uses advanced technological interventions to further gain the amount of input energy or increasing the time of storing heat energy in underground borehole. As this participant himself is currently an academic of architecture, his introduction of the eco-house mainly focused at describing his future plans of installing new solar technologies. However, it was observed that few HPP was owned by HUS1-2 such as windup torch, and 10 day winding stand clock.

[39] Photovoltaics
[40] Sunbox is a bespoke solar energy collector made by HUS1-2. The system changing the angle of the array
[41] Detailed information on this house can be retrieved from participant's blog: http://chargingtheearth.blogspot.co.uk/

Figure 7.2 Photo of Peveril Solar House

7.3 The actual use

During the pilot study, it was observed that many participants had expressed the demand for higher performance of HPP, having longer-duration of available run-time from applying relatively less amount of human muscular effort. Therefore, it can be stated that better performance of HPP may be a significant variable for intention and action towards adopting a new behaviour of using HPP. For this reason, new *material* was used during the HUS stage 1 - the ‘Eyemax’ Freeplay radio, see Figure 7.3. According to manufacture of this product, 30 seconds of moderate winding is sufficient to provide 35 minutes of radio play time, and plays over 24 hours when fully charged[42].

[42] The actual runtime measured by the author ranged from 20~25 minutes with a mid-level volume.

Figure 7.3 ‘Eyemax’ Freeplay Radio

Prior to the actual use of HP radio, electricity monitoring device (Kill-a-Watt) was attached on plug-in radio to measure the usage for the duration of 1 week. The purpose of measuring was to identify the average consumption which represents the potential amount of energy saved by using the HPR for following week. Although this HUS is aimed at understanding the HPR use for period of 1 week, all participants were not obliged to only use the HPR but were consented to use the plug-in radio accordingly, e.g. used by other family member, at emergency use, or at any special situational circumstances. During the trial period, each households were provided with a daily log-in sheet to record the number of charging attempts and also the usage occasion of using plug-in radio. However, it was requested to be filled as in volunteer basis, avoiding participants’ fatigue which may interfere in logging their candid experience. Therefore, a package of recording device was also provided alongside with the log-in sheet that participant can voice record their usage accounts. If necessary, participants were asked to record any instant responses or any issues that may have aroused during the trial period. On the other hand, the goal of logging activity was not to generate any form of data per se but rather to encourage participants’ engagement in using the HPR.

A semi-structured interview took place after 1 week of this product-in-use trial. Interview questions were based on exploring their knowledge, views, understanding, interpretations, experiences, and interactions of HPR use. During the interview, the measurement of plug-in radio usage, that was measured prior to HPR delivery, was planned to be shared with each participants to draw detail discussions on how these external variable (cost saving) would affect their overall practice of human-power use. All interviews were audio recorded and relevant section in the discussion were transcribed.

As suggested in the 'practice theory', carrying out a practice very often means using particular things in a certain way (Reckwitz, 2002). Moreover, in order for such product to induce sustainable use by its user, user-centred design can play significant role. Therefore, thorough understanding of human-product interaction is vital. Shackel (1984) has argued that adopting a user-centred design approach is to improve the quality of the interaction between user and product. However, the usability is not a sole element that controls the sustainable usage. As discussed in previous chapters, there are various other elements that are entangled together to formulate a new practice.

Similar to pilot study, the HUS stage 1 also relied on a scenario based approach. This approach of using scenario-based research technique has been applied in product design process (Fulton Suri and Marsh, 2000), allowing designers to explore future product ideas, study usability, validation of prototypes, or to gather information that can be applied into design iteration. However, distinct to pilot study, HUS stage 1 applied hypothetical scenario of facilitating intrinsic motivation as a starting point. The study recruited users who are in forefront of establishing *meaning* of practicing energy saving behaviour. According to Self-Determination Theory (Deci and Ryan, 2000), intrinsically motivated behaviours are based in people's needs to feel competent and self-determined. Such motivated behaviours do not depend on reinforcements of external rewarding because the doing of an interesting activity is itself intrinsically rewarding. In addition, it was found from literature review that interventions using the persuasive techniques to stimulate the extrinsic motivations are likely to fail as they become obsolete and so does desired behaviour. It is therefore, the study focused on understanding how the longer-termed trial of HPR use and, to some extent, highly eco-motivated (intrinsic motivation) individual may generate different perspectives towards the use of HPP.

7.4 Analysis of HUS stage 1

As this research followed a flexible research design, the development process of ‘HPP Internalisation Model’ remained as ‘hypo-theoretical’ which explained the suggested elements required in bringing the internalisation of HPP use. At this stage of the research, the decision on identifying the two dimension, ‘delegation of control’ and ‘feedback’ has been supported by findings from literature review and with evidences gathered from pilot study. However, these results brought to attention whether the practice of using HPP derived by intrinsically motivated individuals may overcome some of deficiencies involved in the use of HPP, e.g. slow feedback. Moreover, the study followed a replication logic to enhance the finding from pilot study by extending the period of product-in-use trial. As it was suggested by Shove (2003), some practices get formulated through routine activities of non-economic factors such as habit, comfort, and convenience. In this context, the focus of HUS stage 1 involved in understanding the process so called ‘Normalisation’ which refers to ‘process of new object and arrangements becomes established, and through which new expectations and forms of competence emerge’ (Ingram *et al.*, 2007, p. 5); and therefore provide the answers to research questions below.

Q3: Are HPPs user-centred?	Q 3.1: If not, What are the factors driving this response? (What type of feedback is available in HPP?)
	Q 3.2: What motivates user to use the HPP?
	Q 3.3: What are the missing elements or barriers in the design of HPP that prevent people from using it for longer-term or even short-term period?

7.4.1 Unexpected conditions

While the nature of qualitative research remain as to reveal the real problem of studying phenomenon, some unexpected issues were shared by the participants. However, this ‘unexpectedness’ conceivably informs the deficiencies of current HPP which in turn identified the necessary improvement for increasing the quality of its interaction. During the interview, HUS1-1 has number of times mentioned about the low quality reception of HPR which resulted in using the device at limited locations. However, this limitation also led to a discussion on the advantage of HPR which is the ‘portability’. For example, HUS1-1 voice recorded this issue by saying: *“First thing in the morning, I cranked up the radio. It took me about 2 minutes, it last pretty well. But I had to put it on my desk, because the reception in the kitchen isn’t very good.”* (HUS1-1). She repeated this view during interview, *“So, my preference to use HPR was either outside or in front my desk where the reception of radio is better there” (*HUS1-1).

HUS1-2 also took the device to work instead using the HPR as domestic electronic. Also, HUS1-2 charged the battery unit using the solar power[43] which possibly have extended the run-time of HPR. However, this charging method did not overtake the overall charging attempts. As he explains about the experience of using the solar charging: *“I think basically the panel is enough to drive it in the freewill. But if I left it in the sun for 2 hours, I don’t khow much it will charge the battery. I would like to know. But it was enough power to drive it”* (HUS1-2).

To some extent, the researcher faced difficulties in guiding the semi-structured interview. There were several reasons for this cause. First, this was due to the nature of qualitative research where no specific brief was given to participants other than being a 1 week long product usage trial. The rationale behind this decision was to avoid the ‘respondents bias’ where participants in the study tend to withhold information that are not relevant to the study, and attempt to give answers or impressions which they judge that researcher wants (Robson, 2002). Secondly, as these individuals were experts in the field of ‘energy saving’, some extensive knowledge had been overlapped with their own area of interest. Rather facilitating and guiding the interview, many times, researcher dealt with issue where interviewee tends to dictate the conversation moving away from the domain of related topic and spending significant time on topics such as usability, green lifestyle, design improvements, and solar panel technology.

HUS1-1 also failed to log-in her behaviour, but she managed to audio record the account of experience at least once a day. On the other hand, HUS1-2 failed to record any of usage behaviour on neither way. However, it was noted that the purpose of log-in activity was not to generate any form of quantifying data but rather it aimed at encouraging the daily use. The very essence of HUS stage 1 was to

[43] ‘Eyemax’ Freeplay radio can be charged using the solar array as well as through cranking the dynamo.

generate in-depth understanding of how practice of using HPP may differ with selected participants, and to identify the themes to explore in the next stage of HUS. Additionally, the analysis became an iterative process of repeatedly referring the previously found data with the dimensions of 'HPP Internalisation Model'. It was considered as a research activity of weaving back and forth between data and creating evidences for evolving versions of conceptual frameworks discussed in Chapter 5.3.

7.4.2 Are HPPs user-centred? If not, what are the factors driving this response?

Insofar, result of pilot study identified some of deficiencies during the use of HPP. More specifically, it has identified the deficiency of feedback system and different levels of motivations that may become an obstacle in gaining the *competence* of HPP use and to further carry out as practice. While the recruitment in HUS stage 1 proposed to investigate those individuals who have established a *meaning* towards the topic of 'energy saving behaviour', the analysis not only focused on understanding the 'user-centredness' of HPP but also how dynamics of daily life may reveal some interesting aspect in the use of HPP.

7.4.2.1 The Feedback

Since the trial of the product-in-use extended to period of 1 week, participants found enough of time to go through the learning process by perceiving the feedback of HPR performance. Still, participants experienced some difficulties in understanding the precise output equivalency from amount of human-power input. For example, both participants have said*: "In one way, if I do it for 5 minutes, I probably get it for most of the day. I do switch it off when I leave the room. I do it at 10 am, and in the afternoon, it was still going"* (HUS1-1), and *"But as you learn how to… when you have to break… it will go about 1 hour and half and it fades away quietly"* (HUS1-2). The interface of feedback on 'Eyemax' Freeplay radio did not provide the detail information other than a charging indicator, but all participants managed to predict the closer range of available run-time, and they were able to take the action into a routinised behaviour. Throughout the week, they have obtained an acceptable level of *competence* from the first day of use to the point where they have increased the number of task repetitions. Responses accounting this process shows similar process explained by Jordan (1998) as; guessability, learnability, experience user performance, system potential, and re-usability. This view is supported by daily log-in record of HUS1-1 by saying: *"I have used HPR while washing up. I cranked it up for about… I don't know… half minutes but it managed to last all the way through washing up, so that was fine"*; 2 days later, she has recorded: *"I cranked up the radio…, and listened to my favourite programme for about hour or hours and half while doing… cleaning and tidying up the kitchen"* (HUS1-1). And HUS1-2 said: *"10 seconds of cranking will probably give me 10 minutes. If the radio start at 5 pm… and you do that for a minute and it will take you half away through 6 o'clock news"* (HUS1-2). Although the response from HUS1-2 was not reflecting his own experience, but this reflects how he gained some knowledge towards understanding the 'system potential' of HPR and how this can be applied into his daily practice. Especially, this response shows how he made a certain 'goal' as he became experienced user. Nevertheless, the comments related to the performance of HPR was 'predicted' rather 'be exact' and often used the term 'probably' and 'about' as to explain the system performance.

On the other hand, they also shared difficulties in understanding the detail of 'system potential' where maximum performance could not be predicted. For example, HUS1-1 had owned an early version of Baylis Radio which she discontinued to use due to having lack of reception and outworn annoying noise. However, she made a comparison with her past experience of using Baylis Radio against Eyemax radio, and explained the difficulties as: *"The big one (Baylis radio), it just makes you stop*[44]*. And this one, I was very tired winding for 5 min or whatever… this should be fine. But I agree with that, if there was a sort of indicator to let me know if it is full. I've never got to that point… so could have cranked and cranked until…"* (HUS1-1). From this response, it can be argued that current scripted feedback on HPR (Eyemax) provides 'perceived affordance' where this application allow users to perceive the 'possibility' for a certain action. However, it is yet ascertain whether the feedback provides adequate and detail information for user to have much control over the actions taken by the product. This notion had been applied in the framework which demonstrated this deficiency of feedback system on HPR, see Figure 5.4. The question mark depicts this doubtfulness about its effectiveness of bringing internalisation HPP use.

[44] The first freeplay radio uses steel spring-winding mechanism to generate electricity to run as radio. The number of windup motion was limited to the length of this steel spring.

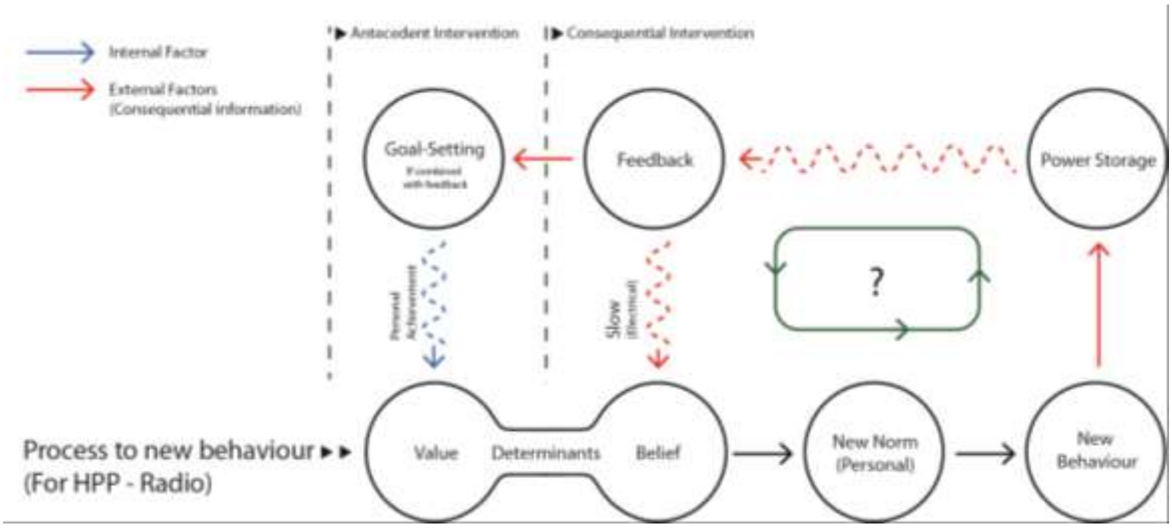

Figure 5.4 Process of behavioural change when using 'HPP'

Whereas HUS-2 did suggest how the feedback system on HPR can be improved. He explained this suggestion based on his own experience with other feedback systems, for example: *"It is just like when I pump my bike tire. It shows the air pressure level. As I pump the indicator tell me the air pressure. On my pump, there is a little meter that tells me whether it is enough. But on the small size pump, it doesn't tell me"*, and he related this notion with other example such as; *"If you have tiny little LED… another light that tell you the satisfactory level of charge… I mean… there will be another light that takes quarter of watt that indicates enough charge to go about an hour. One little grow. Like a LED on my MacBook"* (HUS1-2). However, HUS1-2 did commented and raised a latent problem of this solution which may result in increasing the total power consumption during product interaction. As he states *"But having a meter on this radio could be disappointing. Because battery self-discharge...anything that has battery… they discharge. If you have the indicator, it will cause to discharge faster"* (HUS1-2). This issue has been raised by Jansen (2011), he argued that HPP needs to be designed in a way that maximises the use of human-powered source by decreasing the power consumption of attached functions, avoiding stand-by modes and avoiding energy consumption from graphical user interfaces.

7.4.2.2 New behaviour

During the trial period, some new behaviours were reported during the interview such as 'curtailment behaviour'. This condition was mentioned by HUS1-2 as,

HUS1-2: *"What it does tends to do though is that if you go out to get a cup of coffee, you tend to turn it off rather than leaving it running"*

Interviewer: *"So it does raise your awareness"*

HUS1-2: *"Yes, you are aware of the fact that… it is going to use the power, and if it takes 10 min to make a tea, I don't want to lose that 10 min. so turn it off"*

From this conversation, it can be seen that psychological awareness of generating electricity affected on determinants of changing their behaviour as to save more consumption while interacting with HPR. This was advocated by HUS1-1 as well, mentioned in between following conversation:

Interviewer: *"So do you now know how much you have to crank to get it fully charged?"*

HUS1-1: *"No, I don't. In one way, if I do for 5 min, I probably get it for most of the day. I do switch it off when I leave the room. I do it at 10 am, and in the afternoon, it was still going"*

Interviewer: *"Okay. So because you have to crank this to get some listening, it made you to turn it off as you leave?"*

HUS1-1: *"Yes"*

Interviewer: *"Then if this was power plugged, then?"*

HUS1-1: *"It stays on"*

Addition to behaviours of avoiding power loss, other factor of performing new behaviour was shared by HUS1-2 as he explained his effort of increasing the power capacity. In other words, setting another routine of behaviour that conserves more power into HPR energy system. For example, HUS1-2 commented about his experience of HPR at his work place*: "I was cranking while my email was lifting… coming in. if something boring happens, I was cranking… when I was waiting for PowerPoint to open, I was cranking. There is lots of moments in a day… when you can't do anything… like when student comes in to find their essay from their bag, I was cranking*" (HUS1-2). Linking with Wever's (2008) typology for 'inducing sustainable use'[45], it can be seen that HUS1-2's new behaviour reflects as an attempt to avoid the 'forced

[45] See page 76 for Wever's Typology

functionality' whereby HPR intrusively forces user to have limited access if required actions (power-generating) are neglected. Therefore, his behaviour of coping with HPR performance mainly associated with building the level of competence through constant usage, and to some extent, with limited feedback, and with scripted design of application on HPR.

7.4.3 What motivates user to use the HPP?

Research questions 3.2, and 3.3 may seem similar to each other. This sub-chapter particularly discusses the positive and opportunities of HPP that is deliberated by participants which accounted the motivation of use. Subsequent chapter will discuss the barriers (negatives) of HPP identified during the interview of HUS stage 1.

7.4.3.1 Portability

The 'portability' has been argued by many scholar (Dean, 2008; Jansen, 2011; Jia and Liu, 2009) as one of the benefit of using HPP where it can be perceived as 'convenient' due to the fact that power is always available. During the interview, one of the most commonly discussed benefit of using HPR was the advantage of using the device at remote locations. Although HUS1-1 used the device in other locations due to having weak reception, she made good use of its benefit by using HPR as mobile device. For example, HUS1-1 said: *"I have used HPR while washing up…", "I cranked up the radio. Put it in the washing room…", "Good day. We going to go to allotment. I would love to take it to there, but as this is not my own, I don't dare to take it and get it dirty. It feels like, l like to take the device where there is no electricity",* and *"When I go to allotment, if you are there for long, it is quite nice to have something with you and that (HP Radio) will be fine"* (HUS1-1).

Whereas HUS1-2 has made good use of its 'portability' outside of his domestic environment as he took the device to work place. While discussing about this benefit, HUS1-2 commented as: *"it isn't about saving electricity. It is about convenience of portability. Camping and things"* (HUS1-2). However, it was noticed that HUS1-2 also expressed some level of satisfaction in terms of performance of the HPR, e.g. *"I was very surprised with how long it last", "If I had one, I would be happy with it"* (HUS1-2). Therefore, it can be seen that both of participants find the function of 'portability' as one of the benefit and possible motivation for using HPP. However, it is important to point out that these comments does not reflect or reveal any clues to whether they will continue to use the device in the future - practicing the ‘sustainable use’ or internalising the use of HPP.

7.4.3.2 Emergency VS Scarcity

The notion of ‘portability’ were advocated by participants as they described its benefit of being an emergency use and able to generate the power under concept of ‘available on demand’. Today, the use of energy resource is still perceived to be indispensable in order to accomplish daily tasks. Moreover, it has been argued that people tends to consume electricity inconspicuously while performing routinised behaviour of interacting with many electronics (Shove and Warde, 2002). On the other hand, there are people in the other side of the world who suffers from shortage of resource such as water or electricity, therefore it becomes more desperate in need. Both of participants have deliberated this issue by describing how the benefit of ‘available on demand’ can be perceived differently for people in need of electricity.

“In our culture, we think we have plenty of energy. Once…If the nuclear power station, we have that big gap between next generation and then…. We will have problems. We going to have to make choices… what are we going to use that energy for?” (HUS1-1)

“Light is big thing. If you have torches with batteries, you don’t use it very often. Let’s say if you get power cuts which I anticipate that it is going to happen in the years to comes, this is my personal view, so people will have to get their torches out. And they will find out that torches won’t work because the batteries ran out. Whereas if you have something like this, it doesn’t matter, because you just wind it up whenever you need it. So yes, if we are going to have the power issues that will be very useful” (HUS1-1).

“There is village in Africa…UNICEF gives solar panel and batteries to supply power in these villages. And often they have generator. But the problem of generator is that you needto have diesel. And somebody have to fetch that diesel. So there is point in this. And in emergency situation, this will always work” (HUS1-2).

While the participants in the pilot study mentioned a subject of ‘emergency use’ as potential motivation for HPP use, participants in the HUS stage 1 who are highly eco-motivated emphasised on the notion of possible ‘energy scarcity’ in the years ahead. Therefore, it was argued that the value of HPP could increase beyond simply being a motivation benefited from ‘available on demand’. For example, HUS1-1 have said: *“It is lot of effort for that saving. But If you depend on information and if there is no electricity, it worth more than the cost of electricity”* (HUS1-1).

7.4.3.3 Intrinsic Motivation

In the context of pro-environmental actions, both participants perceive to have strong frontier spirit towards reducing the electricity consumption. It can be seen that their intrinsic motivations towards the issue in question are sufficiently situated and related behaviours are valued and performed for their own right. According to HUS1-2’s blog, his philosophy of Perevil house project aims to tackle environmental issue like CO^2 Emission and energy famine. Linking with the theory of ‘Value-Belief-Norm’ (Stern, 2000), it can be viewed that their pro-social motives are the driver of activating and changing their behaviour rather than driven by their own self-interest or for any egoistic value. The degree of acceptance of their motives is itself correlated with biospheric and altruistic values, as HUS1-1 described herself as:

“I would like to be seen as person who, at the end of life, will give as much as taken on any front. So, If I have been using these electricity a lot, my self being energy, I have to give in the same amount. That is the plan. So if I know I’m going to do something that is highly energy consuming, then I think beforehand, Can my energy replace that? For example, I got criticised on the fact that I visit Holland to see my handicapped sister. I used to go every month. I have to take the train and plane to go and back. So I got lot of criticism from the green brigade. But in my own view, I can do that. The planes are there… my energy that I’m going to give my sister out weights… it is so important that I have to do. So when I’m here, I do look after people like my sister who is ill, which I can do with low level using my bike. So I don’t feel guilty. You can’t measure it but it is just an awareness really” (HUS1-1).

However, in terms of HPP use, HUS1-2 also correlated his motivation with ‘egoistic’ value of using human-power. He explained the reason for commuting to work using the bicycle: *“I have about 4 miles from my home to work, and the part of using is for my health reason, so there is no point of using electrical bike”* (HUS1-2). This comment was made during the discussion about asking reasons of bicycle being so favoured by many publics for relatively long period. HUS1-2 has responded as, *"It get you from A to B. It hasn't been replaced by anything better…so there is no point of using electrical bike"*. Throughout the interview with HUS1-2, it was observed that he has affirmative understanding towards applying what Jansen and Stevels (2006) describes as 'added discomfort', i.e. cranking or winding. For example, number of times during the interview, HUS1-2 were winding up the HPR and he described this experience as, *"It also flexes your shoulder arm, it is enjoyable to have. I just feel better now, I feel the warm in my arm. It is pleasure to have. In the first day it was difficult to have because you have to crank it again and again. But as you learn how to…it fades away quietly. And after while… sometime you don't even notice that it did. Wow it is off! But it is not important, if it was, you can just crank it up again"* (HUS1-2). Contrast to participants from pilot study, HUS1-2's motivation described above supports his intention of using HPP (including the bicycle) which can also benefit from health perspective (intrinsic motivation), even for further use, and likely to decrease the level of 'added discomfort-ness'.

On the other hand, HUS1-1 has number of times mentioned about the stress she felt during the trial period, specifically which related to 'physical fatigue-ness'. For example:

Interviewer: *"There some constraint of making you to do some physical input…"*

HUS1-1: *"I thought I was having heart attack (laugh)"*

Interviewer: *"So, it wasn't really a positive reflection. It was so fatigue?"*

HUS1-1: *"It was definitely, I was really cranking this thing up. It was like… when you haven't done sport for a while and then you just go for it. And two days later when you can hardly walk… it's a bit like that. But it is not end of the world"*

Her comments led the researcher to ask for reasons of using the other types of HPP such as hand whisk and she responded as: *"I don't know… I'm quite happy to just to take any tool or cooking stuff because it is just aid to make something. It is not pleasure, it is something to make an end result like cake or food. That is (pointing at HPR) purely for my pleasure to listen to the radio. The pleasure of cranking it does not… is not as good as… There is too much effort to put in for just listening to music whereas if I do this (the hand whisk), it means that… egg whites will whisk quickly and therefore I will have some nice ice cream in the few hours' time…."* (HUS1-1).

From her comments, it can be viewed that she has set a goal in the use of hand whisk and the method of feedback allow her to acknowledge that actions are being taken, and meaningful indication is given as a consequence of that actions. However, in the use of HPR, the physical stress (added discomfort) received from putting action of generating energy perceives to be much higher than having a pleasure of listening to the radio. In the case of HUS1-1, the feedback received from using instruments to make ‘ice cream’ enables her to observe the progress of actions affecting on the overall consequences. Although it was not a ‘pleasure’ as she comments, but it helps to control those actions to reach her goals. Looking from Self-Determination Theory (see Figure 2.30 on page 80), this autonomous form of motivation is called ‘regulation through identification’ which reflects a conscious valuing of a behavioural goal; and the actions are accepted as personally important (Ryan and Deci, 2000). However, the motivation of making ‘ice cream’ cannot be seen as ‘intrinsic’ since those actions are performed to attain separate outcome rather than action itself being inherently enjoyable. Meanwhile, HUS1-1’s motivation of using the HPR remained at ‘externally regulated’ (Ryan and Deci, 2000) where her behaviour of generating electricity were performed to comply with external demand which was given as a task by the researcher - using the radio throughout the trial period. Despite the other benefits mentioned by HUS1-1, it seemed that her motivation towards using HPR is unlikely to progress to next stage of ‘internalisation’.

7.4.4 What are the missing elements or barriers in design of HPP that prevent people from using it for longer-term or even short-term period?

Various different motivations has been heard during interview from participant in using HPR and also with other types of HPP; however, some negative and challenging comments were raised in the context of using HPP.

7.4.4.1 Non-negotiable tasks

Changing behaviour can be absent due to the perceived non-negotiability of everyday practices such as blowing a hair dryer every morning. In the same manner, experiences related to HPR did generate participants' view of describing similar condition such as *"...it can be annoying if you are busy..."* (HUS1-2). Participant HUS1-1 advocated this view when suggesting for an opportunity of utilising HPP concept through 'parasitic harvesting' way; *"You see like children... they are full of energy. They need to play around to discharge their energy. And they might just like to crank up the radio. But for adults, we are just too focused on the task. And anything that relates to the task... becomes nuisance"* (HUS1-1). The term 'nuisance' can be seen as a negative motivation that could arise in between the moment of 'de-routinisation' which is changing precedent patterns of energy consuming behaviour; and the affordance of HPP and its 'added discomfort' impacting on increasing the higher level of rejection towards HPP use.

Meanwhile, it has been discussed that value of HPP use can vary and dependent upon people in different situations. For instance, HUS1-1 explains how the use of HPP can vary upon the lifestyle:

"But I think that is the only case for Britain. I bet you if you give this device to someone in Africa, they will be delighted. It is like my two folks. If don't have anything.... But all of sudden, it is miracle. But if you got digital radio and IPods and everything else... it is almost feel like step back. I wonder that is the other thing... we are in different level in the west compare to places middle of nowhere in Africa" (HUS1-1).

It is emphasised that more number of mobile electronics will be commercialised with its paralleled development of energy efficiency. Therefore, this thesis has argued that there are opportunities in using human-power as energy source for these devices. However, it is evident from this study that, in most of cases, people will benefit the use of human-power as 'emergency' or under concept of 'available on demand' rather than using it as primary energy source.

7.4.4.2 Obsolete power source

Despite the nature of this 'inconspicuous' pattern of energy use and prolific increase of ICT products, there were other reason shared by participants which brings importance aspect to this research whereby people perceive human-power as 'obsoleted' power source. As it was mentioned by HUS1-1 that people are living in a life style where they acquire number of electronics which can be seen as 'the routine accomplishment of what people take to be the normal way of life' (Shove, 2005, p. 117). In the similar manner, HUS1-1 gained a different perspective during interview: *"The other thing I suppose is, if I didn't have the whisk, I would have used the two forks. Then it will be really hard work. So I'm going back and comparing the hand whisk with two folks. As I said, I don't want to have any electrical gadgets in this house, I don't' really know what it is going to be like if I had an electrical one. But I don't want to have it because I don't have that much storage space"* (HUS1-1).

When people are confronted with the requirement of applying human muscular energy to generate electricity to drive HPR, it was perceived as *"...it is almost feel like step back."* (HUS1-1). However, it was encountered from pilot study that some positive responses were shared in terms of interacting with old-fashioned device such as hand-crank coffee grinder where some viewed it as an activity of bringing 'nostalgic' or reminisce the pre-established competence that is gained from long-ago experience. In addition, one possible reason of success of bicycle was shared by HUS1-2 that *"It hasn't been replaced by anything better..."* (HUS1-2). However, HUS1-2 has added supplementary reason of sustaining the use of bicycle as *"...and the part of using is for my health reason, so there is no point of using electrical bike"* (HUS1-2). From this context, it can be argued that the use of bicycle offer what Jackson (2005a) says as kind of 'double dividend' which is inherited and associated during the use-phase; providing the function as transport as well as providing intrinsic motivation such as health. From 'practice theory' perspective, the *meaning* component of riding a bicycle enable user to make sense of the activities through positive emotions, purposes, and belief that potentially transcend the obsolescence of HPP.

7.4.4.3 Extrinsic Motivation

It was argued that when external factors strongly regulate behaviour through intervention, eventually people find no link to their attitude with related actions or behaviour (Jackson, 2005b; Wilson and Dowlatabadi, 2007). On the other hand, scholars have argued that intervention affecting on the internal factors (attitudinal) alone may not be so effective in bringing a behavioural change, therefore appropriate use of external factor together may have stronger impact (Pierce *et al.*, 2010b; Stern, 2000). However, it is widely accepted that current performance of mobile sized HPP are very limited and that people hardly accept the benefit of using HPP as to gain any tangible incentives, e.g. saving money. Moreover, the common benefit that influences the use of HPP were mainly discussed around notion of ‘portability’ and ‘emergency’. Nevertheless, although the amount of saving from using human-power is ‘little’ to some extent, potential external benefit has been considered, e.g. comparing the ownership against battery use.

The most intriguing finding from HUS stage 1 was the low acceptance of these external factors. Despite the fact that both of the participants’ *meaning* was well established towards performing pro-environmental behaviour, contrary to expectation, dominant negative view were shared during the interview. For example, both of participants were very conscious about the unit of electricity consumptions and therefore easily predicted on the potential gain of using HPR[46].

“I am very keen on reducing the energy… but it is hardly any energy that goes in just running a radio” (HUS1-1).

And during the interview with HUS1-2:

Interviewer: “it saves about average of 9 pence a week”

HUS1-2: “That is about 7 watt (pointing at the plug-in radio). It takes long time to get to a thousand watt”

While continuing the discussion, when asked about how they perceived the amount of this saving, and HUS1-1 has responded as: *“Well, the kinetic energy is very cheap. It’s the heat. I couldn’t think of boiling a kettle, you know? I will be a power woman. If the kettle could be done, that will be useful. I don’t know how you would do that, but that would be useful because boiling water anywhere… will be useful. And that is 3 kW”*. This response shows that these eco-motivated individuals are well aware of their consumption size and even at micro level. The same condition was observed from HUS1-2 as: *“... (after calculating the consumption at the scene)…That consumes half kWh per week, so that is about 7 or 8 pence a week”*. Later in the interview, HUS1-1 made additional view which points to the major limitation of HPP, as she says: *“We have good LED… they are very good. But for heat, there is no way you can sort heat with that energy (human-power)”*. Therefore, it can be seen that the external factor of using human-power, that is generating ‘free energy’ and consequently bringing a benefit,

[46] Average consumption of HUS1-1 radio was measured which calculated to be at an average of 9 pence saving a week. HUS1-2’s consumption could not be obtained due to malfunctioning of monitoring device.

will hardly be accepted as a motivator to use the human-power. Deci and Ryan (2000) has argued that when positive feedback shows the effect of a certain activity, it enhances the intrinsic motivation. In this context, it can be argued that the size of potential saving from using HPP cannot be justified as motivation for further use, and these information were perceived as 'negative' feedback. Although, the positive feedback sometimes exist around other motivation such as health gained from applying human-power. Meanwhile, HUS1-2 advocated this negative notion by comparing the size of benefit produced by his house:

"6.15 Kwh from solar panel, I saved today, so that is about 90 pence. About a pound. From one day! That is about 300 pounds about a year. But we save more during summer time, and I also sell the electricity too which makes about 1700 pounds a year" (HUS1-2)

Although HU1-1 did not share any hard figures of cost saving for herself, above comments from HUS1-2 may account the reason of HUS1-1's comment, that is "*…There is too much effort to put in for just listening to music".* In other words, instead of giving a 'double-dividend' effect, the use of HPR showed 'double-loss' as both internal (physical fatigue) and external (relatively little saving) factors hindered the motivation of HPP use. As Jackson (2005b) reports, there is empirical evidence suggest that peripheral route is less successful in changing attitudinal mind of people when they are highly motivated and engaged in the issue in question. In a like manner, it can be seen that *meaning* component of HUS1-1's practice affected her behaviour to be performed in obligatorily manner or coercively throughout the study period rather than performed through autonomous acts.

7.5 Discussion and recommendation to HUS stage 2

The interview analysis for HUS stage 1 followed a hybrid method of using both inductive and deductive approach to identify the themes. The researcher employed a deductive approach by using existing sociological and psychological theories to account the phenomenon being studied as well as to ask certain questions to participants. However, the aim of analysis was not to test any hypothesis through data, which according to Boyatzis (1998) would be the typical deductive approach. While the development of 'HPP Internalisation Model' was in progress, the result of HUS stage 1 availed in justifying each dimension, and used existing theories to design questions (deductive); however, the researcher also posed new questions to further explore accounts of HPP use within participants' new practice (inductive). The themes identified in this study were used as major category for analysis in the next stage of main study; the HUS stage 2. The following sub-chapter discusses the summary of finding and detail justifications for developing final version of 'HPP Internalisation Model'.

7.5.1 Empowerment

The 'portability' has been suggested by scholars (Dean, 2008; Jansen and Stevels, 2004) as one of the main benefit of using HPP. Jansen and Stevels (2006) also argues that HPP has long self-life as it can particularly become valuable in emergency situation. The benefits mentioned by the users of pilot study and HUS stage 1 overlapped each other. The most common benefit was discussed under concept of 'available on demand'. It was shared by majority of participants that HPP enable user to have sense of empowerment of generating the power in need whenever without relying on the power from the grid.

The parasitic harvesting method of using the human-power is seen as 'self-powered' (Paradiso and Starner, 2005); a way of generating 'free energy' while user's conscious interaction belongs to third device such as merry-and-go or simply walking. In the case of self-powered HPP, the attitudinal factors are absent since they are generating the power in stealth mode. On the other hand, HPP requiring conscious psychological interaction, also physical, face challenges against overcoming the barriers of; giving 'physical fatigue' or certain motivation is required to accept the 'added discomfort'. However, it was also discussed that motivation of using the HPP can vary depending on the situation and as people face the scarcity of electricity use.

Nevertheless, the notion of 'available on demand' still perceives to be the one of benefit among others, and whether they see it as good or even consider the related action as problematic, people's exertion of human-power makes visceral to subject of 'energy use' and raises awareness to practice a 'curtailment behaviour', e.g. switching off the radio when not in use. As argued by Tang (2010), when the power in decision-making lie upon the user, the motivational change and acceptance of intervention may have greater effect. So, while the 'self-powered' products sub-consciously utilise human-power, the use of HPP delegates user to make a ‘choice’, giving an empowerment to control their HPP usage behaviour.

7.5.2 Goal-Setting

Throughout the product-in-use trial week, participants have obtained an acceptable level of *competence* from first day an onwards. However, the user’s gained *competence* were based on ‘probability’ and prediction on the system potential of HPR. It was found that current feedback system of HPP provide somewhat inadequate information over the actions taken and therefore difficult to understand its maximum performance; that is routinising its use to set certain goal and exert appropriate human-power to drive the function. Looking from SDT[47] perspective, it was seen that this uncertainty of feedback system hinders the progression to next phase of internalisation process as user of HPP were faced with difficulties in making conscious valuing of a behavioural goal. Therefore, it was realised that the system of feedback or its interface must provide the real-time consequence, linking the behavioural determinants with the possible goal set by household or HPP users. This notion was presented in a visual diagrammatic framework developed in previous chapter. See Figure 5.5 on page 150. Moreover, it was argued that when continuous feedback in conjunction with goal-setting is provided, the effectiveness of bringing a new behaviour becomes greater (Abrahamse *et al.*, 2005). Therefore, the function of feedback becomes a formation of habit, going through process of routine actions being set and reinforced; and lastly to internalise the behaviour (Van Houwelingen and Van Raaij, 1989).

From reviewing the responses from this study, it is evident that consequential result is not fully communicating with the actual user of HPR. In other words, the current system of feedback on HPR do raise awareness to how it functions, but it lacked in giving detail information about the device that may give much control over the pacing and timing of the interaction.

[47] Self Determination Theory

7.5.3 Double Dividend

The discussion around the motivation of HPP use provided an intriguing account in developing the final dimension of 'HPP Internalised Model' which is the axis ranging between 'intrinsic' to 'extrinsic' motivation.

During the interview, participants had shared their experience with other type of HPP such as hand whisk and bicycle. The activities related in the use of these HPP were seen as behaviour that were mastered, and the intention was closely correlated. The competence gained from the use of these products has been prolonged and they became a 'real affordance' as they are routinised; and that people view them as normal. However, the processes for maintaining the use are influenced through different form of intrinsic motivations combined with external benefit. For example, use of bicycle offers the 'double dividend' providing the function as transport (extrinsic motivation) as well as providing intrinsic motivation such as health. The internalisation process made through this 'double dividend' stimuli was conceptualised in visual diagrammatic framework in Chapter 5.3, see Figure 5.6 on page 152. The *meaning* component within the practice of riding bicycle and set of skill gained as *competence* likely to avail the success of its internalisation process. Moreover, the emotions, purposes and belief related to that activity perceived as so positive where these motivations transcend the obsolescence of HPP.

However, in case of HPP with energy system, study has identified the problems in terms of how the external benefit can be a risk. The opportunities of HPP being a viable solution to powering low consuming electronics, especially the mobile electronics, has been suggested. However, the actual external benefits gained from HPP use (i.e. saving occurred from generating own power) unlikely to appeal as 'positive'. In other words, the size of potential saving from using HPP is unlikely to be justified as motivation for further use. Moreover, the use of HPP may expose to user feeling 'double-loss' as both internal (physical fatigue) and external (relatively little saving) factors hinders the motivation for sustaining the HPP use. Some may argue that increasing the external benefit, giving larger size of saving, could potentially overcome this barrier. However, studies have argued that reinforced external factors may show weakness in linking the activity with the attitude of energy–consciousness (Jackson, 2005b); therefore, study should focus on relating internal factors such as attitude and norm that eventually avail activating new behaviour rather than further increasing the external factor (e.g. incentives) (Stern, 1999). Regarding this notion, the study result highlights the importance of redesigning system of feedback on HPP which may increase the motivation and eventually link the subject (goal or regulation) to help bring the internalisation; and therefore, it makes generating electricity as activity of doing it for its own right - granted autonomous motivation.

However, the level of perceiving the motivation in between intrinsic and extrinsic is still a subjective matter. Therefore, it must have clear indicator to understand how new users of HPP accepts the use and more specifically how they progress through internalisation process.

7.5.4 Instigating Internalisation of HPP use

The research activity of conducting pilot study and HUS stage 1, and the work carried in developing a hypo-theoretical model took place simultaneously. The themes discussed through conducting Pilot Study and the process of developing the conceptual framework availed in identifying the dimensions of ‘HPP Interaction Matrix Version 5’ (see page 140). Through the further data collection and analysis of HUS stage 1, research was able to propose the hypo-theoretical model of ‘HPP Internalisation Model’. However, it was suggested that this model required detail justifications and empirical evidences to support its effectiveness in both theoretical and practical term. As this research used ‘iterative’ approach to further design the hypotheses which involves a weaving back and forth between data and theory, and repeatedly referring back to each other; the major themes identified through the HUS stage 1 accounted the few iteration made on the ‘HPP Internalisation Model’.
First, dimension of the ‘delegation of control’ has been changed to ‘empowerment’ which explains the process of providing volitional control over power generation through HPP. It argues that HPP should enable user to have sense of empowerment that they can generate the power in need whenever without relying on the power from the grid. In order to bring the internalisation of HPP use, the design should delegate user to make such choice, and giving empowerment to control their HPP usage behaviour.

The second iteration, evolving from ‘HPP Interaction Matrix Version 5’ to ‘HPP Internalisation Model’ was adding an ‘arrow’ that represents the process to internalisation behaviour. During the process of developing earlier versions of Matrix, it has been acknowledged that there is no such indicator to measure different levels of psychological attributes involved during the interaction of HPP. Therefore, it was suggested to use the matrix as a ‘taxonomy’ to forecast HPP concepts, and availing designers in deciding types of input and output sources of HPP. In the iterated ‘HPP Internalisation Model’ (Figure 7.4), same as the other matrixes, the emphasis is not to obtain such indicator to differentiate the levels of attributes, but it suggests the empirically proven dimensions that are essential in bringing an ‘Internalisation of HPP use’.

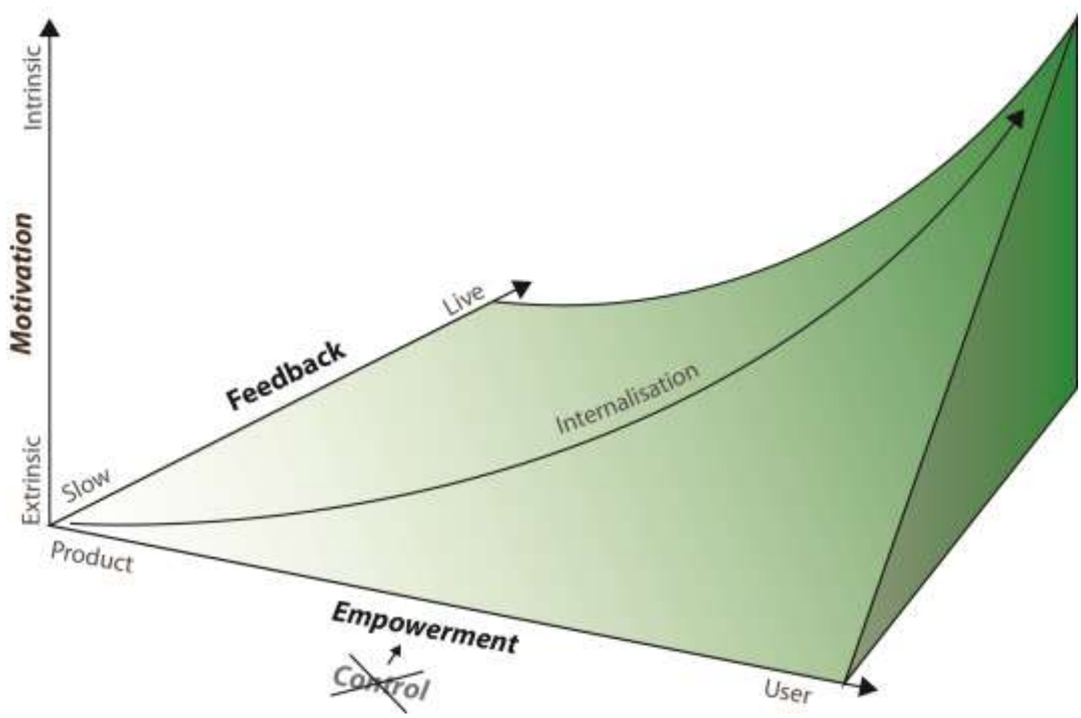

Figure 7.4 HPP Internalisation Model (Iterated)

7.5.5 Recommendation to HUS stage 2

This hypo-theoretical model aims to unite and advance the findings from the literature review and semi-structured interviews described in this chapter. With the decision of moving to next stage of HUS study, it is recognised that literal replication logic, to some extent, supported vulnerably with having only 2 case studies. As noted numerous times, the true effect needed to lie upon success in bringing the internalisation of HPP use in daily practice.

7.5.5.1 Selection of participants for main study

In doing so, Participants' trial in HUS stage 2 must allow them to experience the use of human-power as everyday power source for EuP. It was anticipated that this hypothetical scenario will commence once all elements that formulate a practice gets established and it depends on how they accept such intervention through design, interaction, value, motivation, and etc. Therefore, it is important to gather correct information that can reflect the studying phenomenon and the responses that reflects their own interpretation of experience. Moreover, the quality of the feedback during the interview should not be leveraged towards the notion of any energy saving beliefs or sustainable movement. For this reason, it was realised that non-eco-motivated individuals should be considered for HUS stage 2 and to draw comparative analysis against result of previous study participants. This is to explore how iterated design of HPP (m*aterial*) can influence a sustainable use (*competence*), a new practice or vice versa, and inducing self-determined *meaning* through regulated extrinsic motivations.

It can be viewed that a number of cases explored and inductive analysis approach taken through early two studies may be insufficient to represent the population and to establish a generalisation. However, the large number of data does not always lead to rich data in qualitative research (Bryman, 2004). The size of recruitment for next stage of HUS should not be considered as finding relatively large number of cases but finding the absolute size of sample that can be explored in detail to add validity to current research. However, the decision about size of participants (sample size) can be affected by consideration of time and cost limited to current doctoral research.

From conducting a HUS stage 1, there was also a limitation in terms of recruiting participant using the snowball sampling technique. The challenges did not exist at finding the eco-motivated individuals, but research faced difficulties in finding the frequent radio listeners. Study reports that there are 90.3 % of the UK adult population tuned into radio, and average of 22.6 hours of listening is spent (Ofcom, 2013). However, it is also reported that there are more different way of listening to radio today such as using mobile phone or through digital broadcasting (e.g.

internet). Therefore, the sampling process had difficulties in finding individuals who has similar patterns of radio use. For this this reason, HUS stage 2 required thorough consideration of selecting sample that represent the segment of population in which the profile of these individual need to have common EuP and similar characteristic in the use pattern.

7.5.5.2 The new HPP prototype

As mentioned before, a new set of *Material* is also required in the next stage of HUS stage 2. Findings from previous study recommended following iterations to consider in developing the new HPP prototype.

It is proved by a study that small-scaled design intervention had not as much initiative capital as an artefact (Routarinne, 2009). In the same manner, it was evident that co-existing external benefit in the use of HPP has not been successful in perceiving them as significant benefit and that the size of potential saving cannot be justified as a motive in sustaining the use of HPP. Therefore, it was required to use the prototype that can perhaps impact upon extrinsic motivation by increasing power output. However, it is widely accepted that current power output of HPP system is limited. Despite this limitation, it is suggested that the performance of new HPP prototype should include either higher generator output or larger battery capacity that improves the efficiency of power generation.

It was noticed from monitoring the HPP concept from online media that number of concepts uses the pedal power generator as they seemed to have the highest output power. In order to find the maximum performance of pedal power generator, the author had contacted one of the manufacturer. Through email communications, it was found that a person can power up to 110 Watt of power, although appropriate health condition is required in producing this amount[48]. Similar figure was observed from David Butcher's blog[49], who has been developing bespoke and using pedal powered generator for 30 year, and powers most of his home appliances. According Butcher, the average output from pedal power generator gives about 150 W from

[48] More detail of pedal power generator performance can be retrieved from: http://pedalpowergenerator.com/buy-bicycle-generator-assembled-pm-motor-pedal-power.htm#STATIONARY

[49] http://www.los-gatos.ca.us/davidbu/pedgen.html

30 minutes of pedalling. This range of power output can potentially power flat/LCD/LED televisions, but the run-time varies depending on the screen size.

It is also assumed that activity of ‘pedalling’ has not been perceived as ‘new’. Earlier in this thesis, it was argued that use of human-power has been languished over period of time whilst they were the primary source of energy in the past. Results from previous two study showed that people do reminisce these kinds of kinetic interaction and that there are HPP still widely utilising this long existed *competence*, e.g. bicycle.

Lastly, and most importantly, the feedback system of new HPP prototype or its interface must provide the real-time consequential information. The purpose is to link the behavioural determinants with the possible goal-set enacted by new participants of HUS stage 2. This iteration will avail users to have much control over the pacing and timing of power-generating interaction. For inducing internalisation process, the regulations set by these users can be realised in which the function of feedback confronts user with consequences of people’s actions in real-time. More detail of prototype development will be discussed in Chapter 8.3.

7.6 Conceptual Framework for main study

The result of previous study also availed in clarifying the terminology used throughout the thesis. It has been argued that the main challenges for designing the HPP is how to reduce the labour required. There can be disparate notion related in this ‘labour’ such as it can be perceived as stress level of overcoming ‘added discomfort’ (Jansen and Stevels, 2006) or it can be reduced from improved performance of HPP energy system. However, it is recognised that this challenge may not be relevant with products that are classified in the domain outside of ‘D’ (in Matrix version 3, pg. 134) since they are either commonly being used as of today and sometimes the interactions are in sub-conscious mode. On the other hand, HPP classified in the domain of ‘D’ can be seen as electronics using human-power as primary/secondary energy source. This notion becomes clearer when reviewing the definition of HPP introduced by scholars in the field. While Dean (2008) includes mechanically running HPP such as bicycle into her definition, Jansen defines the concept as 'electrical products powered by muscular work from the user' which focuses on the conversion of muscular work of the user into electricity (Jansen, 2011, p. 2). This is the reason for Jansen to sub-define the 'energy system' within HPP which is 'a technical artefact designed for converting the efforts of human muscular work into electricity' (Jansen, 2011, p. 3).

In this context, it can be observed that HPP in the domain of 'D' attempts to design a new interaction to convert the effort of applying human-power into electricity and use this energy to drive the function of electronic products. Therefore, this thesis term this type of products as 'eHPP' where 'e' stands for HPP with energy system. Insofar, designers of eHPP has introduced intriguing concepts to encourage further use, sometimes by stimulating intrinsic motivations through interaction design and as well as increasing the performance to bring greater external benefit. However, it is yet ascertain whether these strategies are facilitating sufficient motivation to internalise the HPP use.

For these reason, the aim of HUS stage 2 is to design an eHPP that associate all dimensions suggested in the 'HPP Internalisation Model', and evaluate its effectiveness as product-led intervention to bring internalisation of HPP use. As these dimensions in the model embodies finding of previous investigations, and with the notion of further study enquiring around eHPP, Figure 7.5 illustrates conceptual framework for HUS stage 2 using the 'HPP Internalisation Model'.

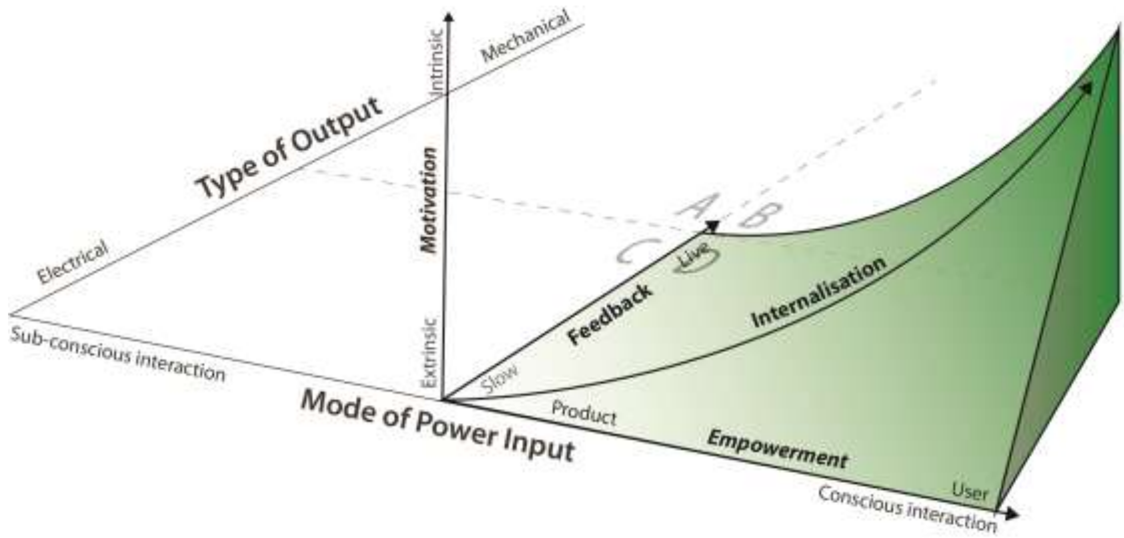

Figure 7.5 Conceptual Framework for HUS stage 2

Chapter 8 At Home: The Internalisation - HUS Stage 2

This chapter details the evaluation phase of 'HPP Internalisation Model' and research process of finding the answers to below research questions:

Q 4: Can HPP influence users to practice energy saving behaviour?	Q 4.2: How can HPP be designed in a way that encourages user to use it in longer-term?
	Q 4.3: How effective is the new model?

Above questions are formulated in order to address the objective mentioned in Chapter 5.5 - To validate and theorise the 'HPP Internalisation Model' with public in interest of HPP - recruitment through appropriate sampling process.

8.1 Introduction

It was argued that shifting consumption patterns depends on the thorough understanding of not only what motivates users, but also on how behavioural change gets formulated; and how it can be influenced through applied interventions (Jackson, 2005b). So far, empirical studies were conducted in exploring how actual consequences of existing eHPP are influencing the behaviour determinants, and identified the challenges in carrying it out as everyday product. Findings from these studies have suggested the required design iteration in developing a new prototype for HUS stage 2. Particularly, it was suggested that selecting sample of this study should represent the segment of population in which the profile of these individuals need to have common EuP and similar characteristic in the use pattern of *material*. In doing so, this chapter discusses the process of selecting participants (10 UK Households) for HUS stage 2 who were recruited through survey. Following a replication logic, the number of house visits, methods of interview and deployment of prototype was identical to HUS stage 1. The semi-structured interviews were based on the experience of interacting with newly developed eHPP prototype – the 'White Box', which applied the design strategy suggested through 'HPP Internalisation Model'.

8.1.1 Selection of 'Material'

At this stage, it merged that human-powering a 'Television' is best suitable as *material* for HUS 2 stage. There were many reasons to support in making this decision. First, TVs are one of the largest electricity consuming appliance in ICT sector. According to Bertoldi and Atanasiu (2007), TV manufactures has been introducing low consuming TVs, but the number of TV ownership has continue to rise ever since, e.g. buying new and old TVs moved to a different room. More recent report also confirms the prolific increase of 'time spent watching TV' in UK. Ofcom (2013) reported that people aged 4+ spend average of 241 minutes of TV watching per day in 2012, which is increased by 23 minutes from year 2007.

In addition, study suggest that improvement in the energy efficiency of current consumer electronics does not address the issue; given the growing number of these electronics, incremental improvements based on current products will do little to curtail the tide of increasing household consumption (Crosbie, 2008). Crosbie (2008) has identified that heavily energy intensive consumption behaviours are encouraged by the design, marketing of TV, and individualised electronic entertainment. Moreover, reconfigured homes and lifestyles are now changing to fit these new product/services and therefore it makes increasingly difficult for household to reduce their energy consumption. However, it is important to highlight that the focus of study is not realising the behaviour around TV usage, but selecting a common electronic to elicit an understanding of human-power use on such product. While this research also posed an enquiry of encouraging 'energy saving behaviour', the selection of TV as *material* seemed appropriate based on above mentioned reasons, and it also helped to increase the practicality in selecting participants for HUS stage 2. However, as this research field is based on 'human-power', it required an additional components which is the energy system to power the TV. The detail process of building this system is discussed in Chapter 8.3.

8.2 The Survey

The first study conducted in this chapter was an online survey[50] investigating how people currently interact with TV usage. The other purpose of survey was to collect user data to understand general public's perception of energy consumption and its monitoring experience. And lastly, it aimed at understanding how people feel about potential adaptation of using human-power as main power source for TV. A total of 29 questions were asked through the online survey. The survey was conducted using the online survey services provider (i.e. Survey Monkey). URL links to the survey was distributed through various communication channels such as Facebook, Linkedin, and University emailing lists. Between July and August 2012, a total of 143 respondents participated in the survey ranging from 18 years of age and older with a complete response rate of 92 %.

8.2.1 Survey Results

Below are the summarised results with sub-chapters broken down into major sections of the survey questionnaire.

8.2.1.1 TV usage

From the survey, there was only 4.9 % of respondents not owning a TV and rest (95 %) owned more than one. For question asking about hours spend on TV watching in a daily basis, the results were evenly varied, e.g. 1~2 hours (21%), 2~3 (17.5%). Interestingly, only 16.8 % (3~4 hours) of respondents matched the hours reported by Ofcom (2013) which was 4 hours per day. Although concerns were argued over growing number of television enabling people to have individualised electronic entertainment practices in the home (Crosbie, 2008), the survey results show that 46.7 % of respondents watch less than 1 hour from secondary TV. However, out of all respondents, 95.1 % did not know their TV energy consumption, nor knowing in unit cost (93.7%), e.g. monthly or annual.

While recognising that the 'use-phase' of the electrical product contributes to increasing electricity consumption, the design feature of consumer appliances such as 'stand-by mode' also take part in this prolific increase. It is estimated that avoiding

[50] See Appendix G for exemplar pages of online survey

the use of ‘stand-by mode’ can generate enough power to supply 2.7 million homes for a year (Energy Saving Trust 2006); proportion of 8.6 % of total TV consumption comes during this stand-by mode (Energy Saving Trust 2007). Against this enquiry, survey included questions of asking their TV usage behaviour, e.g. ‘Do you often leave your TV on whilst undertaking other activities?’. The majority of people responded as ‘sometimes’ which accounts 60.8 %, 29.4 % responded ‘Never’, and 9.8 % of people said ‘Most of time’. Interestingly, the survey reported that 47.6 % of respondent ‘Never’ leave the TV on stand-by mode, meaning that they switch off the main power of TV when not in use.

From these results, it can be seen that most of respondents are not aware of micro level consumption on TV, nor knowing in unit cost. However, the results showed that half of the respondents practices energy saving behaviour by switching off their TV when not in use. Though, some level of ‘energy wasting behaviour’ do still exist during the use-phase. In this case, there is opportunity for design intervention to either make people aware about the contribution during the use-phase or applying a ‘forced functionality’ can prevent people from performing unsustainable behaviour (Wever *et al.*, 2008).

8.2.1.2 Inconspicuous energy consumption

Inconspicuous nature of energy consumption through use of daily electronics has been numerously discussed in this thesis. In addition, current deficiencies of energy feedback system were reviewed. Similar problem was noticed through this survey result where 39.4 % of respondents said that they ‘Never’ keep track of monthly household electricity consumption. Only 21.8 % accounted the people who answered ‘Yes’. In a different survey study conducted by Pierce *et al.* (2010b) reports that although 80.5 % of respondents pay their monthly bill, only 25.8 % claimed to be fully aware of unit cost, and other 24.1 % had ‘no idea’. Similar response rate were collected for current survey that, 46.5 % of respondents keep track of electricity consumption through monthly bill whereas 35.9 % do not keep track. It was argued that the frequency of feedback play imperative role in bringing the behaviour change (Backlund *et al.*, 2007), and that effectiveness of feedback measures high as more frequent the consequential information is given to actual energy user (Abrahamse *et al.*, 2005), e.g. Smart meter. However, current survey shows that only 11.3 % of respondents use such device at home.

Surprisingly, while the majority (88.7 %) of people still receive long-term feedback (i.e. monthly bill, notification by supplier, or not tracking at all), 52.6 % of respondents said that they are 'Moderate' energy savers while 77.4 % see themselves as 'Moderate' energy users. With these results, it can be assumed that people do show some intention towards saving energy and some may put the actions in practice; however, it can also be seen that 'value-action gap' (Darnton, 2004) could exist as their consequential information get confronted in the later term. In other words, people may have difficulties in changing subsequent behaviour followed by their intention, because there are gaps in between the moment of people deciding to make actions and knowing the consequences of those actions.

Question asking about fluctuation of overall electricity consumption for past 3 years were evenly varied: Increased (21.9 %), Decreased (31.4 %), Remain Static (30.7 %), and Don't Know (16.1 %). This question was followed by asking short comment of reasons for such change. All answers were transferred to coding software (Nvivo) and all responses were categorised into segments.

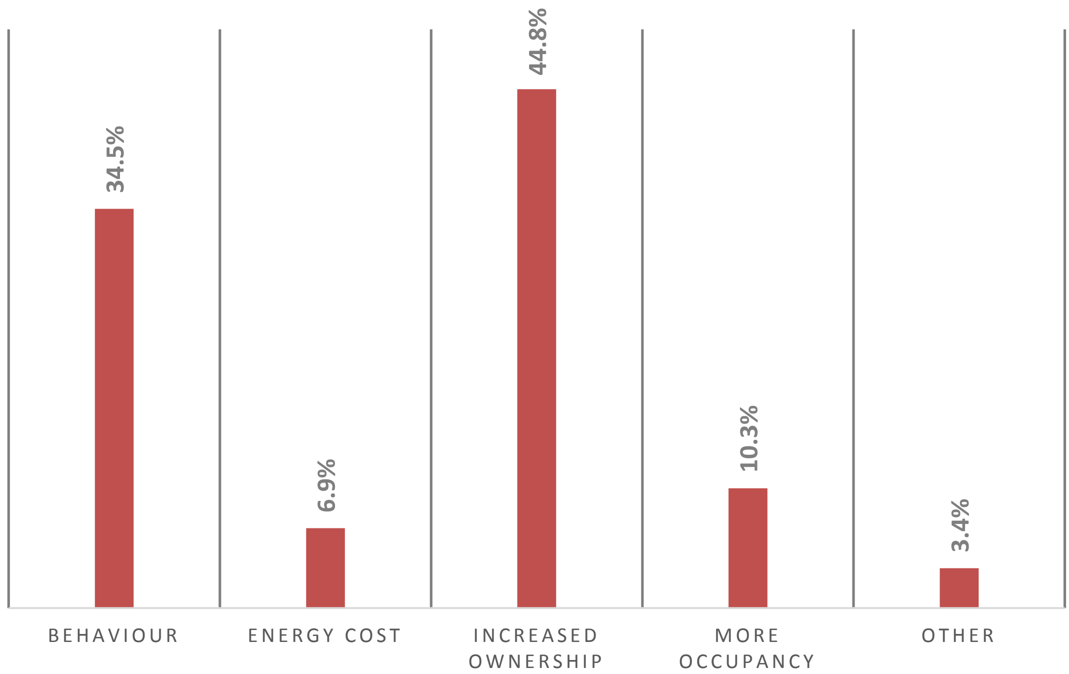

Figure 8.1 Segments of comments for 'Increased' energy consumption

Figure 8.1 illustrates the bar-chart showing the segments of reasons for ‘Increased’, broken down into categories with corresponding percentage. Within 5 common categories, half of the respondents (44.83%) have commented that the cause of their consumption fluctuation is due to owning more electronics. As expected, many had mentioned the cause resulting from owning more numbers of wireless products such as IPhone, IPad, and ICT related products. Also, one of the most common reasons in this category dealt with increased number of children’s gadgets such as game console. The second most common response category was related with ‘Behaviour’. For example: ‘Increased daily use of washing machine’, ‘Now working from home’, ‘Lifestyle – working on a laptop for long hours’. These result supports the notion discussed by scholars that inconspicuous energy consumption is inevitable in order to accomplish daily task, and that people take these activities as ‘normal’ way of life. On the other hand, significant number of respondents have indicated that their energy consumption was ‘Decreased’ (31.4%).

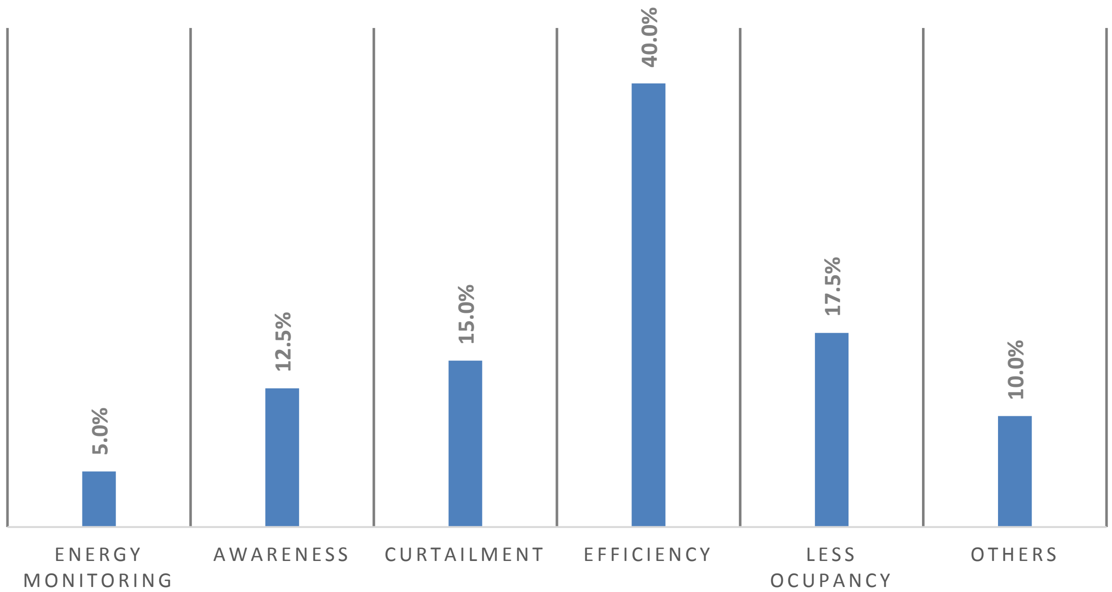

Figure 8.2 Segments of comments for ‘Decreased’ energy consumption

Figure 8.2 illustrates the 6 most common reasons broken down into bar-chart segments. The most common category was respondent’s choice of buying more energy efficient electronics (40%). This type of behaviour was described by Gardner and Stern (2008) as ‘Efficiency Behaviour’ where the forthcoming saving are being generated from one-shot purchase of energy efficient appliances. The other common categories were ‘Curtailment Behaviour’ (17.5%), e.g. turning more lights and electronic off when not in use; and ‘Less Occupancy’ (17%), e.g. child leaving home or at University.

8.2.1.3 Sampling for HUS Stage 2

The rest of the questions in the online survey were designed to make congruence with particular profile of individuals that current research was seeking. In grounded theory approach, theoretical sampling refers to process of collecting data that is controlled by the emerging theory. It is not mainly about boosting sample size, but gathering concepts derived from the evolving theory and constructed through making comparisons (Strauss and Corbin, 2007). The purpose is to maximise opportunities to discover variations within concepts derived from going to either places, people or events, and to consolidate categories or themes in terms of their properties and dimensions.

Insofar, the participants involved in the two previous case studies were recruited using probable sampling (random), and snowball sampling technique (networked contacts). Through data collection and its analysis, the results produced a number of themes that account the suggesting dimensions of ‘HPP Internalisation Model’. As this last research study dealt with evaluating this model, appropriate sampling process was required to obtain suitable size and individuals with having intention of using eHPP. In order for HUS to commence, these potential users required a set of intention and willingness to experience such product-led intervention to practice energy saving behaviour. Therefore, it was required to understand their level of previous experience with eHPP as well as their demographic information to conduct a HUS within the time limit of doctoral research.

From the survey result, it was found that 85.1 % have heard about HPP, and 65.7 % had actual experience. Respondents have mentioned HPP such as ‘windup torch’, and ‘windup radio’. Few respondents had experience with bicycle generator, and because of their experience, these individuals were ruled out from HUS candidate list. This was due to keeping the consistency among participant profile, and also to avoid interview being carried away by anyone’s interest or previous experience.

The question related to obtaining demographic information began by first asking their intention to get involved in the study which probed for participants willing to power their TV using human-power system. 25.4 % of responded showed interest as ‘Yes’, and 37.3 % indicated ‘Maybe’. In the later part of online survey, similar question was posed but with much detail including the trial duration and their role in HUS. For this question, 26.7 % agreed upon participation, 35.1 % requested for more detail about the study itself. An email invitation to HUS was sent out to these respondents (see Appendix H), and households who live in the other district were exempted from this email list. The email invitation requested their consent of participation by clinking on a URL link which guide them to a website for collecting more personal detail, e.g. home address, household occupancy, type of residence. Total of 14 candidates agreed to participate. These 14 individuals were filtered based on address location, occupancy, and distances from the University. However, it is also notable that 22.4 % had no interest towards the idea of using human-power, and 14.9 % responded ‘it depends on its performance’.

8.3 Research through design - The material: “White Box”

In order to carry out a new practice of using HPP, based on Reckwitz’s practice theory, the *Material* element plays key role in constituting patterns of bodily behaviour and to form a mental activities while performing the practice. As the main part of this research is following a hybrid (inductive and deductive) approach to evaluate the conceptual framework presented with ‘HPP Internalisation Model’, the anticipated result and knowledge on practice of using eHPP required a prototype; the *Material*. This prototype in this study can be understood as an instrument that improves the research by communicating its idea or information; on the other hand, it may provide a stimulus or context which enables to discover the information about the studying phenomenon. As argued by Shove *et al.* (2007) that artefacts or things that we use are not merely passive tools involved in the performance of everyday practices, but it can also be a ‘practically useful’ in reproduction of new practices.

In recent years, there has been an on-going debate over legitimacy of incorporating outcome of design project into form of research finding, especially in the level of doctoral degree (Durling, 2002; Pedgley and Wormald, 2007). However, it is argued that the rationale behind doing ‘research’ is to extract reliable knowledge from either the natural or artificial world; and making that knowledge available for others’ to re-use (Cross, 1999). Although the process of designing an ‘artefact’ (prototype) in this research was not originated from any design project, but it should be perceived as a design practice that is reflected upon the research findings, and communication of re-usable result from that flection. Often, this way of creating knowledge or understanding through an artefact is called ‘Knowledge elicited by artefacts’ (Rust *et al.*, 2000).

Zimmerman and Forlizzi (2008) argue that artefact functions as a specific instantiation of a model which becomes a theory. In simplest form, a theory can be thought of as a model which describes the relationship, process or action, and influences between phenomena (Friedman, 2003). So far in this research, ‘HPP Internalisation Model’ attempted to unite and advance the finding from the literature review and interviews undertaken through previous studies. However, as much as this research seeks to develop a new theory, the work of developing this model applied Frayling‘s (1993) concept of ‘research through design’ - producing an artefact to become design exemplars which stresses theme as outcomes that can shed light on transforming the current state to the proposed and preferred state of HPP use.

However, it is suggested that artefacts from the work of design research should intend to produce knowledge rather informing the development of commercial product (Zimmerman *et al.*, 2007). Therefore, the result arising from HUS stage 2 which utilises this artefact produced the knowledge for constructing theory, emerged as guidance in designing eHPP for both researchers and for practitioners.

8.3.1.1 Pedalling

In the previous chapter, several design iterations were suggested in making the new eHPP prototype for HUS stage 2. With having decision of selecting TV as functional product, appropriate artefact (i.e. energy system) was required to drive the power in need. In the HUS stage 1, pedal-powered generator was suggested as to compliment the notion of increasing the external benefit, i.e. the size of saving gained by being off the grid.

Also, the physical movement of 'pedalling' is seen as a skill derived from pre-established competence and has been prolonged; therefore, it was anticipated that this method of power-generation would be suitable, avoiding any rejection arising from complex usability of new eHPP. As indicated, typical power output of pedal power generator produces in range of 110 Watt and up to 150 Watt maximum. In order to match this output, average of TV consumption rate was searched through internet, and an average of 142 Watt was measured from 405 TV brand listings[51]. Therefore, the aim of new eHPP prototype's performance was set to match 1 hour of TV (142 Watt) watching from 30 minutes of pedalling.

8.3.1.2 The Feedback System

It has been discussed in the literature review that the feedback (in general) does affect one's behavioural change. Fischer (2008, p. 83) suggests three considerations that makes it most effective:

- successfully captures the consumer's attention
- draws a close link between specific actions and their effects
- activates various motives that may appeal to different consumer groups, such as cost savings, resource conservation, emissions reduction, competition, and others.

Findings from previous study implicates that feedback system or the interface of new prototype must provide real-time (live) consequential information; that is knowing how much energy is being generating at the moment of interaction, and understanding the remaining available run-time. This avails user to have much control over the pacing and timing of the power-generating interaction. Therefore, the new eHPP prototype requires a design iteration on the feedback interface. The purpose of this iteration was to enable user to make certain goal-set through interacting with consequential information which is provided through the feedback system. More importantly, it is seen as design strategy to link the subject of activity with the behavioural determinants.

[51] http://downloads.energystar.gov/bi/qplist/tv_prod_list.pdf

In order to bring about a behavioural change, the feedback on eHPP must carry consciousness of relevance to the problem – generating electricity instead of using power from grid. This process would require a condition where users become conscious about the consequences of their new behaviour, and helping them to put these actions in routine, i.e. the internalisation process. In other words, not only the focus changes from individuals' capabilities of making choices for their behaviour, but also to understand how these users are constrained and influenced by social-technical systems through aspects such as habits and attitudes.

This notion was supported by scholars that when using the feedback as combined intervention with antecedent intervention like goal-setting, the effectiveness of such intervention achieves better results in bringing about the change (Abrahamse *et al.*, 2005; McCalley, 2006; Van Houwelingen and Van Raaij, 1989). Thus, the effectiveness of combined interventions depends on how well the feedback information is explained to the energy users. Also, Spaargaren (1997) argued that human beings as knowledgeable and capable agents make use of sets of rules and resources within reproduction of social practice. Moreover, it is hypothesised that extrinsic motivations can be controlled invariable to the extent to which they become self-determined as they enact the regulation (Deci and Ryan, 2000). However, it is important to keep in mind that these rules can only be enacted as people generate enough power to control, and when the feedback informs the user that there is no available power to drive the function (e.g. watching TV) in use.

8.3.1.3 The White Box

Suggested iterations were integrated into the prototype design, and the new prototype is named as the 'White Box', shown in Figure 8.3. The name of 'White Box' was inspired from the term 'Black Box script' which refers to design approaches delegating all control to machine for eliminating any undermining forces on behavioural change (Jelsma, 1999); or an approach that measures the input and output but ignores what happens in between mind of individual (Darby, 2003). As an act of insubordination towards this notion, the artefact is named as 'White Box' whereby it encourage user to make their own choice, have control, and the empowerment. This new eHPP system has 2 main components; the 'White Box' (battery storage unit) and ‘eBike’ (Figure 8.4) which stands for energy bicycle (pedal powered generator).

Figure 8.3 The ‘White Box’

Figure 8.4 “White Box” with eBike

8.3.1.4 User-Centeredness of ‘White Box’

The typology suggested by Wever *et al.* (2008) also inspired and became a key reference in the design development of the ‘White Box’. Wever *et al.* (2008) proposed this typology of ‘inducing sustainable use’ for designers when designing an intervention, using different levels of ‘intrusiveness’ respectively. The interaction involved in the use of ‘White Box’ requires set of ‘goal-setting’ for user to control their usage. In order to encourage the spontaneous control, the interface of the box shows real-time generating/consuming power rate through 4 digit display. According to Laurel (1986), the interface of design applications should provide ‘catharsis’ of user’s action whereby the end cause can be realised. The form for a given application (e.g. interactive computer program) may be recreational and utilitarian, but the goals can only be met through engagement at the level of the interface.

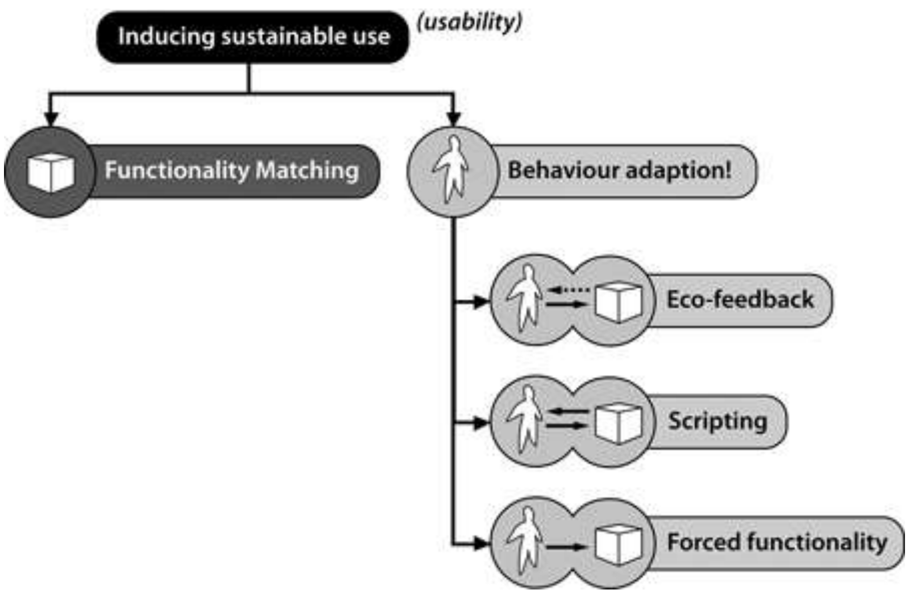

Figure 2.28 A typology of sustainable behaviour-inducing design strategies

The unique feature of ‘White Box’ is that the device can add ‘intrusiveness’ correspondingly, depending on how user controls their battery storage unit. The display unit provides the consequential feedback of remaining power allowance, using an ‘eco-feedback’ strategy. The design of ‘White Box’ also integrated a ‘script’ where the product layout is guiding user to adopt new behaviour of using human-power (pedalling) ‘in a more or less forceful way’ (Jelsma and Knot, 2002, p. 120). The interface display provides the real-time information of how much power is being stored, but it can also simultaneously display the TV consumption rate. For example, as user exerts human muscular energy by pedalling the eBike, corresponding amount of charged energy is shown through display in incremental unit (see Figure 8.5). However, as user plug in a TV adapter into the power inlet which is located on the side panel (see Figure 8.6) and as the power current flows, the unit display shows corresponding power lose in decrementing rate. As user continue to watch TV through stored energy, eventually, the unit reaches ‘zero’; then, the conduction current also switches off (See Figure 8.7). Therefore, the TV switches off. This interaction represent the ‘reward and penalty’ technique, to some extent, to coercively motivate user to exert human-power.

The classification of ‘forced functionality’ is much closer in describing the ‘parasitic harvesting’ or technological intervention that generates ‘free energy’. Therefore, implementation of adding this strategy was not considered during the design process.

Figure 8.5 “White Box” with eBike - pedalling

Figure 8.6 “White Box” – Side panel (power plug inlet)

Figure 8.7 “White Box” with eBike – reaching at zero unit

8.3.1.5 The performance of ‘White Box’

In this research, particularly in developing the ‘White Box’, constraints did exist that concerns the delay of HUS stage 2. The major problem was the technical support in building the prototype where it required quiet complex power circuit board design. In order for ‘White Box’ to function exactly as intended, making all suggested iterations, longer time of experiments and revision were necessary. Considering this constraints, it was decided that the most important function, from research point of view, is to build an instrument which enables to discover new knowledge about relationship between the user and the ‘White Box’. Therefore, the decision was made to build the system as a ‘fake’ piece. However, it was important to design the box up to the level where participants of HUS believe it as fully functioning human-powered system.

First, the portable exercise device was purchased from local merchandising store. This device has a flywheel box where it controls the pedalling tension. To make it look like a ‘generator system’, a DC cable wire was attached to the flywheel housing. This wire is connected to the ‘White Box’ through a detachable 2 pin ATX connector, see Figure 8.4.

In order to understand public’s expectation on the performance of ‘White Box’ system, relevant question was included in the survey. The question was probing for their expectation on the performance ratio of powering TV through human-power system. Fixed answers ranging from 1:1 to 1:5 (1 hour pedalling = 5 hours of TV watching). Although the actual performance was set to give 1:2 ratio, the purpose was to understand the gap between their expectation and the actual practical performance. The results were varied: 1:1 (15.7%), 1:2 (14.9%), 1:3 (20.1%), 1:4 (10.4%), 1:5 (19.4%), ‘I will no use such device what so ever’ (19.4%).

The original exercise bike included a unit display that shows the ‘distance travelled’, and ‘Calorie burned’. This feedback display device was disassembled to measure the sensor signal coming out from the flywheel. It is found that every single pedalling turn sends out a signal which transforms the count into different format. For example, every 5 full turns equal to 1 calorie burn and distance travel of 22 meters.

As a next step, 4 mixed sex students volunteered to measure the average pedalling count of exercise bike. An average of 410 calories burn was measured which is equal to approximately 15 km travelled in 30 minutes of pedalling. With these figures, the power circuit board of ‘White Box’ was designed to match information shown on Table 8-1 below:

Input Rate	• 1 Unit = 5 turns of pedalling (Input) • 1 Unit = 22 meter travelled (45.5 units = 1 km) • 1 Unit = 1 Calorie burn
Output Rate	• 1 unit = watch a 110 Watt TV for 10 seconds. • 6 units = 60 seconds = 1 min of TV watching • 60 min of TV watching = 360 units = 1800 turns of pedalling

Table 8-1 Input and Output value of ‘White Box’

In order to watch 1 hour of a 110 Watt TV, the user on this system requires to exert 1800 pedalling turn counts which will increase the battery capacity (disguised) up to 360 unit. The output rate should have been set to ‘1 unit= watch a 143 Watt for 10 seconds’ which is an average wattage among TV brands. However, since the duration reaching up to this range can vary upon the user’s pace, the output rate was set to minimum of 110 watt[52]. However, from measuring average pedalling with students, it was configured that the range between 360 to 400 units (30 minutes of pedalling) was appropriate level that is equivalent to 1 hour worth of unit from watching 110 Watt Television. Figure 8.8 illustrates the charging and consumption rate of WB system. The bottom images shows how TV switches off when the unit of battery reaches at ‘zero’.

[52] See page 218 for detail.

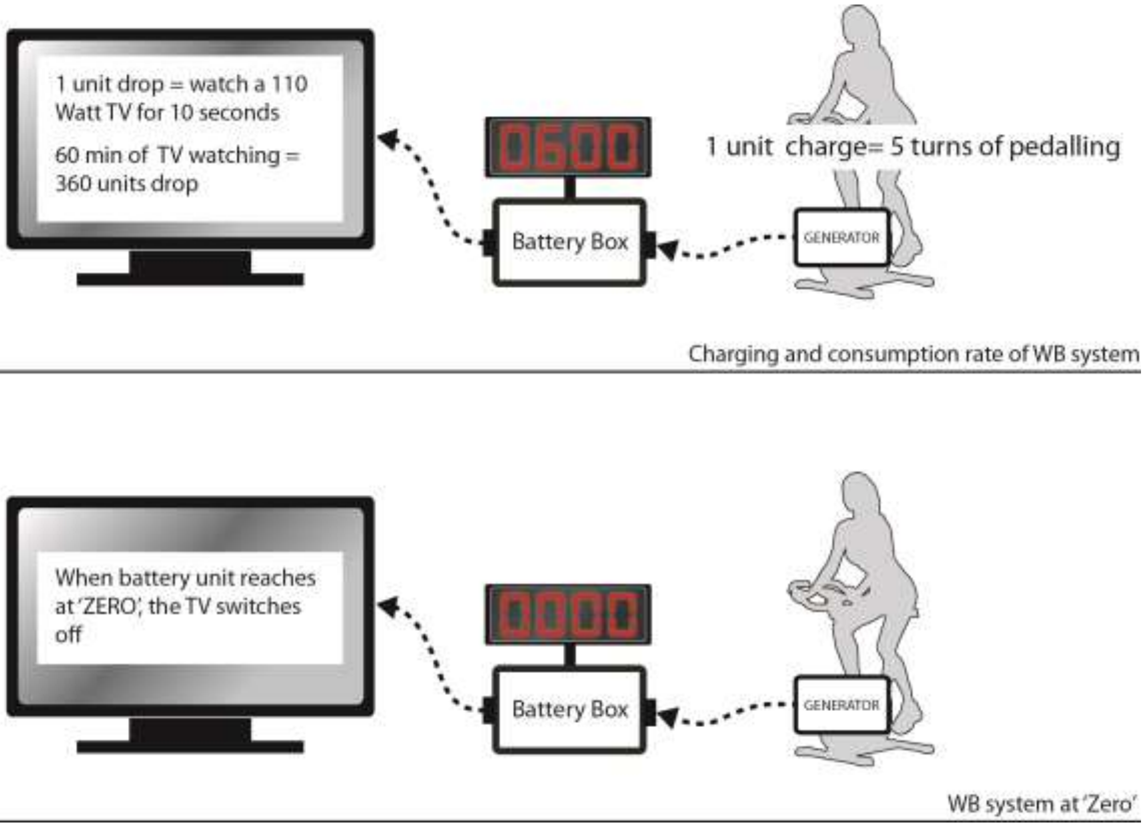

Figure 8.8 Charging and consumption rate of WB system

Inside the 'White Box', there was also a meter device that measures the total input (human-power generation - pedalling) and output (TV consumption) units. The measurement of total units were used during the semi-structured interview to share with participants about their total consumption, the saving in cost unit, calories, and distance travelled during the trial period. The box also included a 10 kg weight of steel plate to match the weight of car battery, making participant to believe it as a real battery box (approx. 15 kg). However, the main issue with the 'White Box' being a 'fake' was the source of actual power in driving the participants' TV. To resolve this problem, a single DC power cable was connected to the system which can be plugged into the main socket. During the HUS visit, participants were briefed that the power plug is placed in case of power lose, to secure the meter reading, and also for powering the display unit.

8.4 Domestication

Between January and March of 2013, a total of 10 UK households across the Nottingham District were recruited for HUS stage 2. Out of 14 people consented to participate through survey sampling, final 10 households were selected and scheduled for deployment of the 'White Box'. Figure 8.9 shows an image of photo taken from one of household during the HUS stage 2. For rest of thesis, the 'White Box' will be used as acronym of WB.

In order to investigate how participants of HUS carry out a new practice of using WB, it was crucial that this *material* is installed in the home to stimulate a dialogue about its usage experience. The concept of 'domestication' was outlined by many scholars in the field of design research (Gaver *et al.*, 2006; Routarinne, 2009). The word 'domestication' refers to the active meaning construction in which the users are engaged both mentally and in real-time actions as they make sense and use of their material environment (Routarinne, 2009).

For this study, researcher used 'domestication' probe methodology as a means to elicit tacit knowledge about how WB are used in real world domestic setting, and to reveal deeper understanding of their value, experiences and attitudes related in using such device. The end goal of domestication is to evaluate the effectiveness of each dimension suggested in 'HPP Internalisation Model'.

Figure 8.9 Scene of HUS stage 2

8.4.1 Participant Profile

The large number of data does not always lead to rich data in qualitative research (Bryman, 2004). However, within the available time and budget of doctoral research, the researcher must manage the scale of data collection. According to Strauss and Corbin (2007), the data collection continues until the theoretical saturation takes place. Theoretical saturation refers to the point during the category (themes) development at which no additional dimensions or relationships emerge during the analysis. However, in this research, previous two studies have identified central category as well as sub-categories that represent the dimensions in ‘HPP Internalisation Model’. Therefore, the size of sample data in this HUS stage 2 was to evaluate the effectiveness of each dimensions in which the 10 UK households became the adequate sample size to explain the phenomenon hypothesised; that is internalising the use of eHPP (White Box).

Group	Age	# of TV	TV usage	# occupants	Participants Description	Participants Code
1	21-25	1	0~1	2	Publishing Assistant	HUS2-01
	N/A				Web Designer	HUS2-02
2	41-50	1	1~2	1	Creative Industry Consultant	HUS2-03
3	41-50	2	4~5	6	Company Director	HUS2-04
4	41-50	1	2~3	4	Designer Goldsmith	HUS2-05
	N/A				Play writer	HUS2-06
5	31-40	1	3~4	2	Team Manager	HUS2-07
	31-40				Commercialisation Fellow	HUS2-08
6	21-25	1	5~6	3	Research Assistant	HUS2-09
	N/A				Solicitor	HUS2-10
7	41-50	1	2~3	3	Sales	HUS2-11
8	31-40	2	2~3	4	Project Coordinator	HUS2-12
	N/A				Charity Director	HUS2-13
9	41-50	1	1~2	4	Programmer	HUS2-14
10	41-50	1	0~1	4	Software Developer	HUS2-15
	N/A				Therapist	HUS2-16
	N/A				Student	HUS2-17
	N/A				Student	HUS2-18

Table 8-2 Participants profile for HUS stage 2

Table 8-2 shows the profile of participants involved in the HUS stage 2. Total of 18 participants from 10 households were involved during the semi-structured interview.

8.4.2 HUS Stage 2 procedure

The HUS stage 2 was scheduled for three visit at an interval of 1 week. On the first visit, a smart meter was placed to measure their TV electricity consumption and hours of watching. This measurements were compared with WB meter records, and exposed to participants during the interview. The purpose was to draw more dialogues on the notion of 'saving electricity' and how these external benefits influence on their motivation for further use scenario.

The second visit took place a week after the first visit, deploying a WB and eBike in their home. A 'warm up' exercise guideline was given to household to avoid for any health and safety issue. The briefing started with demonstrating the power generation using the eBike and operation method of WB; showing how the conduction current switches off as the display reach at ‘Zero’ unit.

An in-depth interview was the foundation of last visit. As this interview were semi-structured, the interview guide were explored flexibly under major themes. The interview guide was based on the following dimensions from ‘HPP internalisation model’; empowerment, real-time feedback, and motivational factors that stimulate the intention of further use. The process of designing the questions for interview also aimed at avoiding participants to discuss or focus on variables that are most important to them. These questions were tested and revised after the first household interview. The topic of ‘energy saving behaviour’ and the effectiveness of WB inducing internalisation of eHPP was central to the development of the interview guide. The interview lasted no more than an hour, minimum of 30 minutes. All interviews were both video and audio recorded for later use, and transcribed into coding software (Nvivo).

8.5 Data Analysis Method

The interview conducted in this section attempted to understand the meaning or experience of participants using ‘WB system’. Rather approaching by statistical procedures or other means of quantification, qualitative interview analysis explored more substantive areas of Human-powered products’ research, that is the actual ‘use phase’ which little is known.

It is important that the theory developed through interview analysis should reflect as resemble of ‘actual experience’ with WB system rather than a theory derived by putting together a series of concepts based on experience or solely through speculation (Strauss and Corbin, 2007). Unlike other study which the new theory emerge from collected data, this research method attempts to elaborate and generalise participants responses based on their experience and motivations. However, it is important not to make any assumption that leads to narrow and accurate version of participants’ comment or belief.

The analysis chosen for HUS stage 2 and the thematic coding process maps onto research objective mentioned in Chapter 5.5, which is to evaluate the theoretical notion of 'HPP Internalisation Model' as a product-led intervention to practice energy saving behaviour. The 'theory-driven' approach was chosen as coding process (Boyatzis, 1998). One of the variant of this type of approach is 'template analytic technique' in which the researcher uses framework to process and/or analyse the information (Crabtree and Miller, 1992).

The process of thematic coding process starts as researcher begins to notice, and look for patterns of meaning and issue of latent interest in the data (Braun and Clarke, 2006). This process is also known as 'descriptive coding' whereby excerpts from data is symbolically assigned into salient themes (Saldana, 2009). According to Saldana (2009) theme is an outcome of coding, categorisation, and analytic reflection, not something that is itself coded. As the data collection proceeded, each interview transcripts were thoroughly reviewed and identified codes were grouped into higher-level categories. Similar to 'Theoretical Saturation' of grounded theory, all categories were identified until no new or relevant data seem to emerge (Strauss and Corbin, 2007). Codes within these categories were reviewed again and sub-categories were generated respectively which accounted more specific phenomenon arising from WB use.

Following this step, process similar to integration in 'selective coding' was applied where it is described as organising the categories around a central explanatory concepts (Strauss and Corbin, 2007). These categories were again allocated to major themes (concepts) which can be seen as 'template' derived from dimensions of 'HPP Internalisation Model' presented through conceptual framework, shown in Figure 7.5 (See page 208). In the interpretive phase, the units of codes and their reoccurrence were connected into the framework which now becomes an explanatory dependent upon the confirming/disconfirming evidences in the interpretation. However, as this thesis include notion of reducing the energy consumption, interview included the discussions on their precedent energy consuming behaviour as well as to understand their perception about eHPP in general.

The end goal of the analysis is to provide in-depth explanation on how each participants cope with the use of human-power to watch TV. These explanations connect to themes that account whether they have reached an internalisation of eHPP use and understanding the effectiveness of implemented design strategy; or vice versa, barriers in regulating their intended behaviour.

After categorising all identified themes into concepts, the research went through all interviews again to analyse each paragraph whether it was contributing in any way to the identified major themes. Some new concepts were then developed to account the other important aspect in constructing the theory. An example of coding process can be found in Appendix I which shows a screen shot of identified themes under the category of 'Post Motivation' which discusses the motivational change after the trial period. All the references (comments made by participants) categorised in a particular theme can be re-accessed through using the coding software. Appendix J shows an example of a generated report that shows all the comments made within the theme of 'Identified Regulation'.

8.6 The Analysis

This chapter is divided into 4 sub-chapters that accounts the concepts extracted from the analysis which represent as 'building blocks of theory' (Strauss and Corbin, 2007). Themes drawn from interview data centred on the 4 major concept of; precedent behaviour, 'WB' evaluation, the 'internalisation' process, and the new practice.

The interview began by having conversation about HUS in general, and a set of questions were followed by asking how participants would define the human-power products. Majority of responses commonly included words of 'Interaction' and 'energy'. For example, HUS2-06 said that *"anything that is… does not rely on another energy source to make work";* and HUS2-09 described its definition as *"things that are powered instead of from main electricity… would be from a human physical activity"*; and HUS2-11 commented as *"sound like device that has some sort of mechanism that going to deliver power from human interaction"*. However, number of responses were also supported by participants giving examples of HPP such as bicycle, sewing machine, hand whisk, and coffee grinder where all these were items either personally owned or experienced. On the other hand, few participants give examples of 'parasitic' HPP. For example, HUS2-08 mentioned as *"kinetic flooring system. Kinetic pavements and they are developing it. They use is as concert that power lights"*, and HUS2-05 and HUS2-11 gave example as 'kinetic wrist watch' or 'chronographic watches'. Similar to previous study finding, participants (HUS2-04, HUS2-14, HUS2-15) had owned a 'windup torch' where they all describe the use as outdoor or for emergency use.

8.6.1 Precedent Behaviour

The interview proceeded to next phase where the researcher led the questions related to behaviour around energy consumption in their household.

8.6.1.1 Energy Consumption

It has been argued in the literature that most of everyday energy we use is invisible, and it is likely that those phenomenon will become part of 'inconspicuous' habits and routine (Shove, 2003). Similar phenomenon was shared during the interview that all of participants' method of tracking their energy consumption was through 'Direct Debit'. None of the participants had recalled an exact figure (e.g. kWh) to share during the interview but most of them were speculating a rough figure in cost. For example, HUS2-01 commented as *"so, I guess we are paying 30 pounds a month and presumably we are using more and less than 30 pounds in the summer"*. Most of Energy Companies recommend this monthly payment methods where the company sets an average amount of automatic payment throughout the year which eventually evens out the total cost. In some cases, it was realised that this automatic payment system contribute towards making energy to be more 'invisible'. HUS2-01 and HUS2-15 advocates this situation by saying "*well, we don't see it. Because we pay fixed price every month and it is supposed to even out throughout the year so even less tracking on what we are using*", and *"no, because it is being paid by Direct Debit, and it just automatically… it stay fixed for a while and when you have too much credit or debit… it is difficult to know in numbers how much you are using"*. Therefore, it can be seen that current feedback method provided by Energy Company is unlikely to help user to be conscious about their energy consumption, and in same time, consequences of any attempted energy saving behaviour is provided in a longer-term basis; *"I just* *plug something into main socket and not think twice... there is kind of sense that disconnects what I do and how I behave and what the outcome is"* (HUS2-14).

This notion of 'no feedback' was shared numerous times during interview (HUS2-01,02,04,14,15). In question asking about their consumption unit, comments were immediately followed by expressing the demand towards tracking those consumption other than conventional methods (Direct Debit). For example, HUS2-2 shared that "*it will be nice to get some data from the company…see some graphs of our usage"*. Similar comments were received when explaining their difficulties in knowing the size of energy consumption of each commodities that they own. HUS2-09 and HUS2-16 particularly described this notion by mentioning high energy-consuming products such as kettle, as they said; *"but households, like I wouldn't have any clue of how much are kettle uses"*, and *"I wouldn't know how much this printer take. It sound like ti take huge amount of energy. Or it is just the noise. Like a kettle makes lots of noise"*.

Chetty *et al.* (2008) has pointed out that, within household, there are only certain people who take prices into consideration since the labour around bill paying is dispersed. Similar condition was shared from participants' comments. HUS2-09,11,14 shared that they have no direct connection to energy cost as someone else in the house were responsible in paying the bill. For example, HUS2-09 described the way she pays the bill: *"my housemates send me how much I owe them at the end of month and he deals with all of that"*. Although her interview indicates that she constantly try to reduce the energy, but the consequential feedback of those actions are far from knowing in real-time. For example, *"we wouldn't have any idea how much it (curtailment behaviours) will affect us how then… we don't know the detail of it"*. However, it was also heard that few households demanded for a new feedback system; for example, HUS2-15,16 said that *"It will be handy to know which devices in the house… have USB or something like that tracks various different devices, where you can plug this into computer to look at it as app"*. Although this household occupant (HUS2-15) often track their consumption through the meter, both of participants demanded for more detail and frequent type of feedback by saying *"what would be ideal is to log the information to see what you have been using"*.

On the other hand, there were three households where they had a real-time 'smart meter' that is also known as IHD[53]. However, while these household purchased the device to receive the feedback in more continuous form, obsolescence of its use was shared. For example, HUS2-12 shared her experience of using such device as *"we got an energy monitor in the kitchen, started to look at it when I bought it, but not much anymore"*, and her husband (HUS2-13) added as *"we rarely look at it"*. This phenomenon has been discussed in literature review as 'Fallback Effect', described as 'the phenomenon in which the newness of a change causes people to react, but then that reaction diminishes as the newness wears off (Wilhite and Ling, 1995, p. 147).

8.6.1.2 Behaviours increasing the energy consumption

Throughout this thesis, it has been argued that increased number of electronics we use today is in prolific pace. Similar view was shared by many participants, and responded as one of the cause on their increased energy consumption. Most commonly discussed item that contribute towards the increase was the use of 'Laptop', and followed by comments related to children using increased number of electronics such as game console. It was stated by HUS2-05 that *"I have laptop, Andy has laptop, there is home computer, TV upstairs, TV down stairs… do you know what I mean? We become more consumer of electricity, and having more devices"*. However, this increase of electronic use also suspects to be derived from issue of personalisation. For example, HUS2-04 described the reason for having 2 TV as *"just to share the TV viewing habits… my wife want to see something different to me.. So TV box which… we put the old box into the bedroom.. so we got another…"*.

While recognising that these activities are becoming more indispensable, some non-negotiability everyday practices were mentioned that involuntarily contribute to the increase of energy consumption. This notion was advocated by HUS2-08, as she states *"I remember we use to charge phone once a week and now we gone through smartphones and it has to be charged everyday if not more than once a day for excessive user"*. However, still laptop now days seems to be the most 'non-negotiable' item among participants' everyday use. Other comments related to 'non-negotiability'

[53] In-Home Display

also includes notion of *“increase washing due to toddler”* (HUS2-04), and *“painful hand whisk so change to electrical one”* (HUS2-16).

As this research dealt around behaviour of using TV, many had shared their bad habit involved in this activity that contributes to consumption increase. For example, participants stated that they leave the TV on while undertaking other activities such as working on computer (HUS2-14) and cooking (HUS2-08) or excessive use (e.g. empty room with TV on, HUS2-05). HUS2-13 and HUS2-03 stated that they leave TV on as a companion while being alone or as habitual behaviour: *“because when I come home I put it on to watch the news at 6. And often even though I’m not watching it particularly, it stays on until I go to bed. Even though we may not watching it all the time, it probably stays on for 5 hours”* (HUS2-15), and *“it is like coming home and it is like having other people in the house… it is having that background noise so that there is something else going on”* (HUS2-03).

8.6.1.3 Curtailment behaviour

It was found from survey result that 17.5% of respondents gave the reason of practicing ‘curtailment behaviour’ for the cause of decreased energy consumption in their households. Likewise, majority of the HUS participants have stated that they are constant practitioner of ‘curtailment behaviour’. Most frequently mentioned words from their comments were ‘lights off’ and habits of turning the home appliances off when not in use, although this contrast with few participants’ comments mentioned above. However, it is seen from interview that most of participant like to be viewed as individual who constantly attempts to practice curtailment behaviour, e.g. *“I’m very careful about lighting. I never leave the lights on”* (HUS2-03), and *“we actively try to reduce our cost so we turn the lights off now. We switch the TV off when we don’t need them for some period”* (HUS2-11).

Interestingly, most of participants were very aware about the heating in their household. While the use of daily electronics products were perceived as ‘invisible’, many had emphasis on their awareness to how their heating equipment gets used and be controlled. HUS2-01,02,03,05,06,08,09, all shared how mindful they were in terms of controlling the heating in the house. Therefore, it can be viewed that people are aware about consumption arising from high-energy impact appliances such as heating. However, as it is expected that consumption on ICT related products will be doubled in years ahead (Owen, 2012); therefore, the reduction on energy consumption is still in doubt when considering the increase number of ownership of these devices in the future.

8.6.1.4 Efficiency Behaviour

Addition to curtailment behaviour, many participants had shared their experience of practicing 'efficiency behaviour', i.e. adoption of energy-efficient equipment. It was observed from their comments that 'energy rating' is one of strongest impact on their decision when replacing the white good in the house. For example, HUS2-14 mentioned that *"we did go for most energy efficient white goods. You know the ratings on the side? We especially tried to find the most energy efficient one. Although we haven't replace the oven yet, but um… which uses quite a bit of power… but when we try to replace things, we try to replace with most energy efficient ones"*. Other similar behaviour accounted practice of; replacing energy efficient lights bulbs (HUS2-03,14), LED TV (HUS2-04,12,13), home insulation (HUS2-04), purchasing hybrid car (HUS2-14), timer on heating (HUS2-03,15), eco-kettle (HUS2-16), and considering to install solar panel on roof (HUS2-04,14).

8.6.2 'White Box' evaluation

This chapter presents the analysis of participants' experience and comments based on the design of 'White Box' system. More specifically, the chapter discusses how iterated design of 'WB' helped people to volitionally regulate their behaviour to gain *competence*.

One of the most critical iteration made on the 'White Box' system was providing a display that deliver the real-time (live) consequences for applied human-power generation. Among many interventions for bringing the reduction of energy consumption, they prominently share the common view that raising energy awareness through a feedback system is foremost step. As argued before, new behaviour gets formulated through the process of; awareness, learning and decision-making (e.g. perceived behaviour control), and 're-routinisation' (i.e.

Internalisation of eHPP use). Similar process has been observed from participants' interview, and they are discussed in following heading chapters.

8.6.2.1 Awareness

Throughout the HUS stage 2, no participants ever recalled or knew about unit of their TV consumption. The meter measurements during house visit became an opportunity to raise their energy awareness towards TV usage. However, the activity of pedalling on eBike to watch TV and understanding the consumption rate through display unit did raise their awareness in main two areas. First, it enabled participant to become aware of their TV consumption unit. For example, HUS2-05 found the HUS to realise how low her TV consumes; as she states *"we didn't have to work hard enough for it and get the exercise benefit because of the TV. We didn't even know that it was a low energy consuming TV"*.

Subsequently, the most intriguing phenomenon was the feedback display making the activity of TV watching as 'conscious'. HUS2-03 states as *"I was much more mindful about what I was watching, when I was watching"*. The front display system also became a tool for inviting the user into a 'thoughtful engagement' (Backlund *et al.*, 2007) as the WB system visualised their TV consumption. It was shared that participants began to notice and make sense of related activity. For example, HUS2-09 stated that *"and then I think I would be very conscious… look at it… keep thinking like will I have enough time?' or Should I get on it now so that it is topped up and then relax to the end"*. Since the intention behind the display system was making the use of energy as 'conspicuous' material, and therefore, it became as communication tool for user to interact with TV energy consumption as well as giving control to generate human-power, e.g. *"Oh! the meter is running low, let's get on the bike and cycle some"* (HUS2-08). HUS2-06 exemplified the WB display as *"you are always aware. There is always like… what we got is what we get. You know? I think it was like… clocking what we need…"*

8.6.2.2 Perceiving Behaviour Control (learning)

It was discussed that intrinsic motivation get enhanced as positive feedback signifies the effect and spurs the satisfaction of the need for *competence*. However, it is important that people first need to access the outcome of consequences and would require a process of making it into a belief as to how easy or difficult the related behaviour is, i.e. 'Perceived Behaviour Control' (Ajzen, 1991). In this case, the function of feedback should foremost include process where people learn the consequences of their behaviour through acknowledging the information. During the HUS stage 2 interview, dominant responses were collected in relation to how the feedback display helped participants gain their *competences* through understanding their outcome of applied action of generating human-power.

Within 1 week period of HUS, no participant failed to estimate the closer range of understanding the input and output rate of WB system. All participants were able to go through 'Perceived Behaviour Control' where they began to access the outcome and start planning out the time required to watch TV accordingly. For example, HUS2-08 said *"we would check it quite regularly to see what it was doing. It was quite good to see that like… what credits you got… because we would be able to work out how credits related to hours of viewing"*. Number of similar responses were collected in explaining how they acknowledge the information communicated through the display panel. Below are exemplar comments related to this notion of 'learning':

"It was about…. 100 units gave 30 minutes of TV. The first day you dropped it off, I played it around and trying to figure out how much time I would need to… A. how much time I need to pedal, how much time that will calculate in how much TV I would watch" (HUS2-03)

"It was helpful to know… first I thought it was time. But quickly realise that it wasn't so…" (HUS2-10)

"And then you put the TV programme on, watch it and check it. 'Oh we are at 70, let's give a quick pedal'. So it was just so easy" (HUS2-07)

"1 hour of pedalling was 2+ hours of TV… something like that" (HUS2-04)

"The first night, we let it drain but were topping up again to find out the ratio… how many hours we would get from pedalling and so on" (HUS2-12).

As participants began to interact with WB feedback system, comments describing this experience included words like 'times' and 'minutes' which accounted the number of attempts and duration of human-power generation; and they found themselves linking the outcome of effort against managing their TV usage. For example:

"If you are watching the TV at same time, you could see the number go down and you cycle for 2 or 3 times and it will go up. So you can see… 'oh I can actually putting in (the units) than going out again'. So that was good, and it gives you an idea like 'I got to 1000 units so I can watch it for a while'". (HUS2-14)

8.6.2.3 Goal-setting

While the feedback signifies the consequences of TV related activities, including the power generation, the feedback system also availed user to have volitional control of TV usage through goal-setting. This process has been discussed through explanatory framework presented in Chapter 5.3. It was suggested that the system of feedback or its interface must provide the real-time consequences, linking the behavioural determinants with possible goal set by users, see Figure 5.5 on page 150. Below are comments received from participants that explains the effect of real-time feedback system:

"Sometimes when I got on, I was like… not competitive but I would set myself, I get to certain target" (HUS2-09)

"I wanted to get up to about thousand and then keep it about at 500. And then top it back to 1000" (HUS2-11)

"I was always aiming to kind of top-up to 400 and then you knew that it wasn't going to run out. Although we did… watch more TV one night and had to add to it. I would say between 300~400. And that was our average target. Once it hit that we stopped" (HUS2-08)

From above comments, it can be viewed that behaviour determinants were derived from commitment of achieving the goal-set pledged by oneself. Obviously, these determinants were acquired through experiencing the 'perceived behaviour control'. However, from intervention perspective, WB system in this case were performing as 'antecedent intervention' where it assumed to influence one or more determinants prior to the subsequent performance of behaviour. It has been argued by Darby (2001) that further 10% of energy saving can be achieved in household through use of motivation techniques and feedback information. However, a study suggest that significant amount of energy could be saved when immediate energy feedback gets delivered, but only if the user first sets a goal (McCalley, 2006). It was observed from interview that majority of participants have gone through process of; breaking previous habit of TV watching, realise the new option, and makes decision to perform the new behaviour based on their set goal. However, it is yet ascertain whether this behaviour can re-occur regularly to bring an 'internalisation'. Detail motivational factors involved in this process will be discussed in later chapters.

8.6.2.4 Problems with WB

Since the use of WB has only been evaluated by users of HUS stage 2, it also revealed new design problems. Although the feedback system had an intention of increasing the 'awareness' as foremost step, other issues were raised by participants that eventually became the barrier for raising awareness. One of the common problem was the 'engrossment' of TV watching that often makes users 'unaware' of decreasing consumption rate. Some participants have experienced instances where they had to hop on the eBike to add extra credit on to WB while watching TV or felt annoyed by its 'reward and penalty' function. For example, HUS2-14 commented as *"I suppose the only time that I felt that is was a bit annoying is when I was playing game"*. It was observed from interview with HUS2-05,06 that they had turned the display face away to avoid the distraction which made HUS2-05 feel a 'guilt'; as she says *"I was watching the numbers go down, but after having it for few 20 minutes, you forgot about it. Actually at one point, I turned it away so I couldn't see the lights (the numbers). I didn't want go get distracted by watching the numbers dropping and going 'we are wasting all our energy'"*.

8.6.2.5 Recommendation for WB system

The possible design problems of WB system were also identified through recommendation made by participants. Number of comments were related to the feedback system where many had demand towards seeing different form of information. Not only it provides the unit of stored energy, participants had demanded the consequential information derived from exercising as well as seeing the actual cost saving which may become a greater influence towards the further use. For example, HUS2-09 indicated that *“If you had some form of way of easily seeing the amount of money that you save, even though it was like estimate, I think that would be quite incentive because you can see it on daily basis…”*. This was advocated by HUS2-13 as he comments *“like to find the way connecting that (battery pack)… would have separate line that says how much I generated and how much I saved in cash terms on that”*.

However, the dominant recommendations or demands for future use derived from the idea on how WB system can be used as socio-technical system within their household. Many had expressed the demand of WB system being connected or feedback into the grid to generate potential saving from use of other EuP as well, e.g. *“I like it to be able to, not just TV, but to our system if you like”* (HUS2-13). Participants of HUS showed demand towards expanding the use of human-power into other devices, practices, and habits that are beyond the use of TV. Often, these interdependency use of WB and other practices result in increasing its viability, e.g. *“6 hours of laptop, that is more attractive than 2 hours of TV”* (HUS2-04). Although the WB system was designed in a way to produce larger size of power output compared to portable eHPP, many had the desire of expecting even higher up to macro-level power generation which then can be fed back into the house. For example:
“if it wasn’t just that… you pedalling straight into the grid or something… that would be great. The notion of it being there. And if you wanted to add up the energy source and that basically has a plug attached to it… which it does… if you could… just like a basic big battery… rather than plugging it to TV, you can take it out and plug in the radio or something else to make it work… it will be cool” (HUS2-06).

Addition to idea on feeding the generated energy into grid or house, majority of participant imagined the use of other every day EuP such a smartphone through WB system. This comments were often followed by demand of having higher resistance of eBike pedalling to generate more power, e.g. “*There got to be a way. Like gearing the bike… and get some serious power output. And then self-training for 2 ½ hours a day. It could be… with the right gearing… it is achievable. Surely, you can power more than just TV”* (HUS2-11) and *“if you can get ratio that is higher than 1:2… I don’t know what would be possible, but that would make me more receptive to having to power a heater or something”* (HUS2-09).

Particularly when they were discussing about the eBike function, some participants imagined the use of human-power to link with other exercising activity. HUS2-11 who expressed himself as frequent exercise person said *"If you can wire it to somewhere like gym, you can use bike for hour and machine does this and that… from kinetic to current than… you might power the whole house"*. This notion of using the exercising activity to generate power was also shared with other participants (HUS2-08,09). Nevertheless, it was found that when they link the subject of human-power generation with 'exercise', they seemed to be keen on increasing the resistance of pedalling to gain more external benefit which is related to health. For example, *"so if the bike was harder or that was something that I could use for other means, I would probably done three or four times as much"* (HUS2-06), *"But then as an exercise perspective, to have a harder resistance be something that would give you more"* (HUS2-09), and *"people who have like indoor gym or want to get fit at home… they would want the exercise bike anyway, it would just have benefit of savings and money so it will be able to power something like TV off of that. Then I think, something like resistance would be more important in that case"* (HUS2-10). Other recommendations or demand dealt around the usability or ergonomically issue of eBike, e.g. desiring bespoke seat. And few others (HUS2-03,13) wondered about its lack of market availability.

8.6.3 The 'Internalisation Process'

In accounting the internalisation process, it was very important to identify their initial motivation of deciding to participate in the HUS stage 2. As Stern's VBN Theory (Figure 2.17 on page 46) became the basis of frameworks discussed in this Chapter 5.3, initial motives were classified based on this theory's value-based attitudes, and they are; Biospheric, Altruistic, and Egoistic. However, no codes were identified in ration to Biospheric value where related motives deal with, for example, lowering the household emissions. Also, no particular codes emerged under 'Altruistic' value. Nonetheless, one particular participants had made a comment which perhaps relates to both Altruistic and Biospheric value: *"I'm the one who turns off the lights and it is financial thing but it is more trying to get kids to realise that leaving lights in some room… it is their future"* (HUS2-06).

Contrast to two participants of HUS stage 1 who were highly eco-motivated individuals, most of participants of HUS stage 2 had 'Egoistic' value as initial motivation. These values primarily derived from ‘self-efficacy’ (Bandura, 1994) where they had some level of belief in their own ability to practice this energy saving behaviour of powering their own TV. The common rationales received were *“sounds interesting”* (HUS2-01,02,04,06,07,09,12) and *“make best out of their exercising habit”* (HUS2-07,08,11). However, majority of participants had interest towards the concept of ‘how can we cut down’ the energy consumption, especially towards upcoming future. For example, HUS2-14 stated that *“I always think about how we can save energy, how I can sort of cut of electricity bills because it is always going up”*. These self-interests were also related to the notion of *“alternatives efforts of powering home”* (HUS2-04) and perceived the WB as another option of *“keeping the energy efficiency in house”* (HUS2-12) that are derived from the *“idea of the sustainability and generating some of your own electricity instead of depending”* (HUS2-07). These idea of being ‘off the grid’ seemed to emanate from their intentions and motives towards practicing alternative way of consuming energy which has been done passively to date. As HUS2-04 states: *“We passively acquire energy. We passively fritter energy. Whereas if we take more of active role in generating energy, we can take much more active role in how we then use and utilise the energy”*. This comment, as well as the other rationales stated by other participants, links with the concept of ‘empowerment’. The meaning of ‘empowerment’ when discussing the function of ‘feedback’ primarily dealt with having volitional control of their power usage. Therefore, the decision of participating in the HUS can be seen as opportunity for these individual to be an autonomous decision-maker and having sense of ‘empowerment’.

In addition to above mentioned initial motivations, some participants have described their motivation in relation to obesity concern and issue of suffering from physical inactivity. These motivation will be discussed in more detail at later sub-chapter since this issue has turned out to be the one of the benefits participants gained through HUS.

Whilst these participants had shared the initial motivations mainly derived from ‘self-efficacy’ which can only predict the intention of behaviour, it is important to measure how each participants coped with subjective ‘perceived behavioural control’ of experiencing the use of WB system. More specifically, the study required in-depth understanding of how people perceive the behaviour control over both internal and external factors to predict the internalisation of eHPP use. As Ryan and Deci (2000) argue, people may show a lack of desire in changing their behaviour, but it can be controlled by different types of external motivations. These motivations will vary to the extent which they are either controlled, sometimes punished or become autonomous through their feeling. The end goal of this behavioural change technique is to bring an ‘Internalisation’ process whereby people become self-determined as they enact the regulations and finding the related activity as important. As this study aimed to understand how WB bring the ‘internalisation of eHPP use’; the taxonomy (Figure 2.30) of motivation types presented by Ryan and Deci (2000) was used as the basis to categorise the codes describing the different form of motivations affecting on participants’ behaviour change.

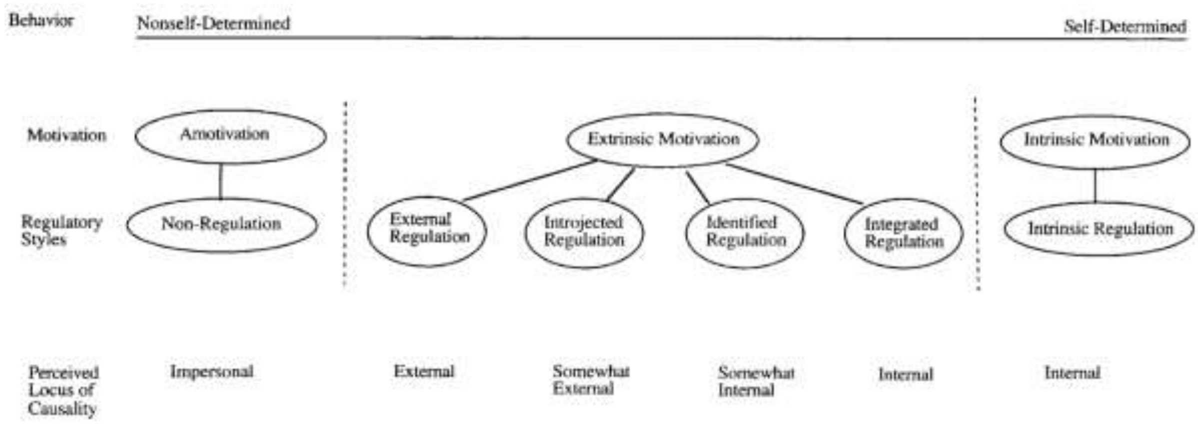

Figure 2.30 Different types of motivation with their regulatory styles and the locus of causality
(Ryan and Deci, 2000)

8.6.3.1 Amotivation

In spite of all participants made a decision to participate in the HUS, it is not certain whether the external benefit provided by WB fosters the former motivations. By way of contrast, these external benefits may hinder the overall motivation as it may differ with what participants had expected. Therefore, the researcher revealed these external benefits during the interview, e.g. cost saved during the trial period. These figures were calculated based on the meter reading that was installed inside the WB. The meter provided the total credit input (1 unit = 5 turns of pedalling) and the total consumption output (6 unit = 1 min of 110W TV). These units were then recalculated to total calories burned, distance travelled, total power consumed through WB (Kwh), and hours watched. When revealing the KwH and hours, these figure were also presented with previous week measurements.

After revealing all the information, the external benefit of ‘cost’ generated most intriguing and astonishing reactions from participants which almost made the other benefits out of their mind during the interview. Below are exemplar comments related to the cost benefit:

“So… but I have to say that I expected little bit more than 40 p (laugh)" (HUS2-14)

“I’m shocked that it only costs 10 pence… would the cost… that obviously the cost calculated with national grid cost” (HUS2-09)

“10 pence is less than what I expected” (HUS2-10)

“That is really shocking. That is nothing. I thought you were going to say 8 quick or 5 pounds and I was going to go ‘Yeah that’s great’. But looking at how much we spend on TV, we spend 10 pence a week for TV” (HUS2-08)

It has been discussed through LCA study that the size of the cost benefit gained through use of eHPP may not imply as significant motivator. As above comments from participants advocate, these external benefit seemed far less than what they had expected. Although the WB was designed to produce, but phony, higher power output compared to portable eHPP, the amount of cost saving is yet sufficient to become a significant motivator. Although the cost we pay are masked and criticisms were made against relatively low priced energy cost, the majority of participants responded with ‘disappointment’, and few had commented that their expectation was around price range of 5 pounds. Moreover, HUS2-15 pointed out that there are more cost involved in apply the human-power, as he comments *“so it cost us lot more in food to give pedal”*. This result shows similar aspect to what Pierce *et al.* (2010b) reported on their survey that only 5.1 % of respondents claimed to be ‘very sure’ of energy cost per 1 kWh. Therefore, it can be seen that people do show lack of knowledge about basic per unit cost at macro-level, and eventually more difficult at micro-level.

In spite of this low cost benefit, it was observed through interview that most of participants had progressed into early stage of internalisation, which will be discussed through next chapters. Whereas few participants had shared a ‘negative’ view towards sustaining the WB use or still showed lack of intention. Commonly raised issue was involved with ‘added discomfort’ (Jansen and Stevels, 2006). For example, HUS2-10 has commented as he imagined the use of WB with other EuP: *“...having a cup of coffee in the morning require 2 hours of bicycling…”*. One particular participant had remained at level of ‘Amotivation’ after HUS. When the potential saved cost was presented to this participants, his response was *“Unfortunately, you have to do better than that for it even getting close to being considered. 15 pence… it’s good that we didn’t do this for money. Let’s put it that way”* (HUS2-04). In addition, this participant had even higher expectation of WB by specifically explaining the ideal condition for consideration:

“if you could obviously pedal or do generation, but for that impact of energy production to have a more… I guess dramatic charging effect to something so that let’s say you could pedal for half an hour or an hour, and that would give you X amount of power that could run all your lights and TV a day, that starts become little bit more practical” (HUS2-04).

Moreover, his concerns dealt with the TV usage where its consumption is relatively high, and believes to be prolific, therefore not so practical in longer term scenario. In the question of asking for his intention of primarily using this device as everyday product, his response was *“But having to cycle for 4 hours to watch 6~7 hours of TV or other electrical appliances… I think… it is nice idea for week… but I don’t think we can do for month or year”*. Therefore, it can be seen that participant HUS2-04 and his perceived behaviour control led him to remain at ‘Amotivation’ which showed lack of intention that unlikely to proceed to ‘internalisation’ of WB use.

8.6.3.2 External Regulation

Externally regulated behaviours are described as extrinsically motivated behaviours that are least autonomous (Ryan and Deci, 2000). These behaviours are performed to satisfy an external demand (by others), controlled or alienated, or reward contingency. In identifying the codes within this theme, number of comments were related to how household find the WB as tool to regulate their children’s TV usage.

Participants like HUS2-05,12 who both raise children found the HUS as an opportunity to control their excessive usage on ICT related products. For example, HUS2-12 described how this HUS became a compromise through making her child to give effort (Punishment) for earning the reward of watching TV: *“I think it is particularly good for the kids. Because we are always trying… let’s not watch too much TV, and it makes exercise more and it feels like it compromised that you can watch TV too”*. Whereas, participant HUS2-05 had curiosity over her teenager possibly alienating the TV use during the HUS, but in turn, she observed how affirmative they reacted towards the use of WB: *“I was also curious to see whether…because there is time when teenagers just completely flake out on the sofa. If they had to, would they get up and do it? When we got the bike and when it was here, he (her son) was first to one to hop on it”*. An intriguing comment was received from HUS2-05 which emphasise this particular stage of internalisation process that is people realising the external rewards contingency upon their effort. In other words, the HUS makes people to view the energy use as ‘take it from earned’ instead of ‘take it for granted’. As she comments: *“I love the idea of having to work for phases that we always take it from granted. Because it makes awareness what you are using and how precious the commodities it is that we all have”*. Also, HUS2-07 describes this concept as *“I like the idea of ‘put something in’ to ‘get something out’”*. Arguably, identified external regulations in this stage enables critical reflection on energy consumption and new practice emerge that eventually materialise the energy use from ‘inconspicuous’ state to ‘conspicuous’ routine.

While people realise the access to alternative form of using the energy and those contingent rewards, it is argued that this early stage of ‘internalisation’ is only possible through instrumentality (Deci and Ryan, 2000), e.g. WB. Therefore, the themes discussed in the ‘external regulation’ phase strongly links with function of feedback discussed in the theme of ‘goal-setting’. This means that as user begin to accept the outcome of WB use as ‘benefit’ (positive), it is likely to avail people to gain *competence* through routinising its use. However, the benefit in this phase of internalisation still remain as ‘external’ rather than ‘internal’. Although the size of the potential saving in cost perceived to be a ‘disappointing’ figure, some participants acknowledged the upcoming increased saving upon its continuous use. Below conversation between two participants illustrates this notion:

HUS2-10: *"I can say that that was quiet week for us. We use 4 times less than what we normally use. So we can say that it is about 40 pence that we can save each week."*

HUS2-09: *"But that is still so cheap."*

HUS2-10: *"Over that course of years… it is saving…"*

Other participants such as HUS2-03, 11 positively viewed the entailing benefits upon continuous use by saying *"over course of year"* (HUS2-03) or believing that there will be greater benefit when WB is used with wider applications beyond TV (HUS2-11). Although the motivation of HUS2-04 seemed to remain at 'Amotivation', he also commented that *"so certainly there is something about health…"*. Therefore, it can be stated that interaction of WB along with its feedback system helps people to *"recognise that we get reward if there is effort"* (HUS2-03).

8.6.3.3 Introjected Regulation

While the phase of 'external regulation' refers to stage when users begin to realise a potential or possible increase of 'external benefit' through performing behaviour, the 'introjected regulation' is second type extrinsic motivation in which behaviours are performed to avoid guilt or anxiety (Ryan and Deci, 2000). These type of behaviour involves user taking in a regulation but not fully accepting it as one's own or yet fully internal. Often, these behaviour gets performed to attain ego enhancements or represents regulations gained through self-esteem in which people are motivated to avoid failure. Similar phenomenon was observed through participants' interview. HUS2-13 described himself as 'competitive' person who tries to avoid being worried on thing, e.g. *"see my psychology wouldn't let me go to zero (the unit on WB)"*. Similar comments were repeated which accounted how he kept the units of WB at certain range by saying, *"I would rather put in hard hours at start and never worry about it"*. Whereas HUS2-09 commented about how her intention aimed to ensure the reward by making conservative effort: *"I would make a conservative effort to then get to a certain maybe like 300 or something before… I got enough time to watch. So think that was more driven by ensuring we had enough time rather than exercising…"*. Again, it can be seen that these type of behaviour were only possible through interacting with WB system, particularly with the feedback display. Likewise, HUS2-

05 described how the whole HUS turn out to be an intent of avoiding guilt by taking alternative energy use rather than 'taking from granted': *"when you live busy life style, I'm American…but watching TV is, at some level, I think of it as waste of time…So therefore, having to work for the reward makes it seamless guilty"*.

Similar to intention of HUS2-13 where his behaviour was performed to avoid punishment, the most common word mentioned by many participants accounting in this phase was the 'competition'. The interaction involved with WB not only provided an alternative way to watch TV, but the feedback display also helped people to induce a 'competition' between household occupants. HUS2-14 described how his children were competing each other: *"I think they definitely noticing that it was going up, and they did wanted to put the number up. They wanted to see who can put it up the most"*. Same phenomenon was observed from interview with HUS2-05,06. In this interview, they described how the feedback display helped them to set a goal, reaching certain target of units, and competing against each other:

"So 'Oh I did 300' and then Andy come along 'well, I did 400' so we got 700 total. So there was sense of competition. And it is kind of obsessive thinking 'I just do 250, no, do to 300'…cause you just keep wanting to get the numbers up to store up some viewing time" (HUS2-05).

This phenomenon of what might be described as 'attaining ego enhancement' were perceived as a 'game' to other participants. For example, HUS2-02 explains how he viewed his behaviour as *"I think immediately it turned into a game. Simple Game. If I pedal faster, then the numbers go up more quickly"*, and HUS2-04 described it as *"it is big and gaming thing sort of"*.

Above all, most intriguing part of ego-involvement was derived from notion that majority of participant found HUS as interest due to many feeling the need in 'exercise'; growing apprehension that people suffer from 'physical inactivity'. It is noted that average TV watching time in UK has been increasing, watching average of 4 hour per day (Ofcom, 2013). Moreover, concerns are raised over the fact that third most popular activity carried out by people in Great Britain was watching TV/videos/DVDs or listening to music (Energy Saving Trust 2007). Eventually, the behaviour around TV watching contributes to what Veerman *et al.* (2012) says as

'Sedentary behaviour', e.g. too much sitting, as distinct from too little exercise. Veerman *et al.* (2012) argues that TV viewing time may be associated with a reduction of life expectancy that is comparable to other major chronic disease risk factors such as physical inactivity and obesity[54]. However, this does not mean that they participated in the HUS purely for exercise reason but rather they favoured the idea of producing more than one benefit of *"enhance my well-being, and there are benefits to planet as consequence"* (HUS2-03). Nevertheless, it was shared by majority of participants that they feel the need in doing more exercises. Particularly considering the cold weather, the motivation increased as they regard the WB as an indoor exercise device which became the remedy to ease the stress of feeling 'physical inactivity'. Although the external benefit such as 'cost saving' still perceive to be at a 'not significant' motivator, using human-power can offer benefit beyond 'off the grid power'. Human-power enthusiasts suggest that HPP is cost savings for society, as it offsets the health conditions caused by physical inactivity (Dean, 2008).

Behaviours performed in this phase observed to be controlled to avoid guilt by putting conservative effort of increasing the external benefit, but also it availed to attain ego enhancement that are more related to internally driven motivation, e.g. exercise and good for health.

8.6.3.4 Identified Regulation

The behaviours discussed in the phase of 'identified regulation' can be seen as more autonomous. Although the behaviours are mostly motivated through extrinsic factors, it is yet solely done as a source of spontaneous enjoyment and satisfaction. In more detail, the identification refers to a conscious valuing of a behavioural goal or regulation, therefore person accepts the action or owned as personally important (Ryan and Deci, 2000). During the course of HUS period, it was already discussed that many participants identified with the importance of either exercising regularly or accepting a regulatory behaviour to watch TV for their own right; i.e. self-determined. No particular participant discontinued to use the WB system during the period of HUS. However, only HUS2-04 lacked to find additional motivation to agree upon his intention of future use.

[54] Veerman *et al.* (2012) quantified the impact on life expectancy from TV viewing. The result shows that every single hour of TV viewed after the age of 25 reduces the viewer's life expectancy by 21.8 minutes.

Regardless of HUS2-04 case, rest of participants recognised their behaviour as 'valuable', and volitionally putting those behaviours into a routine. The intention of these behaviours are endorsed by themselves, and expects to have greater chance of being maintained and to be associated with higher commitment. Themes classified in this category mainly explained events or behaviours that accounts their established *competence* of WB use. For example, HUS2-05 explained how she controlled her regulatory behaviour of using WB: *"I was tired and just wanted to watch TV, I put it on easiest and pedal fastest I could just to get the credit. So that was my goal"*. In same time, particularly in relation to this phase of internalisation, participants have begun to consciously value the behavioural goal whether that is for health or to further increase their contribution to energy saving. Comments from HUS2-16 advocated this notion of how they began to realise various form of benefit gained through HUS as: *"it's nice to know that you used that many calories, I think that is the good side… I can see that as a motivator to do it from that perspective other than the money side for me… you know? Behavioural change aspect"*. In consequence, interview revealed that 9 participants have progressed through last stage of 'internalisation' which is the 'integrated regulation'. However, it is important to emphasise that the function of feedback on WB and its function as 'intervention' played key role in inducing the behaviour and to regulate them upon their goal.

8.6.3.5 Integrated Regulation

Building on from phase of identifying with the importance of behaviour, the final phase of internalisation, the most autonomous form of extrinsic motivation is 'integrated regulation' (Deci and Ryan, 2000). In this phase, the initially perceived external regulation assimilates into self-regulated and the result is self-determined extrinsic motivation. However, it is not argued that participants in HUS trial must progress through each phase. Rather, it was observed that they relatively internalise a new behavioural regulation at any given developing continuum.

In spite of low cost benefit, participants had identified with the importance of behaviour which showed their motivation to continue carry them as a 'practice'. This new practice of using WB and its internalised routine of use were formulate through; 'de-routinising' precedent patterns of energy consuming behaviour; and through 're-materialising' the 'inconspicuous' energy consumption habits; and 're-routinising' that behaviour through an 'internalisation' process. For example, below comments illustrates how participants described this routinised behaviour:

"I would quiet happily… it is something that I would get very easily get into a routine using it in regular basis" (HUS2-03).

"Initially I just get one and just feel like 'oh I just do half an hour or so'. But then you get slightly addicted when you can see the box racking itself up" (HUS2-09).

The theme of 'Cycling as habit' emerged within this category where some participants described how the use of WB became as a habit:

"They definitely used it more than once… they used it every day" (HUS2-14).
"But I got into a habit of…thinking that I have to do sort of 10~ 15 minutes of bike when I get back from work… spend some time on the bike" (HUS2-03).
"It was funny how you can get into a routine of doing that without even realising" (HUS2-09).
"It just felt like quite 'oh, that's how our TV work for us now" (HUS2-08).

The last section of interview guide drew a discussion about their decision to carry WB as everyday product. Number of codes were identified which accounted their self-determined motivations, and their intentions of adopting the device as *material* for daily practice. For example:

"I would quite easily incorporate into my evening life" (HUS2-12).

"If the bike was able to be used for longer, I would use it for longer" (HUS2-11).

"Leaving the TV on, being more discerning about what you are watching, and how long you want to watch it for… those kinds of various things. I think over time, you can get used to having to pedal to watch the TV" (HUS2-16).

"I can do it. I can still do my exercising whilst I'm winding down and relaxing and watching TV. Because that is not as hard as going out for a run. And I'm happy to do that. I would be happy to cycle everyday" (HUS2-08).

In the end, these internalised motivations were not only derived from regulated behaviours, but 'double dividend' (Jackson, 2005a) played a significant role within this process. Similar to most of 'fun' applied HPP, the WB system influenced on their motivational factor which provided 'double dividend' stimuli that is beyond the objective incentives arising from generating 'free power'. As HUS2-09 states, *"It would be fully exercise purposes when I think about relative cost saving actually. But again, if we had more TV and it consumed more energy… over the course of year as well… I think it still would… slight monetary saving still would be the main driver with the added of bonus of prolonging my life"*. This notion of providing 'double dividend' stimuli was identified during the HUS stage 1 and this phenomenon was demonstrated in visual diagrammatic framework in Chapter 5.3, see Figure 5.6 on page 152.

However, it should not be regarded that these motivations were more oriented towards either dividend. As HUS2-07 states that primary motivation still reside at *"making difference in energy"* use, and *"of course the extra exercising bit too"*. Linking this with the practice theory, a behaviour co-evolves in between devices, system and practices as they are interdependent to each other. Similar notion was shared by HUS2-05 describing how she will cope with WB system in future practice of TV watching: *"I would either exercise more to watch TV more. Because I have to… want to watch TV to motivate me to exercise and we don't watch that much TV in first place. So, I suppose if we watch lot more TV, I would exercise more to make the TV work"*. Moreover, participant like HUS2-16 described her post-motivation which unlikely to include extrinsic motivation of 'money saving': *"I know I'm saving little, but it will be like you are doing something beneficial for yourself as well as maybe saving little bit of money. But it will be more about… you would be doing something, you are powering something, and benefiting your own well-being at the sometime. So I think that would be more the motivator for me rather than the money saving"* (HUS2-16).

Thus, it can be concluded that participants' view on WB primarily related to 'egoistic value' of attaining 'double dividend', rather being reliant to individual's forthcoming incentives arising from its use. These results shows that participants' autonomous decision facilitated the internalisation and it played as critical element for regulations to be integrated as a ‘new practice’.

It is also notable that some level of ‘intrinsic motivation’ was situated. Beyond the incentives or for any exercise purpose, the HUS introduced an *“experience of watching TV more enjoyable”* (HUS2-03), *“new level of activity into TV watching which is quiet fun”* (HUS2-01), and *“more enjoyable way of watching TV”* (HUS2-02), and participation itself giving ‘enjoyment’ (HUS2-04,08,09). However, not all household occupants had a decision of participating in the HUS, others may have got involved coercively by either their parents or flatmates. Nevertheless, no particular comments were received about any rejection of WB use by these individuals. Although their behaviours were not driven by any extrinsic motivation, or even intrinsic, it is assumed that behaviours were prompted, modelled, or valued by others whom they feel related. As Ryan and Deci (2000) suggest, the most powerful influence on intrinsic motivation is ‘relatedness’ which plays such crucial role in the maintenance of intrinsic motivation. Even for HUS2-04 who expressed his intention of remaining at ‘Amotivation’, shared how this HUS turn out to be a; *“We’ve learned, not just the basic, but interactively within family it was quite… new activity… it was* another *interesting… something to bring us together at some extent so every got involve so it was useful sort of social tool… interactions… that is probably it”*.

8.6.4 New practice

It is fairly up to the actual user whether they decide to continue to use the WB system as permanent domestic product and that their practices become established through ‘re-routinisation’ process – the Internalisation of eHPP use. The design elements built onto the prototype may fall under concept mentioned by Ingram *et al.* (2007), the ‘sociotechnical scripting’ which gives more subtle understanding of reciprocal and constitutive relationship between the users and technologies. The decision is purely up to these social agents who are capable of resisting or complying with embodied and materialised scripting. However, it is now evident that design of WB, including the function of feedback, played such crucial role in gaining control to progress through ‘Internalisation’ process, and to be able to manage its use in between the phases. Within the various different form of extrinsic motivations, the feedback system on WB availed them to gain goals and regulations; and the need of autonomy and *competence* were identified, and integrated into their daily practice.

However, the result showed that the motivation induced during the HUS only enacted around the use of TV, rather it influenced on lowering the household energy consumption as whole. HUS2-13 and HUS2-16 had described how HUS help them to raise the awareness to energy use, e.g. *"It made me think about how much other electrical devices might be using which I wouldn't necessarily think about in a day to day basis"* (HUS2-16). However, the HUS experience mostly did not reach to level of influencing each household to induce additional 'energy saving behaviour' with other EuP. As HUS2-13 says *"I think we became more aware of the consumption again. Because you get reminded. But I don't think this particularly changed much"*. Therefore, it can be seen that the intervention of WB contributed as to increase the awareness, but it does not necessarily mean that it affected on changing their behaviour on lowering the consumption with other EuP.

Since the HUS period only last for duration of 1 week, concerns over obsolescence of WB system was also received. Participants like HUS2-03 had very positive expectation towards future use: *"I would like to see what longer term benefits are. Because, in a week, so much has changed. In terms of figures, it is great to get that feedback. But I think in longer term, if this was month, 6 month, or year, how would it change? Powering other devices, how would that effect other area of behaviour*?" Whereas HUS2-13 showed curiosity towards their motivation when imagining it as permanent use: *"it will be very interesting to see how much… how our behaviour towards it change if we had it for like 5 months… That is critical thing, it is novel. It is new. Very exciting, I would buy it, but whether that will still be the case in 5 months. If this was permanent feature…"* (HUS2-13). Interestingly, it was observed that most of household with children were typical participants who showed similar concerns. For example, HUS2-05 says *"Because it was new. If we had it for year, and it wasn't fun and new to him anymore, it would probably be a big fight over who is going to have to pedal… with kids"*. This phenomenon was described as 'Fallback Effect' where the use of human-power system can become obsolete. Similar result was found from human-power related study (Stein, 2006) that experience of pedal-power generator increased people's awareness and knowledge of energy topic. However, no significant statistical change was found in people's 'behavioural intention', e.g. curtailment behaviour with other EuP.

8.6.4.1 Curtailment Behaviour

While the HUS failed to further influence on behaviour related with other EuP, number of codes were identified under theme of 'curtailment behaviour' around TV use. It has been highlighted through survey result that 60.8% of people leave the TV on while undertaking other activities. During HUS period, majority of participants had observed themselves practicing a 'curtailment behaviour' by turning their TV off when not in use. For example, HUS2-06 explained that his behaviour around TV watching has changed to: *"when finish we turn it off, rather than let the news go on for 10~15 minutes, you are not really watching… so I think you are more likely to not to be induced into catching/wasting 15~20 minutes of program that you are not really watching"*. Similar behaviour was observed from HUS2-03,04,09,16 where they were switching the TV off during the adverts, while receiving a phone call, or switching it to 'energy saving mode'. HUS2-15 described that HUS gave an opportunity for his children to learn about TV function of 'energy saving mode'. In addition, some participants used the other lower consuming devices to replace the entertainment of TV such as 'reading' (HUS2-03) or 'instead listen to radio'. For example, HUS2-16 described an instance of making alternative decision during leisure time: *"But I found myself thinking, 'well, I just want to relax and watch TV, but I have to pedal', and 'maybe I just listen to radio instead'. So I kind of avoided the TV because of that"*. It can be seen that these behaviours are, at some level, linked with 'introjected regulation' where WB use induced a psychological motive of avoiding 'anxiety'. For example, many households performed behaviours that avoid from losing the credit that they generated; therefore, most of times, *"they usually leave the TV on and walk out the room, but I don't think it happened this time. They were switching it off once they go out"* (HUS2-15). Whereas HUS2-09 was frequent radio listener who uses TV radio function, but she described how it change: *"with the radio taking into account that we did have to cycle, we ended up either playing it through one of our phones on the speakers, or just not having it on in the morning"*. HUS2-03 also changed the behaviour to be more 'curtailment' as she discontinued to leave the TV on as background noise.

The meaning of 'energy saving behaviour' can be seen differently with the use of WB system. The terminology can be used to refer those behaviours that curves overall energy consumption. However, in the case of WB use, the meaning applies to behaviour that attempts to minimise the credit (generated energy) loss, routinised behaviour performed for conservative effort, or formation of human-power generating habits. Within the process of 'internalisation', many instances were coded, categorised, and clustered under theme of 'energy saving behaviour'. However, these codes also significantly related to other hierarchal codes that accounted the locus of causality for each phase of 'Internalisation' process.

8.6.4.2 Parasitic HPP

During the interview, it was observed that many participant had idea of using human-power in more ancillary way. Discussion around this type of idea were not based on using the 'sub-conscious' generation, but mostly related to utilising the daily muscle exertion. Most of the idea were related to 'Gym' or 'exercising machine', e.g. *"if you have 20,000 people running through your gym everyday… how about it? It will make sense"* (HUS2-08). Some participants were already aware of 'parasitic HPP' examples like Pavegen[55] (HUS2-08,14), others mentioned new technology such as electro-yarn (HUS2-04), but rest of the idea/comments were related to use of human-power generated from people in the gym.

8.6.4.3 Technical issue with 'White Box'

The WB was not a product of a completed design project but more like a prototype for HUS. Therefore, it did not always function as intended. This instance occurred during HUS with HUS2-14. The device failed to keep the meter reading, therefore, the size of potential saving had to be speculated. However, since the study did not primarily focus on retrieving the quantifiable data, the instance did not significantly hinder the quality of interview data.

On the other hand, many participant also favoured the eBike as it didn't make any noise. Many had mentioned how they were 'impressed' with its technical quality. Since all participants were not aware that this eBike was a 'fake' material, it brings

[55] http://www.pavegen.com/ , tile of panel that harvests energy from peoples' footstep.

to a point that such ‘noise’ may be a critical variable upon making decision to continue carry as domestic product.

8.7 The Quantitative result

Although the HUS study and its data collection method was more oriented towards being qualitative, some quantitative results were gathered that are worth to consider. These data were originally planned to use during the interview to inform participants about the possible external benefit. The purpose was to understand how their motivation may change as they encounter those figures. However, as the HUS revealed the importance of ‘double dividend’ strategy, the analysis included a detail breakdown of possible ‘external benefits’ that occurred during the HUS period.

Table 8-3 shows the detail breakdown of each households TV consumptions and changes made through HUS stage 2.

HUS stage 2 - Statistic Table

Household	# of occupants	TV (Watt)	Hrs - Prev	Hrs - HUS	Time Saved	Up/Down	Calories	Travelled	KWH - Prev	KWH - HUS	Up / Down	Cost Saved
1	2	35	2	1.6	0.4		1,358	30 km	0.5	0.395		£0.06
2	1	175	2.2	1.14	1.06		4,813	106 km	2.8	1.4		£0.20
3	6	120	7.5	2.9	4.6		8,470	186 km	6.7	2.496		£0.36
4	4	40	5	7.4	-2.4		13,073	288 km	1.43	2.08		£0.30
5	3	82	4.14	1.5	2.64		2,410	53 km	3.74	0.738		£0.11
6	2	161	2.6	1.4	1.2		5,500	121 km	3.02	1.61		£0.23
7	2	90	2.7	1.7	1		3,666	81 km	1.5	0.72		£0.10
8	4	62	4	3.3	0.7		4,861	107 km	1.75	1.457		£0.21
9	4	135	7.37	3	4.37		11,170	246 km	6.97	2.835		£0.40
	3.11	**100 W**	**4.17**	**2.66**		8/9	**55,321**	**1217 km**			8/9	**£1.97**
		Avg.	Avg. Hrs	Avg. Hrs			Total	Total				Total
		A		B			C	D				E

Table 8-3 HUS Stage 2 Statistic Table

As mentioned before, meter reading on one household was not retrieved, therefore the data from this household was not included in the table. As table shows, average TV wattage within 9 household was 100 watt (see ‘A’), which is closer to average wattage (110 W) set for WB system. Depending on the TV wattage for each household, the time of pedalling were varied. For example, household #1 had a TV consumption rate of 35 watt which would have given approximately 90 minutes of TV watching from 30 minutes of pedalling. Whereas, household #6 had wattage of 161 which would have given only 45 minutes of TV watching power from 30 minutes of pedalling. Interestingly, most of participants responded in the survey with lower TV watching hours compared to their actual average measured during the HUS. However, the survey responses may only apply to respondent’s individual time watching, rather than accumulated for all household occupants. Nevertheless, an average of 4.17 hours (see ‘B’) of TV watching was measured which is very closer to statistics reported by Ofcom (2013) which is 241 minutes per day.

Only single household showed increase of TV watching, whereas all 8 other household’s TV usage time has decreased during the week. The decreased amount ranged from maximum of 4.37 hours to minimum of 0.4 hours reduced on average. Only Household #4 increased their TV usage with an average increase of 2.4 hours. Total calories burned by all 9 participant were 55,321 calories (see ‘C’), and the distance of 1217 kilometres (see ‘D’) travelled (a return road trip from London to Edinburgh). Dean (2008) has provided a calculation that 380 calories are required to power 100 watt colour TV for an hour. If same calculation is used with HUS data, it equals to 146 hours of TV running power generated by all households.

However, total incentive generated by all 9 household can still be seen as ‘disappointing’ as it is only £1.97 (see ‘E’). On the other hand, a speculative calculation may give more weight to this figure and helps to realise its potential when WB users increases. Consider the scenario of 1% of household in UK using the WB system, it generates approximately £3 million of money saving each year[56].

[56] £1.97 / 9 household = £0.21, £0.21 x 52 weeks = £11.38 per year saving. £11.38 x 1 % of UK household number (26.4 million) = £3 million. The number of UK household was referenced from http://www.ons.gov.uk/ons/rel/family-demography/families-and-households/2013/stb-families.html

The coercion designed in the prototype of 'white box' did generate some irritation and few participants have commented the possibility of resistance towards further use of WB. However, all above figures define the actual 'external benefit' gained upon success of 'internalisation of HPP use'. From individual perspective, this value may not be significant to maintain the use of such eHPP; but on the other hand, the value may appear as much greater when number of users increase.

8.8 Email survey

A follow up email was sent to all participant on January 2014. Total of 6 participants have replied to email asking for their after-thoughts on WB use. The email requested their comments based on whether their behaviour have changed or for reporting on any additional curtailment behaviour performed after the HUS.

From their emails, it was reported that no participants have performed any curtailment behaviour nor commented that their attitude have changed in relation to energy consumption. However, these comments were followed by reasons that *"this is mainly because we were very energy conscious before the trail"* (HUS2-12). 4 other participants gave the same reason.

Few participants had mentioned that they miss the experience as HUS encouraged them to *"gave me a good opportunity to exercise during the evening and encouraged it so that I could watch the news"* (HUS2-08), and other participants mentioned that *"we would love to have a bike to power telly all the time, get fit save energy and earn your reward of TV"* (HUS2-05). All these comments still relates to pre-defined benefit of 'health gain' and, although little, the 'energy saving'.

Interestingly, participant HUS2-15 had found the HUS as a motivator to build more interest towards the idea of HPP which eventually made him to build a bespoke bike exercise machine. As he described, his future plan will involve transforming those exercising energy into human-power system.

The definition of 'sustainable energy consumption' has been defined earlier in this thesis as 'a conscious choice of using products (and their usage behaviour) with the goal of reducing energy consumption'. Martiskaïnen (2008) has classified that both 'efficiency behaviour' and 'curtailment behaviour' as types of household 'energy saving behaviour'. As it is evident through HUS that 'curtailment behaviour' were observed and regarding their motivation to participate in HUS as a decision of performing 'efficiency behaviour', it is argued that design of WB has induced a 'Internalisation of HPP use' at practice level and helped them to practice 'energy saving behaviour' around TV usage. However, the result of HUS and these email responses proves that WB did not succeed in influencing behavioural change on a wider scope. Given these points, it can be concluded that WB as product-led intervention did instigate participants to practice 'energy saving behaviour'; however, it was not sufficient to induce motivation for 'sustainable energy consumption' at overall household energy consumption. In the beginning of this research, the title of this thesis was determined as 'Switching the human-power back on: using human-power as motivator for sustainable energy consumption'. However, after HUS analysis, serious review on this title was inevitable as it may argue for behaviours not covered through current research. Therefore, these email responses have affected on the decision of changing the title to current state: 'Switching the human-power back on: domesticating human-power to practice energy saving behaviour'.

Another cause for insufficient influence suspects to be the absence of intervention. A study has reported that no long-term habit or energy-conscious attitude has occurred during the post-intervention stage, even though the investigation last for 3 years (Darby, 2006; Dwyer *et al.*, 1993). In the same context, it is assumed that no further influence will be identified unless intervention is used by intended users.

8.9 Conclusion

This chapter addressed the fourth objective which was to validate and theorise the 'HPP Internalisation Model' with publics in interest of HPP - recruitment through appropriate sampling process. In this chapter, an artefact (WB system) was developed and functioned as a specific instantiation of proposed conceptual framework along with integrating dimensions suggested through 'HPP Internalisation Model'. Through evaluating this model, the analysis described the relationship, process, actions, and influences between phenomena caused during WB use. The result of HUS stage 2 produced extensive knowledge upon constructing the theory for this research and it emerged as guidance of designing future eHPP for both researcher and for practitioners.

Following a concept of ‘research through design’, instead of developing an artefact from researcher’s own theoretical perspective, iteration elements were empirically identified through conducting multiple case studies. In between, measurable results were obtained through survey that gave more weights to the validity of those design iterations and as well as selecting appropriate sampling unit. Moreover, strategies of behavioural change has been carefully reviewed and key techniques were applied to induce change of behaviour at practice level. For understanding the dynamics of daily life of using WB system, the research has chosen a common product (TV) to draw discussions which accounted the relationship between the user and object, and around topic of using ‘human-power’ to practice energy saving behaviour.

All conducted studies and their analysis reported in section 3 of this thesis showed comprehensive exploration and iteration to reach to current outcome. Through undertaking research into substantive area of HPP study, that is the actual ‘use-phase’; it showed the process of understanding the real-world problem and suggested design iterations were evaluated through series of ‘Home-User-Study’. ‘Domestication’ (Routarinne, 2009) probe study was conducted as a means to elicit knowledge of how participants of HUS stage 2 progressed through internalising the WB use and to understand how each dimensions of ‘HPP Internalisation model’ have affected in bringing that process.

One of the most intriguing result was the phenomenon related with ‘Feedback’ system. It was hypothesised by Deci and Ryan (2000) that extrinsic motivations can be controlled invariable to the extent to which they are self-determined as they enact the regulations. Within the internalisation process of eHPP use, it was evident that ‘feedback’ plays crucial role in inducing new behaviour and to regulate them upon their goal. In pursuit of these action, behaviour determinants were derived from commitment of achieving the goal pledged by themselves. In understanding the ‘perceived behaviour control’, the information delivered through feedback system helped eHPP user to realise the new options, having volitional control, and made decision to perform the new behaviours based on their set goal.

However, it is also evident that the size of 'incentive' arising from the use of eHPP is not sufficient to draw significant motivational impact. Nevertheless, the users of eHPP acknowledged the entailing increase of those incentives upon their continuous use. Participants of HUS stage 2 not only perceived the 'incentive' as potential rewards, but the concept of 'double dividend' played significant role in gaining further motivation. As Stern (1999) suggests, combination of intervention is much more effective than applying sum of two to bring pro-environmental behaviour. In between the internalisation phases, participants realised various different form of benefits that mostly contributed towards putting those behaviour into routine. The concept such as 'take from earned', 'reward for effort', 'coercive punishment', and 'avoiding guilt' were motivational factors identified during the interview in which they account key aspects of each phase. During these identifications phase, they found satisfaction of the need for gaining more *competence* to control their regulations and realised the 'double dividend' benefit such as health or idea of having an empowerment to avoid passive energy consumption. Participants view on WB changed from expecting certain value of external benefit to more internal based motivation that primarily relate to 'egoistic value' (Stern, 2000) of attaining 'double dividend' (Jackson, 2005a). However, it is important to highlight that the system of 'feedback' is indispensable element in propelling the 'internalisation of HPP use', and user accepting these benefit simultaneously.

Beyond the 'double dividend' gains identified during the use of WB system, number of other behaviours were observed, e.g. curtailment behaviour around TV and WB use. These behaviours include actions such as reducing the TV watching time, using alternative entertainment device, using energy saving mode, and minimising the credit (human-power generated energy) loss. The changes of behaviour induced by WB system also produced quantitative data which needs considerable attention. These quantified figures define the detail of 'external benefit' gained upon success of internalisation, and they can be used to speculate and forecast the size of potential impact consequent to further use of eHPP.

Regrettably, the use of WB was not sufficient to bring greater impact that would motivate people to perform additional 'energy saving behaviour' with other EuP. However, these experience have given participants a great sense of interest towards the topic of ‘energy saving’ and acknowledging the alternative form of using the energy.

Section 4: Discussion & Conclusion

Chapter 9 Internalising HPP – The Theory

9.1 Introduction

Obsolescence of using human-power, or waste of HPP can be understood as symptom of expired motivation or empathy. Chapman (2005) has argued that certain empathy arise at the point of purchase, or at first use, and the longevity of product is dependent upon maintaining the sustainability of that empathy. While the concept of product longevity hopes to contribute for influencing on continuity of sustainable consumption; in a similar context, this research enquired the longevity of HPP in which the study focused on understanding its ‘use-phase’. Leading scholar in the field of HPP, Jansen (1997), has comprehensively and empirically proved the advantages of using HPP, and its financial benefits based on life cycle scenario. However, his study results left behind a new research enquiry of understanding whether those advantages become an efficacy in maintaining the stability of HPP use. Therefore, this research took a vital step in understanding the ‘use-phase’ and explored how intended behaviour of generating human-power gets reproduced, maintained, and internalised. In doing so, the research also posed additional research questions for understanding different kinds of motivational factors that affects on those behaviour determinants.

Affordances in HPP require user to change their precedent behaviour of consuming energy from non-renewable to ‘human-powered’ energy. Therefore, current research reviewed literature related to theories of behavioural change, and their intervention strategies of using ‘design’ to bring greater impact. However, all these studies emphasise that more attention should now be focused in designing the intervention that maintains the stability of changed behaviour, and inducing them into a ‘routine’ at practice level. Linking this notion with HPP, current research proposed a ‘HPP Internalisation Model’ which incorporated the design elements required in bringing the effect that can prolong the human-power use. Through conducting series of case studies with actual HPP users, this hypo-theoretical model was empirically iterated and final recommendations were integrated into research artefact which represented a design exemplar that induces a preferred state of HPP use. This theoretical model suggested a three dimensional, and interdependent to each other, constituent elements of design for bringing internalisation of HPP use, and perhaps to transcend its possible obsolescence. Below three sub-chapters explain the detail knowledge found for each dimensions of 'HPP Internalisation Theory Model'.

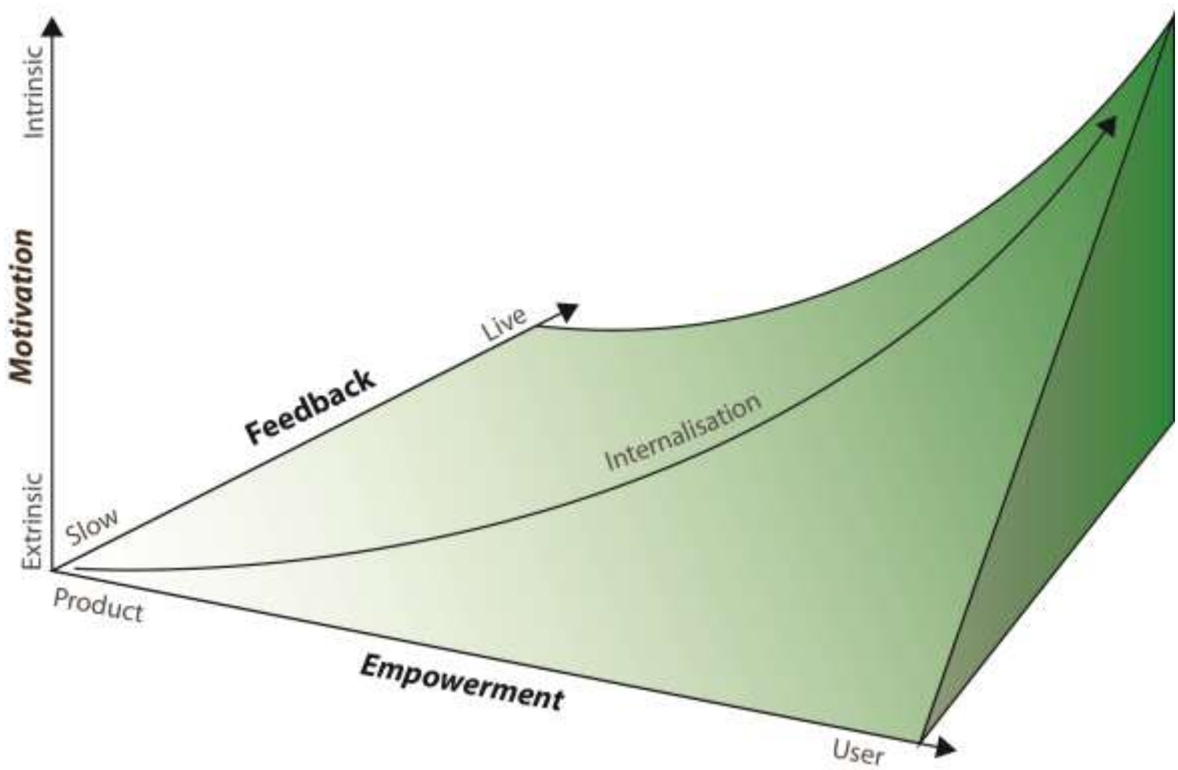

Figure 9.1 HPP Internalisation Theory Model (Final)

9.2 Empowerment

Device with having 'portable' power function have been perceived as one of main benefit of using HPP. This notion has already been argued by many scholars in the field of HPP. This benefit was often linked with what HPP is widely known as 'emergency use' among many publics. Through conducting the pilot and HUS stage 1, it was evident that peoples' view towards the use of HPP had similar perceptions. However, the concept of this portable power was also perceived as feature of 'available on demand' which enable user to have sense of empowerment that they no longer rely on the energy source from the grid. In HUS stage 2, it was evident that people found the use of human-power as a behaviour of insubordination against what Jelsma (1999) calls as 'black-boxed' scripts of daily EuP, where people often find themselves involuntarily in routine pattern of energy consumption over which they have little control (Sanne, 2002). The essence of using human-power emanates from intentions and motives of practicing alternative way of consuming energy which has been done passively to date.

However, it is also acknowledged that human actions are not predictable; therefore, scripts of inducing new behaviour may be resisted or refused. Therefore, researcher in the field have introduced product-led interventions that bring reduction of energy consumption through concept of 'sustainable by stealth' whereby it brings sustainable gain without necessarily modifying the existing routine of practice (Lilley *et al.*, 2005). Nevertheless, sense of concerns were discussed over notion that when essential everyday actions are 'trained' by machines, people's' autonomy will eventually be threatened (Brey, 2006). To some extent, these machines make goals and plans on behalf whereby humans become no-longer an autonomous decision maker. For this reason, one of early decision made during this research was excluding the exploration of 'parasitic harvesting' HPP. One of justification for this decision was based on the inconspicuous nature of consumption caused by use of electronic devices, which can be seen as 'mundane socio-technical system' (Latour, 1992). Therefore, it shared a view that new intervention should move from descriptive to inscriptive (Jelsma, 1999); avoiding from being inconspicuously controlled by another 'a mundane artefact' (Latour, 1992); delegating user to make choice of using alternative energy; and therefore giving empowerment to control their HPP usage.

This notion was also supported by Tang (2010) that when the power in decision-making lie upon the user, the motivation and acceptance of intervention may have greater effect. Therefore, while the 'parasitic' products sub-consciously utilise human-power, the dimension of 'empowerment' emphasise the ability of making a 'choice' and giving an empowerment to control their HPP usage behaviour.

During the HUS stage 2, it was also evident that having an empowerment to avoid passive energy consumption and motivation derived from the concept of 'reward for effort' were perceived to be strong intrinsic benefit that people gained through WB experience. Therefore, it is argued that this constituent element within the model is essential in bringing the internalisation of HPP use. At last, it is important to highlight that this element is interdependent with other dimensions, especially with ‘feedback’ in which its function account the key aspect of gaining the *competence* of HPP use and materialising the energy use from ‘inconspicuous’ to ‘conspicuous’ state.

9.3 Feedback

Probably, the most common words used throughout this thesis is the ‘feedback’ where its function has been perceived as central element in many related researches. Whether the research is related to behavioural change, or intervention related, it shares common view towards the profound role of ‘feedback’ as it provides consequential information of any intended behaviour. However, it was observed that existing eHPP lacks in providing these consequential information, and therefore, advantages of using these devices is unlikely to be understood by its user since they are delivered at ‘slow’ means. From behavioural change perspective, Stern (1999) has pointed out that these consequences (e.g. financial incentive) may influence on behavioural change but less likely to occur unless appropriate information makes individuals to be aware that incentives are available. It was evident through case studies that current design of feedback is not sufficient for HPP user to fully acknowledge the consequential information. Moreover, the information was very limited that people have difficulties in assessing the outcome of consequences; and understanding the ‘perceived behaviour control’ (Ajzen, 1991).

However, it was also acknowledged that providing consequential information through system of ‘feedback’ does not necessarily bring affirmative outcome. The anticipated behavioural change can sometimes be absent due the disconnection between the information data and everyday practices. Therefore, it emphasised that feedback system must be designed in a way that encourages a user to instigate behavioural change from self-regulated-efficacy. In making those regulations of behaviour, it was argued that multiple intervention strategy of using both feedback and goal-setting becomes fundamental. In HUS stage 1, it was evident that feedback system on existing eHPP hinders user to progress through internalisation process. It was observed that these users build their *competence* based on ‘probability’ and prediction on its system potential; therefore, users were faced with difficulties in making conscious valuing of behavioural goal. Scholars (e.g. Abrahamse *et al.*, 2005) have argued that continuous feedback in conjunction with goal-setting is more effective in bringing new behaviour and to maintain them. Moreover, it was suggested that the function of feedback becomes a formation of habit, going through process of routine actions being set and reinforced; and lastly to internalise the behaviour (Van Houwelingen and Van Raaij, 1989). All above findings suggested that system of feedback or its interface on eHPP must provide the real-time (live) consequences which links the behavioural determinants with the possible goal set by the users. This notion strongly linked with what Wever *et al.* (2008) argues as 'inducing sustainable use' whereby the design of WB feedback used both 'eco-feedback' and 'scripting' approach to allow user to gain their own *competence* 'in a more or less forceful way' (Jelsma and Knot, 2002) upon their motivations. For bringing more effective internalisation process, the regulations set by these users must be realised in which the function of feedback confronts user with consequences of people's actions in real-time means.

In HUS stage 2, it was evident that iterated feedback system on WB played a profound role for user to realise various different form of both internal and external benefits. In between the phases of internalisation process, the behaviour determinants were derived from commitment of achieving the goal-set, and the feedback system played a key role in regulating them into a routine. Within the various different form of extrinsic motivations, the feedback system on WB availed them to gain what Deci and Ryan (2000) says as 'goal-related regulations'; and the need of autonomy and *competence* were identified, and they were integrated into daily practice. Thus, it is argued that designing appropriate feedback system on eHPP is indispensable element in propelling the 'internalisation of HPP use'.

The case study result highlighted the premise condition in designing the feedback of HPP. Jansen (2011) has argued that HPP must be designed to maximise the use of human-powered source by decreasing the power consumption of attached functions such as avoiding the stand-by modes and any energy consuming graphical user interfaces. His argument may conflict with current research finding; however, current research argues that without making user to internalise the HPP use, those identified advantages will unlikely to be realised during the 'use-phase'. Moreover, it was evident that 'incentive' generated by HPP system is not sufficient to motivate for further use. However, given that rapid growth of current technology related to batteries and energy efficiency, designing more 'interactive' feedback system becomes more practical.

9.4 Motivation

The last constituent element of bringing the internalisation of HPP use is the 'motivation'. The idea of using parasitic harvesting methods on HPP originates from resolving the issue of requiring deliberate muscle effort during power generation. Jansen and Slob (2003) describes this type of physical stress as 'added discomfort'. It was noted that main challenges for designing HPP is how to reduce this required 'labour'. Therefore, some HPP examples have been using the technique of designing the interaction involved in applying this kinetic energy to be compensated by other form of motivation such as 'fun'. However, it was noted that there are downsides of this kind of motivation. The feedback on this type of HPP provides how 'fun' the related activity can be. Thus, there may be a risk of people using such device as a 'standalone' rather accepting its role as a device for generating alternative energy resource. In other words, the motivation for using such device may not be around the notion of generating resource but it may be based on its user-centeredness, i.e. designed around 'fun' and 'play' interactions. As argued by Jackson (2005b), when behaviours are strongly regulated or reinforced by external factors, in this case the 'fun' aspect, it may show a weakness in linking the their attitude with related behaviour, i.e. 'power generation' when using HPP. Therefore, it is argued that these types of HPP application may derive motivation to use the system of HPP, but it may not link the attitude of 'power generation' to their intended activity.

De Young (1993) argues that 'intrinsic motivation' may reduce the side effects of intervention by making individuals discover a behaviour that is worth doing for its own right. For Ryan and Deci (2000), intrinsically motivated behaviour is defined as when individual find the activity interesting enough even in the absence of operationally separable consequences. Deci and Ryan (2000) argued that intrinsically motivated behaviours do not depend on reinforcements since undertaking activities that are interesting in itself are intrinsically rewarding.

However, not all behaviours are performed through intrinsic motivations. Ajzen (1991) argued that new behaviour can be predicted through ‘perceived behaviour control’ whereby people assess the outcome of consequences and make it into a belief as to how easy or difficult that behaviour is. Nevertheless, it was acknowledged that intrinsic and/or extrinsic motivations are a driving force for human behaviour and that the later fosters the former motivations to repeat the intended behaviour. Although many HPP users accept its use from ‘interest’ (intrinsic motivation), it was evident through HUS that the size of entailing incentives (external motivation) are far less to be a significant motivator for further use. Ryan and Deci (2000) argued that people feel subsequently less motivated as they feel controlled by extrinsic motivation. However, they have argued that extrinsic motivations can be controlled invariably to the extent where people become self-determined as they enact the regulations - the ‘Internalisation’. The ‘internalised’ extrinsic motivation can be controlled, sometimes punished or become autonomous through use of instrumentality such as an ‘intervention’.

However, in the case of HPP use, it was evident that use of HPP may expose user to feel ‘double-loss’ as both internal (added discomfort) and external (relatively little saving) factors hinders the motivation for sustaining the HPP use. Therefore, it was acknowledged that increasing the size of entailing incentive may not be an only solution, but much attention should be given to strategy of inducing more autonomous form of motivation. In pursuit of this enquiry, current research referred to the concept of ‘double dividend’ strategy where the design of HPP provides additional psychological motives, although still extrinsic, to maintain the changed behaviour, e.g. flower lamp (reduce energy consumption through aesthetical reward) or bicycle (gaining health through travelling).

But most importantly, in understanding those various form of controlled motivations, it solely relies on how the system of ‘feedback’ on HPP interact with the actual users. This point advocates the notion that all three dimensions are interdependent to each other. Along with the designed feedback on WB, various different form of regulations were reported by HUS stage 2 participants. These behaviours did not always progressed through each phase of ‘Internalisation process’; which is ‘external regulation’, ‘introjected regulation’, ‘identified regulation’ and ‘integrated regulation’. Rather, it was observed that participants relatively internalise a new behaviour regulation in between any given developing continuum. Some level of 'intrinsic motivation' was also situated where users found the activity of using HPP as 'enjoyment', but again, this intrinsic motivation derived from acknowledging the potential 'double dividend' gains premised upon their continuous use. However, it is very important to define this 'double dividend'. It was evident that this combined form of benefit can vary upon user's goal, value, or belief. Results of HUS stage 2 showed that type of dividend can either be; the size of entailing and forthcoming incentive, egoistic value, personal achievements, and health. But above all, it points to the notion that the 'HPP Internalisation Theory Model' encourage product longevity through making the activity as durable as user acknowledges these internal 'double dividends'.

To reemphasise the interdependency of each dimensions, the feedback and sense of empower enable the HPP users to gain *competence* of having control, regulating their behaviour (e.g. goal-set), and internalising them into a routine practice. As Ryan and Deci (2000) puts, the feeling of competence will not enhance intrinsic motivation unless they are accompanied by a sense of autonomy.

9.5 Designing HPP as intervention (Conclusion)

The aim of this thesis was set to investigate how the 'use of human-power' and designed interactions in HPP could lead to interventions for instigating changes in attitude and behaviour in regards to energy use and consumption. More specifically, the focus was to design new interactivity of HPP – as a means of de-routinising the current habitual energy consumption, and making individual to make conscious choices of using HPP with the goal of reducing energy consumption. In relation to this aim set of research objectives were formulated for main study.

While the examples of existing product-led interventions attempt to either curve or raise awareness to overall energy consumption, the attempt of deploying WB as intervention was not sufficient to induce motivation for 'sustainable energy consumption' at overall household energy consumption. However, it was evident that intervention of WB contributed as to increase the awareness of energy use in general. But the result of HUS and follow-up email responses proves that experience with WB was not sufficient to bring greater impact on a wider scope that would motivate people to perform additional ‘energy saving behaviour’ with other EuP. Given these points, it can be concluded that WB as product-led intervention did instigate participants to practice ‘energy saving behaviour’ around the selected ‘material’ (TV); however, it did not necessarily affected on changing their behaviour to lower the energy consumption at macro level.

In addition to ‘added discomfort-ness’ of applying human-power, it was evident that people find the use of human-power as ‘obsoleted power source’, and regarded as *‘it is almost feel like step back’* (HUS1-1). It is such difficult task to apply this old-fashioned human-power for whom inconspicuously consumes electricity through use of everyday EuP. However, it was revealed that certain HPP does not perceived in the same way, e.g. bicycle, hand whisk, and Coffee grinder. From ‘practice theory’ perspective, the *meaning* component of riding a bicycle enable user to make sense of the activities through positive emotions, purposes, and belief that potentially transcend the obsolescence. People viewed this kind of mechanical HPP as an activity of bringing ‘nostalgic’ or reminisce the pre-established *competence* that is gained from long-ago experience and has been sustained for so long. This notion has applied in the design of WB where it used the technique of ‘pedalling’ to generate the energy, to avoid any rejection arising from complex usability. Therefore, this research suggests that using the pre-established and sustained competence from existing HPP as technique of power generating, will become much effective when adopting HPP as intervention.

Chapter 10 Conclusion

10.1 Conceptual contribution

This research took an exploration into particular products which use human-power as main power source or to power everyday electronics. It viewed the ‘product’ not merely as an object that simply generates ‘free energy’, but instead considered as object that people can make sense of, and as a tool to practice energy saving behaviour. This research emphasised for the notion of sustainable life style by conceptualising the possible future scenario of how everyday product can be redesigned and developed to encourage energy saving behaviour.

As indicated in the literature review, there is lack of relevant literature in the research field of human-powered products. So far, the study on HPP mainly circled around identifying the barriers and suggestions in the design of human-powered energy systems and broadening the knowledge required during the design process of related products based upon a scientific approach (Jansen, 2011). Therefore, current research undertook the work into substantive area of HPP study that is understanding the actual ‘use-phase’. The research findings suggest methods of approaching HPP design that explore potential solution dealing with the broad and from diverse perspectives, understanding entangled relationships between artefacts, behaviours and experiences of daily practice arising from the use of HPP. Not only identifying the need of scientific or technological development in HPP to encourage its sustainable use, this research emphasise on the need of exploring other form of benefits arising from applying human-power as alternative to electricity/grid power. The findings suggest a theory of designing such value into HPP to increase the empathy arising in between product and user relationship which leads to its sustainable use.

This research began from a belief that sustainability is a problem of behaviour, not a product or resource. Therefore, the research contribute as a case study into academic study of behavioural change in relation to energy consumption. Many experts argue for the need of discursive or often conscious engagement between subject and object, bringing user into discourse for raising the awareness to people’s consumption. HPP can be considered as intervention of engagement through product that de-routinise current habitual behaviour, empowering alternative mode of energy consumption and providing personalised control over it. Therefore, this research contributes towards building sufficient real data on effectiveness of design intervention studies in relation to behaviour change towards sustainable energy consumption. This study has therefore used the social practice theory to investigate how people practice the use of HPP. It has explored different variables that influence in bringing the process of internalisation, new habits and perpetuation of using such device for longer-term perspective, and to practice energy saving behaviour. In the context of inducing energy saving behaviour through product-led intervention, current research explored design applications that are beyond the traditional understanding of user-centred design but making energy-saving activities relatively more attractive. It has considered not only from user-centred design point but also from accepting the notion that *meaning*, *material*, and *competence* are included as elements in the constitution of practice. Therefore, the series of HUS has cross-fertilised the practice theory to investigate how each element of practice affects the usage of HPP. This research has therefore contributed to current knowledge by bringing social-psychological theories and strategies of ‘design for sustainable behaviour’ together to develop, iterate, and evaluate the theoretical model of ‘HPP Internalisation Model’.

In order to maintain induced behaviour, the *competence* must arise in between the *materials* and *meaning* related to those activities. Not simply aiming to design another commodity, this research approached by paying more attention to how interdependent practices and habits of using HPP get organised and performed in everyday life. Therefore, case studies were conducted in congruence to follow the concept of ‘practice-as-entity’ (Røpke, 2009), understanding the role of *meaning, material, competence* in using HPP, as it requires user to perform a new practice. Research followed a concept of ‘Research through Design’ (Frayling, 1993) to develop a new *material* in which this element played profound role in constituting patterns of behaviour and to form a mental activities while performing the practice of HPP use. The research artefact (WB) functions as an instantiation of ‘HPP Internalisation Model’ along with its conceptual framework. The result of main study described the relationship, process or action, and influences between phenomena that account the explanatory concept for each dimensions of ‘HPP Internalisation Model’. The artefact was not merely as a passive tool involved in the performance of everyday practices, but it became a ‘practically useful’ (Shove *et al.*, 2007) in reproduction of new practices around HPP use.

The result of this research is still closer to the beginning of generating knowledge towards the development of HPP design theory. Therefore, there is still outstanding knowledge to be explored as in academic discipline. Rather than starting a research with clear hypotheses, the research questions were formulated in the matter of provoking more detail questions to understand the real world problem around HPP use. As this research takes grounded approaches to research through design tradition, the artefact used in the case study and its development process serves as an instrument to make proposition of ‘what could/should be’, linking the current state of using HPP to proposed and preferred state – using human-power to practice energy saving behaviour. The proposition lay a foundation, as Zimmerman and Forlizzi (2008) describe as ‘nascent theory of the near future’, emerging as guidance in designing HPP for both researchers and practitioners in the field of HPP study.

10.2 Contribution as research

Initial research questions were generated on the basis to absence of significant prior work in the related field. While recognising the extensive knowledge investigated by (Jansen, 2011) in relation to design of HPP system, no such theoretical framework has been discussed or explored in relation to how people use HPP in their daily practice. This research is one of the first qualitative field studies to be carried out with households who have personal interest in using HPP and being an one of the few doctoral research, the contribution should be treated as outcome of its process. Rather seeing it as building a framework to continue the analysis, it established a template for further development of the theory found. In this context, the validity of current research should not be examined upon how results are related to previous research, or vice versa. Rather, it highlighted the opportunity in terms of new research preposition within the study of HPP, focusing on the use-phase to help better use the HPP. The theory of ‘HPP Internalisation Model’ should therefore be treated as a nascent theory, setting up a new research agenda for further refinement. Until further evidences are collected and compared to current study, the validity and credibility of current research should not be simply judged based upon scientific paradigm. Instead, it should be regarded as a theory to grow as part of research discourse which requires future researchers to refute, refine, and extend the knowledge in the field of HPP.

The work undertaken in defining the different attributes involved in HPP and the series of ‘HPP Interaction Matrix’ would assist designers at practical level to decide the strategy of utilising the human-power in diverse means. Also, the process of developing this matrix became the foundation of theoretical conceptual model for inducing internalised use of HPP. The LCA study conducted in this research addressed the major deficiencies of current HPP performance. The result shed light on the opportunity and emphasised on the importance of ‘design’ that may expand the life cycle to bring greater impact upon their longevity.

Whilst this research has made significant contributions to knowledge, it is worth considering the limitations of this research in order to put the accrued knowledge into context. It was noted that one of the main drawbacks on using LCA software such as SIMPRO is the inconsistency between LCA studies. The issue appears to be caused from different researchers selecting subjective choices, therefore, impossible to relate new LCA calculations to existing studies (Andrae and Andersen, 2010). Therefore, the objective of this LCA study was not to cross examine any results with Jansen’s LCA study but to provide speculative quantifiable data to find the answers of raised enquires. In doing so, inventory data can be seen as ‘subjective’, meaning that data is not reviewed by any third party expert but inputted based on researcher’s knowledge with the help of internal experts in the University. Upon the availability of real data from the manufacturer, the result would have produced more detail and affirmative form of results.

10.3 Summary of contribution to knowledge

In summary, this thesis has contributed to knowledge in the following areas:

- It viewed the ‘use of human-power’ not merely as technology of generating ‘free energy’, but instead as a tool to help household practice energy saving behaviour. Therefore, it offers a number of outstanding research opportunities beyond traditional study of HPP.

- Developed a series of taxonomy (HPP Interaction Matrix) that help to classify HPP into different domains. It can be used as a tool to forecast future concepts and avail designers in deciding product attribute among various different types of input (human-power interaction) and output (types of functional power) of HPP.

- Addressed major deficiencies of current HPP performance through LCA Study. The result highlights the opportunity and emphasises on the importance of 'design' element that can expand the life cycle to bring greater impact upon their longevity.

- The research undertook the work into substantive area of HPP study that is understanding the actual 'use-phase' - understanding the role of *meaning, material, and competence* when using HPP. In doing so, it revealed the real world problems during the use of HPP device, and offered an explanatory framework for theorising the process of behavioural change using preferred state of HPP use.

- Broadened and contributed concrete knowledge to current study of eHPP. It incorporated social-psychological theories and strategies of 'design for sustainable behaviour' together to propose a 'HPP Internalisation Model'. Through evaluation, the research developed a nascent theory which recommends the imperative design elements required in bringing the effect that can prolong the human-power use.

- Developed empirical evidences to contribute as case study data, investigating the effectiveness of design intervention in relation to behaviour change and towards 'design for sustainable behaviour'.

- The outcome serves as building a framework to continue the analysis, established a template for further development of the theory found.

Figure 10.1 shows the overview of contribution to knowledge in a diagrammatic format. All research methods were applied and contributed towards embodying the evolving versions of ‘HPP Interaction Matrix’. The HUS stage 2 were guided by empirically developed conceptual framework which later became the theory of this thesis - ‘HPP Internalisation Model’.

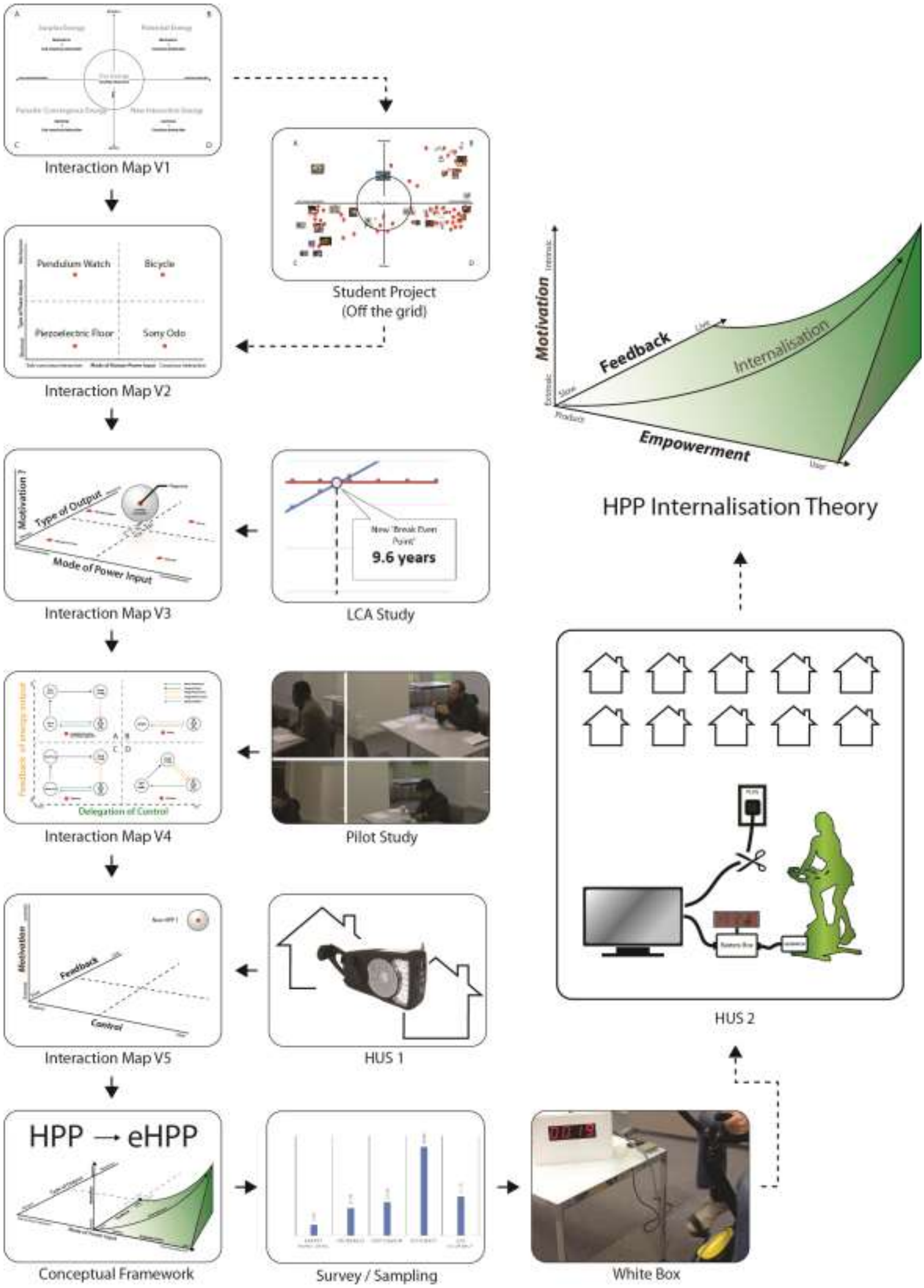

Figure 10.1 Overview of contribution to knowledge

10.4 Research Recommendation

Within the time and budget of doctoral research, it was not able to carry the HUS study longer than 1 week. There were total of 3 visits to each households that required total period of 3 weeks. Therefore, the total duration of conducting HUS with 10 household nearly took 5 months. Under this reason, current research leave outstanding opportunity for future research to further investigate the obsolescence and effectiveness of 'HPP internalisation Model' through longitudinal study (5 to 6 months). It should also be stressed, however, that results from HUS stage 2 is based on a single case study with 10 embedded units (households) and, as such, excessive generalisations should be avoided. Instead, further research and 'domestication probe', particularly comparing the WB with 'no feedback', appears to be absolutely vital. Therefore, set of HUS stage 3 is recommended as future research opportunity, using the theoretical replication in the development and refinement of proposed theory.

For empirical reasons, the main focus in the process of developing WB system considered designing only a single type of feedback system. This offers future research to implement various forms of feedback system such as metaphoric display or aesthetical form of display other than digital number which may enhance the psychological motives during HPP interaction.

Figure 10.2 New Feedback design for future HUS

Figure 10.2 shows the rendering of new WB concept design. This new design emulated the Flower Lamp (Figure 2.26) strategy where it provides psychological factors of ‘aesthetically rewarding’ symbolic flower to influence on motivation to apply human-power and controlling their usage. As user stores the energy into WB, the flower blooms, and vice versa. The concept depicts the possible new form of feedback system that can be used for future HUS study; therefore, this design should only be considered as ‘concept’ not as an essential design element.

10.4.1 For parasitic harvesting HPP

This research has taken longer period of identifying the exact ‘research gap’ for this thesis. First, the research has started with a notion of exploring and contributing knowledge towards the use of ‘human-power’ that is either using parasitic or direct application of use. The intention of starting this doctoral research has originated from the work undertaken at author’s undergraduate design project which has brought many attention across the University. The project resulted in developing a dynamo that uses a flywheel system and improved design engineering which reduces the number of human-power charging attempts, and at same time, generate enough power to drive portable electronics. With having an actual working dynamo, 2 additional design concepts were proposed where each used the idea of ‘direct application’ and ‘parasitic harvesting’. Whist still having interests towards investigating the essence of ‘HPP’ in the beginning of this PhD research, it resulted in spending significant amount of time to reach to the point of deciding to exempt the further exploration of ‘parasitic’ concepts. This decision still leave much to be desired in terms of exploring its feasibility, following similar research methods used in this study – applying the ‘HPP internalisation Theory’ for designing parasitic concepts. Particularly, it offers opportunity in understanding how the ‘feedback’ system can avoid it being another ‘mundane artefact’ that generates ‘free energy’; but more importantly, investigating it as an object that increases value to celebrate the use of HPP.

It is also author’s hope that all ‘parasitic’ HPP should not be considered as a mundane object that generates ‘free energy’. Future studies should not primarily focus on increasing the further external gains through use of these system, but it should consider designing the feedback system to relate internal factors so that it avails activating those behaviour with a sense of awareness to energy use.

10.5 Final Conclusion

The work carried out through this doctoral research should be seen as the first attempt in casting a theory for designing human-powered products. The motivation of this research derived from a belief that human emits energy from everyday behaviour; however, the use of this energy source has been languished over period of time. Therefore, the result of this research provides significant information and knowledge to rediscover its potential; and measures to encourage using human-power as main power source for everyday EuPs. As a final remark, it is hoped that this thesis and future research can contribute in making people to attract the notion of ‘switching the ***human-power*** back on’ - the renewable energy source that is the cleanest, healthy and fun to use.

Chapter 11 References

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Chapter 12 Appendix

Appendix A

Student Project Part 1.

BA Product Design: Project 4

Handover: Week 19: Friday 3rd December 2010, Arkwright 006

Hand In: Week 20: Tuesday 7th December 2010, Arkwright 006

Everyday product pt1

Introduction

Everyday we interact with hundreds of products. These products range from mobile phones, swing doors and everything in-between. There are literally tons of products that we interact with as part of our daily routine. Because they work so well and we are so familiar with them we almost dismiss or forget their existence. What type of everyday products do you interact with?

The Brief

You are to produce an observational sheet consisting of products that you interact with the most in your daily routine.

The Approach

Observation is an essential part of the design process. Thorough observations sometimes lead you to realize numbers of design opportunities and it gives inspirations to generate innovative ideas. You are to produce an observational sheet (bingo game sheet), 5 boxes across and down, consists of 25 pictures of products that you interact with in daily basis. These can be any items that you physically interact with, such as phone, laptop, kettle, pots, keys, chairs. The template of the bingo sheet is downloadable from NOW. Selecting common items may help you to win the bingo, but remember that others may probably have the common items as well. Please refer to timetable and details of the deliverables to realize the project.

BA PD Design Projects, Project 3: Everyday Product Timetable
Friday 03/12/10

For Tuesday 7th:

- Over the weekend take photos of products you interact with in your daily routine.
- Observe what products you interact the most and what product you rarely use
- Download a bingo game template from NOW and fill every box with your products
- Write brief description for each product explaining how they interact with you as a user, at what occasion, and how often.

Tue 07/12/10

am

- Gather with your assigned tutorial group
- With your filled bingo sheet play a bingo within the team. Every member takes turn to call out an item. Who is the winner?
- Discuss between team members about the winning items and non selected items – As an individual, list items that are common and un-common (the template will be given after the game).
- Discuss and choose the 25 items to build a bingo sheet for group game
- Paste chosen photo of products onto given A3 Group bingo sheet
- Let's Play Bingo! - Group Game with bingo caller extraordinaire: Chris Lamerton! There is a prize for winners.
- Pin up both individual and group sheets

pm

- Project 4 pt2 Introduction

Deliverables

1. 1 x A3 Observational Sheet
2. 1 x A4 Common / Un-common list
3. 1 x A3 Observational Sheet for Group Game

Details of Deliverables

1. 1 x A3 Observational Sheet

The template(observational sheet_individual.ppt) will be downloadable from NOW. Insert your product pictures into each box. Write the name of each product in the description section and write a short sentence if required to explain the product. Email the PPT file to daniel.shin@ntu.ac.uk by 9 am, Monday 6th December. Please write the email subject as "project 4 observational sheet".

2. 1 x A4 Common / Un-common list

The template of this list will be handed out to you. List the items that are called out during bingo in the *common* section and the items that have not been called in the *Un-common* section.

3. 1 x A2 Observational Sheet for Group Game

The template of the A3 size bingo sheet will be given after the individual bingo. Discuss with your team members for selecting the items to insert into group bingo template. Discuss with team member for selecting between common items and non-common. Think about the layout when inserting the pictures. This strategy is the key to win the bingo.

Appendix B

Student Project Part 2.

BA Product Design: Project 4

Handover: **Week 20: Tuesday 07th December 2010**
Arkwright 006

Hand In: **Week 27: Tuesday 25th January 2011, Arkwright 006**
The hand in for the project will be assessed via a 'pin up' in the level one studio.

Off grid Everyday product pt2

Introduction

The quantity of electronic products in our consumer market is increasing. Electrical features have improved products' performance and in some ways usability of these products has improved and become more convenient. However, the majority of these products relies on energy from the power grid or uses batteries that must be changed or charged through a power connection. If we look around, we live in a life style where we unconsciously use excessive amount of energy through the use and consumption of everyday products. Energy is becoming an increasingly expensive and precious resource. In order for certain products to function they do not always require electricity. How would the product design(s) evolve if, as is currently the case in some cultures (and possibly more widespread in the future) there isn't a plentiful and reliable electricity supply?

The Brief

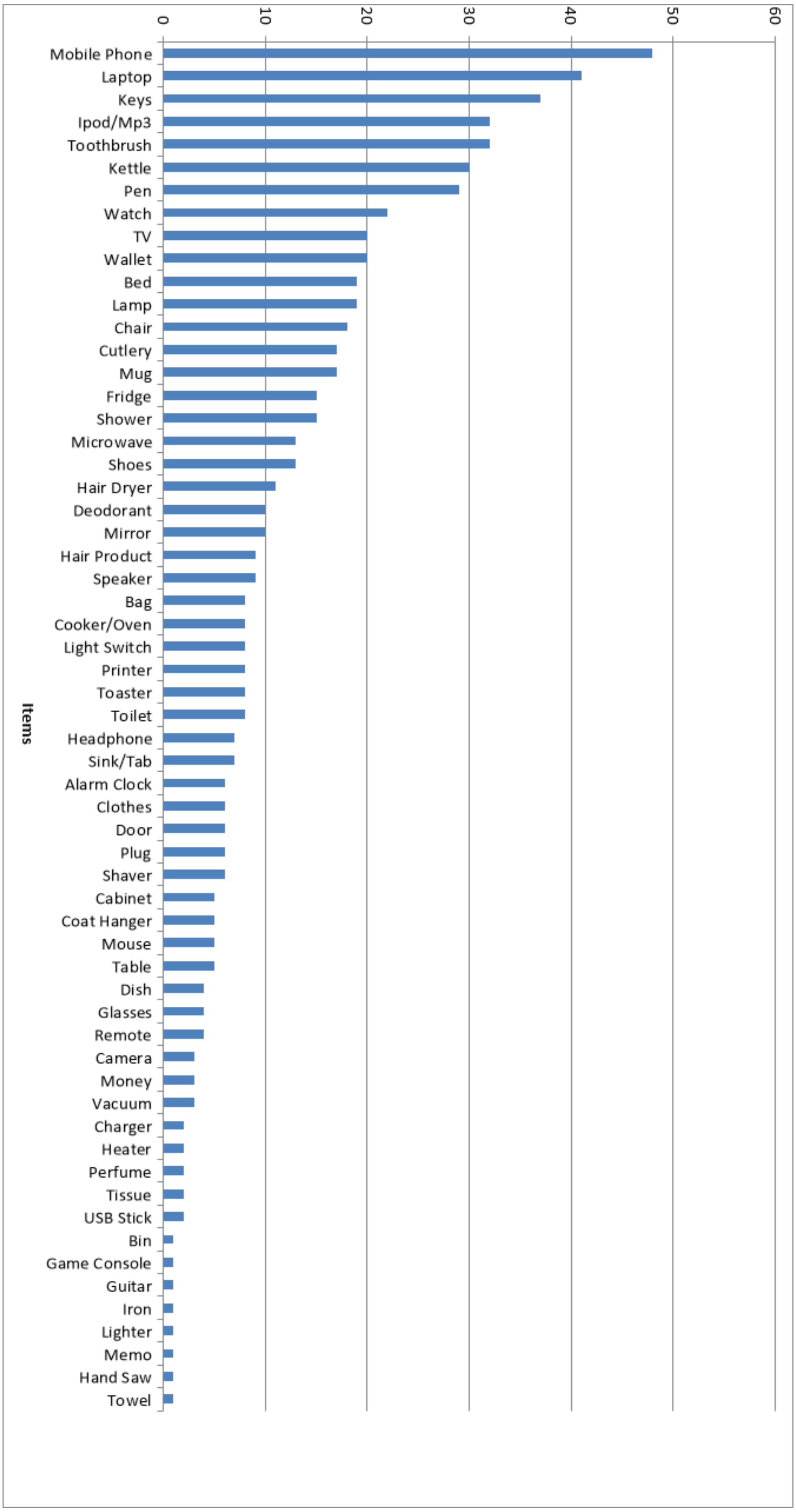
Choose 3 electric products from part 1 observational sheet and redesign your products so that it does not use electricity from power grid system. Observe research, design and present one final idea as a design proposal.

The Approach

Key to this project is for you to understand the functionality of a product and reinterpret it through a new design concept. Clearly understand how each product functions and see if you can find another innovative way to apply the same function of the product without it being plugged into the power socket. For example, if the fan's function is to lower the temperature of a room, then find a way to do this with new design idea that does not rely on power source from the grid. Please do not submit product ideas that use simple dynamo system or solar power for powering the device. If you are to use the dynamo or any other alternative power generating technology system for storing/powering the energy, design it in certain way that interacts beneficially with the user. Remember that your final result must be a design proposal not an introduction to new technology.

Take time to think about the products that you interact with in your everyday routine. You must begin with establishing a clear rationale for selecting these particular products for this project. Investigate how your selection of products has evolved through history. You must clearly understand why it was made, how it evolved, and what similar products exist in the market, and understand how they interact with the user. You must include a visual diary or real time photo showing the user experience of the product. Perform a thorough observation of the product and study how they work and what each functions of the product do. Try to understand how a product and the user interact together. Try to be specific as possible when you analyze the research. What type of technical/technological features does it include? Make a quick storyboard to imagine your idea being used and quick sketch models to test and visualize the practicality of your ideas.

Appendix C



0
10
20
30
40
50
60
Items
Mobile Phone
Laptop
Keys
Ipod/Mp3
Toothbrush
Kettle
Pen
Watch
TV
Wallet
Bed
Lamp
Chair
Cutlery
Mug
Fridge
Shower
Microwave
Shoes
Hair Dryer
Deodorant
Mirror
Hair Product
Speaker
Bag
Cooker/Oven
Light Switch
Printer
Toaster
Toilet
Headphone
Sink/Tab
Alarm Clock
Clothes
Door
Plug
Shaver
Cabinet
Coat Hanger
Mouse
Table
Dish
Glasses
Remote
Camera
Money
Vacuum
Charger
Heater
Perfume
Tissue
USB Stick
Bin
Game Console
Guitar
Iron
Lighter
Memo
Hand Saw
Towel

Appendix D

EmpowerToast-Cranker   Magic Brush

Students Concepts

Above figures show 3 speculative concepts resulted from this case study. Empower (Domain D): It is a human-powered alarm clock that generates electricity when the user pulls down upon the counter weight to switch the alarm off. The counter weight then recoils back to the original position. In doing so, this charges up the alarm clock for the next morning. It gears down the movement of the pulley to allow the inbuilt generator to convert the kinetic energy into electricity.

Toast-Cranker (Domain B): Inside the toaster and attached to the crank (which is rotated on the outside of the toaster), there are two metal substrates or plates When these two substrates rub against each other, heat is produced, and therefore the potential to create toast.

Magic Brush (Domain D): A roller brush, sweeping the carpet floor, is attached to a wand which contains a battery.. A dynamo is embedded inside the roller brush which allows the user to generate electricity as they sweep. A replaceable LED bulb and shade are attached on the top of the wand, expressed as a secondary function as a standing light. The user can detach the bulb if required when sweeping, and simply re-attach when used as a mobile standing light.

‘Off the grid project’ – full list of student concepts

Design Description	Map Sector
Solar charging Device	F
Ball charger for Wii	D
Twist Mp3	D
body heat mobile charger	E
Blender using push mechanism	B
Scrubing pad	B
foot pedal speaker	F
foot pedal generator for lighting	F
foot pedal generator for lighting	F
Shaking toothbrush	C
foot pedal generator	F
water pressure generator	F
Twist Charging shaver	B
Wind up toothbrush	B
Kinetic body wear charger	C
Shaking Speaker	C
Push Blender	B
Shaking remote controll	D
Roller charger	D
360 Rotating light	D
Gyroscope dynamo remote	D
Camara Zoom turning dynamo	C
Squeezing Phone	D
Roller carrier bag	C
Water tab dynamo	C
Squeezing camara	D
Water pressure powered toothbrush	B
Shaking toothbrush	D
Pulley Alarm Clock	D
Footstep generator	F
Metronome fan	D
Solar panel Light	E
power pad	F
Solar cooker	B
Remote	C
Bathroom Radio	D
Shoe Generator, Headphone	C
Footstep generator	F
Cycling generator	F
Wii controller	D
Solar mobile charger	E
Body heat mobile	E
Guitar with rolex tech	D
Body Heat MP3	E
Air ball squeeze charger	F
Pull cord torch	D
Solar charger	E
solar+kinetic iphone	D
Bicycle dynamo MP3	E
Shaking toothbrush	C
Balloon Alarm clock	B
Wii controller charging console	C
Guitar foot pedal generator	D
Rubbing steel toater	B
Pumping Iphone	D
Mouse generator	C
Yoyo Alarm Clock	B
Twist Alarm clock	B
pull cord grenade alarm clock	D
Rolling carpet cleaner with lighting	D
ps3	N/A
Strap alarm clock	C
rubbing clock	D
Body heat iphone charger	E
Piezoelectric Wii controller	E
finger rotating ipod	D
Stepper charger	F

Appendix E

Questionnaire 1 for Pilot Study

Questionnaire 1

Name: ___________________________

Do you know what this product is?

____

Do you have any experience of using similar product?

If yes, please provide more detail.

____

____

Please describe your first encounter with this product.

____

____

How would you rate the product's aesthetics? (Poor 1 ~ 10 Excellent)

____

How long do you think it will last once it is fully charged by winding up?

____

Will you use/purchase this product?

____

How much would you pay for this product?

____

When/where would you use this product?

____

After you finish with the questionnaire, please listen to whatever radio station you would like to hear for duration of 30 min. While you listen to it, you are free to do whatever you like. For example, chat with your colleague, internet searching, Iphoning, etc, but just don't leave the room!!!

Thank You!!!

Appendix F

Questionnaire 2 for Pilot Study

Questionnaire 2

Please describe your first encounter after using this product.

____

____

How would you rate the product's functionality? (Poor 1 ~ 10 Excellent)

____

How many times did you wind up while listening to it for 30 min?

____

How long do you think it will last for one minute of wind up?

____

Would you consider replacing your radio with this plug-in power radio if you had one?

For both Yes and No, Please give one or more reason why you would/wouldn't.

_1.____

_2.____

_3.____

What change/development would you apply to make it a 'better product'?

_1.____

_2.____

_3.____

Thank You.

Appendix G

Exemplar pages from Survey

Are you interested in saving Energy? SurveyMonkey

1. How many TVs do you have in your residence? This does not include watching TV through mobile devices or computers.

	Response Percent	Response Count
None	4.9%	7
1	**48.3%**	**69**
2	30.1%	43
3	9.1%	13
4+	7.7%	11
	answered question	143
	skipped question	0

2. On a daily basis, on average,how many hours per day is the main TV switched on?

	Response Percent	Response Count
I don't watch TV.	6.3%	9
0-1 hours	12.6%	18
1-2 hours	**21.0%**	**30**
2-3 hours	17.5%	25
3-4 hours	16.8%	24
4-5 hours	11.2%	16
5-6 hours	6.3%	9
6-7 hours	3.5%	5
7+ hours	4.9%	7
	answered question	143
	skipped question	0

1 of 13

3. If you have more than 1 TV, Please indicate the total hours use (per day) for the remaining TVs.

	Response Percent	Response Count
0-1 hours	46.7%	35
1-2 hours	22.7%	17
2-3 hours	9.3%	7
3-4 hours	8.0%	6
4-5 hours	4.0%	3
5-6 hours	2.7%	2
6-7 hours	2.7%	2
7+ hours	4.0%	3
	answered question	75
	skipped question	68

4. Do you know how much energy your TV consumes?

	Response Percent	Response Count
Yes	4.9%	7
No	95.1%	136
	If Yes, How much?	8
	answered question	143
	skipped question	0

18. On what basis would you consider using an exercise bike (energy bike) whilst watching TV? Please select the ratio from below.

	Response Percent	Response Count
1 hour of pedalling = 1 hour of TV watching	15.7%	21
1 hour of pedalling = 2 hours of TV watching	14.9%	20
1 hour of pedalling = 3 hours of TV watching	**20.1%**	**27**
1 hour of pedalling = 4 hours of TV watching	10.4%	14
1 hour of pedalling = 5 hours of TV watching	19.4%	26
I will not use such device what so ever.	19.4%	26
	answered question	134
	skipped question	9

19. In your opinion, would other house residents or family members consider using an exercise bike (energy bike) whilst watching TV?

	Response Percent	Response Count
Yes	33.6%	43
Maybe	**39.1%**	**50**
No	27.3%	35
	answered question	128
	skipped question	15

27. Are you interested in reducing energy use and exercise more? We are currently recruiting people to participate in the energy bike study. The study will be conducted at your residence, duration of approx. 1 week, using an exercise bike to power your TV. If you are interested and wish to participate, please enter your information below. We will send you an additional flyer which will include details about the study, and how you will be participating in the experiment.

	Response Percent	Response Count
Yes, I would be interested in parcipating	26.7%	35
Maybe, please send me the details	35.1%	46
Never	38.2%	50
answered question		131
skipped question		12

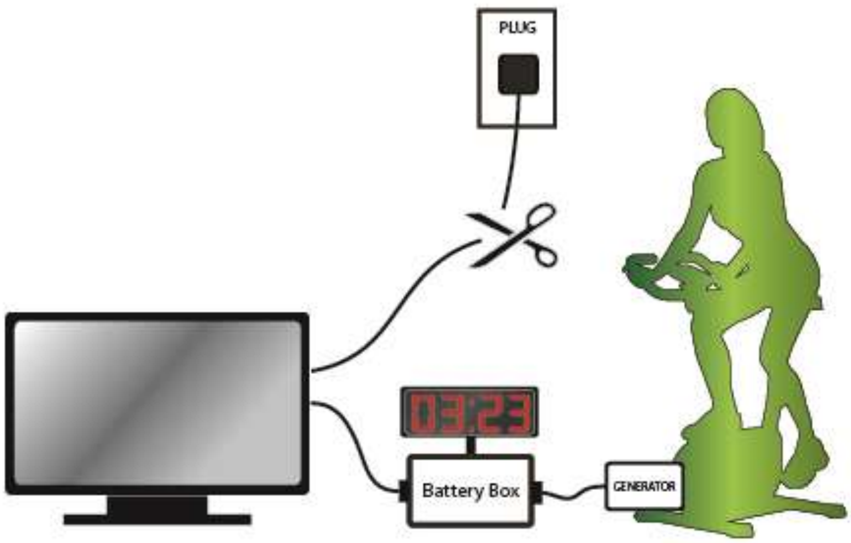
28. If you wish to participate or would like to know more detail about the study, please enter your information.

	Response Percent	Response Count
Name:	100.0%	76
Email Address:	100.0%	76
answered question		76
skipped question		67

Appendix H

Invitation Flyer (email) to HUS stage 2

"Are you interesed in reducing energy consumption? and exercise?"



Are you looking for ways to save energy?
Be a part of practicing green lifestyle that can reduce energy consumption and exercise!!!

Research Team at Nottingham Trent University is inviting you to participate in home-user-test experiment, using exercise bike to power your home appliances (TV). We are currently recruiting for participants living in Nottingham County to get involve in this exciting research.

What you will be doing?
We will be delivering an exercise bike (energy bike) and battery pack to your residence. All you need to do is simply try using the device for 1 week! All the measurable data will be collated automatically through the system in the battery box. At the end of the experiment, there will be a semi-structured interview, asking about your experience with the bike.

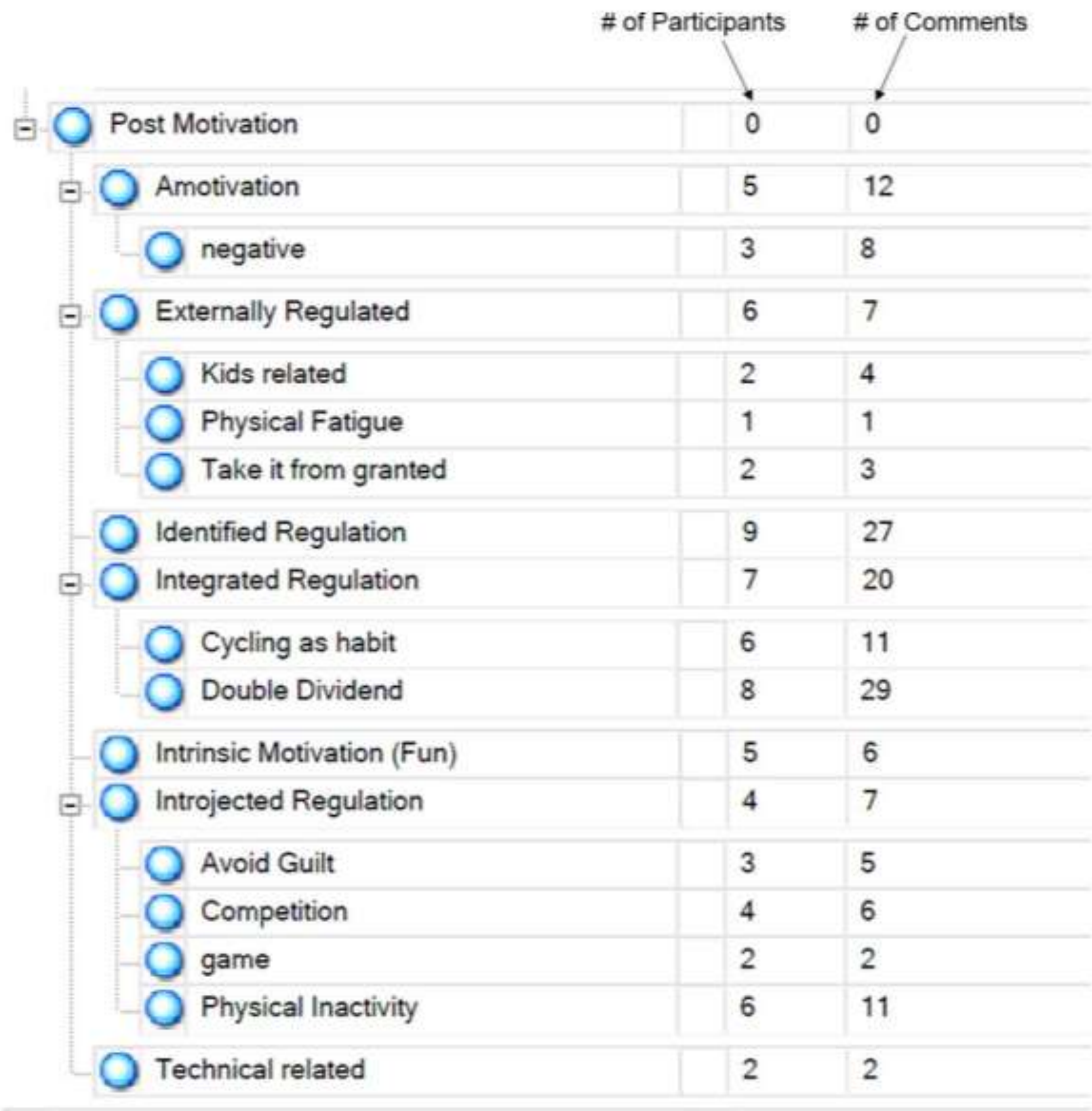
If you are interested and wish to participate please fill in the information below, and one of our research team member will be in contact.

NOTTINGHAM TRENT UNIVERSITY

Daniel Shin
Dotoral Research Student
Email: daniel.shin@ntu.ac.uk

Appendix I

A screen shot Hierarchical tree map of thematic analysis for HUS stage 2. Themes identified under the category of ‘Post Motivation’ refers to coding which account the process internalisation of eHPP use.



	# of Participants	# of Comments
Post Motivation	0	0
Amotivation	5	12
negative	3	8
Externally Regulated	6	7
Kids related	2	4
Physical Fatigue	1	1
Take it from granted	2	3
Identified Regulation	9	27
Integrated Regulation	7	20
Cycling as habit	6	11
Double Dividend	8	29
Intrinsic Motivation (Fun)	5	6
Introjected Regulation	4	7
Avoid Guilt	3	5
Competition	4	6
game	2	2
Physical Inactivity	6	11
Technical related	2	2

Appendix J

Example of thematic analysis - HUS stage 2

Name: Nodes\\Tree Nodes\\Post-Experience Behaviour\Using Human Power\Motivation\Post Motivation\Identified Regulation

Description: Behavioural Goal, action is accepted or owned as personally important

<Internals\\Interview Transcripts\\Debra [redacted] Transcription> - § 2 references coded [1.50% Coverage]

Reference 1 - 0.51% Coverage

Matt: I don't think I would have done any other exercise.

Reference 2 - 0.99% Coverage

Matt: It was weekend when they spend all day pedalling. He was on it for full 1 hour as he was watching a film.

<Internals\\Interview Transcripts\\Eric [redacted] Transcription> - § 2 references coded [2.33% Coverage]

Reference 1 - 1.36% Coverage

it didn't seem to hard work actually doing the cycling... I suppose you have to quite a few turns to get one unit, but it didn't seems like too hard work. I'm not sure what session I did, but probably 20 min or so.

Reference 2 - 0.98% Coverage

And she was even saying 'Can we have the bicycle again?' before you brought it back, so they were definitely looking forward to it and have another go.

<Internals\\Interview Transcripts\\Fil [redacted] Transcript> - § 4 references coded [4.27% Coverage]

Reference 1 - 0.44% Coverage

Fil: No, not really. I think on Sunday I spend about 45 min, breaking down to half hour and 15 min. I got bit of sweat on. But I felt I getting benefit from this later.

Reference 2 - 1.23% Coverage

Fil: yes, absolutely. That was kind of my first thought. I need to get it to certain level otherwise I can't watch it. Otherwise, I'm not going to be able to enjoy watching a TV programme because if you watch something and you get completely absorbed. So in order to ensure that there is continuous enjoyment of watching a programme, I've got a make sure it is topped up to certain level. And that is kind of 'and some', just enough and little bit of extra just in case.

Reference 3 - 0.96% Coverage

Whereas, with this device, it is much more direct. As consequences of my actions, there is something happens. I think it puts that level of control back into my hand rather than being passive. Yes of course you can make changes to behaviour to adapt new energy usage but there is something so gratifying that you can actually generate something... that you are powering.

Reference 4 - 1.64% Coverage

Fil: I think it is about having that level of control. Not being controlled in, but basically... if I'm generating this power, it's like having money in the bank. I've got it, I can spend it. But how do I use it? How do I use it more effectively? If I use it more effectively, does that mean, in longer term, my attitude towards my well-being is going to be more effective? Because I'm thinking more about how I'm powering and empowering myself on a physical, intellectual, and emotional level. I think it has that impact which is... it is so simplistic but it just switches that emphasis of taking back the power to the individual.

<Internals\\Interview Transcripts\\Frankie [redacted] Transcription> - § 7 references coded [8.51% Coverage]

Reference 1 - 1.18% Coverage

I don't know whether that was because it's novelty of it but I found lots of decent amount watching time for the times spend on the bike which is good because that was something that I was worried about that you might have to be cycling in the bike whilst watching the TV. Um... yes, no issue really. It's been fine.

Reference 2 - 2.38% Coverage

Frankie: They didn't have option. One of very receptive of it. Um... my barrister house mate was not particularly pleased... 'whenever I have to watch TV I have to down cycle it?', but I think that is because we all had the vision that we had to cycle as we were watching the TV. But once that kind of...was overcome... and I did rack up 2 hours of watching time initially and they couldn't complaint about it. And he participated with it as well, so I think by midway through it was accepted by everybody. And I know my housemates didn't accept straight away... but kind of... quite through phase, he had the exercise bike here to kind of use and...

Reference 3 - 0.64% Coverage

Yes, quite often... say that we all sat around and TV was on, I probably hop on the bike for a period of that just to keep it up. Again, that novelty kind of help with that.

Reference 4 - 0.88% Coverage

Um... so I don't think I would but then obviously if I was really busy and had lots of things on... things like that... it might then be a bit of issue. But if you got those things and you can plan around them, you can kind of bank your time...

Reference 5 - 1.27% Coverage

Frankie: Never happened to me, and then I think I would be very conscious… look at it… keep thinking like 'will I have enough time?' or 'Should I get on it now so that it is topped up and then relax to the end'. It wasn't obsessed way, it was quite natural. It was funny how you can get into a routine of doing that without even realising.

Reference 6 - 0.68% Coverage

Ryan: I haven't really thought about it. I was more coming at angle… conserving energy… that kind of thing… and getting sort of look at renewable energy source rather than the cost.

Reference 7 - 1.47% Coverage

Frankie: Yes, I think the money is true thing. Because people can relate to… particularly at the moment with people watching pennies all that of sort of stuff. I think it would make you feel that it is worthwhile process to be able to see that. Cause 10 hours of TV, like you said, before… you told me that was 10 pence worth of money, I got no kind of… I don't have value associated to that.

<Internals\\Interview Transcripts\\Jasper [redacted] Transcription> - § 1 reference coded [1.53% Coverage]

Reference 1 - 1.53% Coverage

Jasper: Yes, I will take the device and use it but if you can fit that dynamo into my gym and put a cable from my gym to that box, it will be very happy.

<Internals\\Interview Transcripts\\Joris [redacted] Megan Trascription> - § 3 references coded [3.36% Coverage]

Reference 1 - 1.55% Coverage

Megan: If you watched a lot of TV, if you are like TV addicts and then you have to cycle for 4 hours a day to charge enough to watch the TV. I think that would make people reduce their TV consumption. Because we are not huge TV watchers, and it didn't impact in our life that much… and also quite handy because he cycle and I can watch TV or other way.

Reference 2 - 0.53% Coverage

Joris: We were watching with her brother, and the TV went off because it ran out of credit. Then 'Oh Yeah~' (realising).

Reference 3 - 1.28% Coverage

I've learned interesting facts about saving but also about calories burns and the fact that we cycles for 80 km. It was interesting to put those together. If we both put half an hours a day, the benefit of that would be 6000 calories and 160 km. Those kind of figures are really interesting.

<Internals\\Interview Transcripts\\Loree [redacted] Andy transcipt> - § 2 references coded [1.66% Coverage]

Reference 1 - 0.63% Coverage

And then I go…'oh gosh~ there is humble to do'. But the reality of it was… it just seemed like it was something that you had to do and it was actually okay.

Reference 2 - 1.04% Coverage

Loree: Well I found that… because normally when I'm in spin class I wanted to be hard. The purpose will be workout. But when I was tired and just wanted to watch TV, I put it on easiest and pedal fastest I could just to get the credit. So that was my goal..

<Internals\\Interview Transcripts\\Michael [redacted] Transcription> - § 5 references coded [8.73% Coverage]

Reference 1 - 0.47% Coverage

Jane: I'm not surprised that it only saved small amount of money.

Reference 2 - 2.20% Coverage

I think if we have been powering the kettle, then I might have expected more saving. But it's nice to know that you used that many calories, I think that is the good side… I can see that as a motivator to do it from that perspective other than the money side for me… you know? behavioural change aspect.

Reference 3 - 2.62% Coverage

Jane: I know I'm saving little, but it will be like you are doing something beneficial for yourself as well as maybe saving little bit of money. But it will be more about… you would be doing something, you are powering something, and benefiting your own well-being at the sometime. So I think that would be more the motivator for me rather than the money saving.

Reference 4 - 0.76% Coverage

Jane: Yes. I don't do any exercise, so something like that would motivate me to actually use this thing.

Reference 5 - 2.67% Coverage

Michael: The TV in particular, it is nice actually to know you are doing something good even if you are watching it. Self-powering on that. So nothing to do with the cost saving, even though it is a bit disappointing that I through it might be more than that. 40 pences… Even so, just the fact that you are doing something active and something useful at the same time.

<Internals\\Interview Transcripts\\Rose & John Trancription> - § 1 reference coded [1.28% Coverage]

Reference 1 - 1.28% Coverage

John: because often one of us was sitting and pedalling on the bike because it was entertaining thing to do.... Sort of store it up for later so that perhaps you wouldn't have pedal while you watch a film.

Relationships

From: Nodes\\Tree Nodes\\Post-Experience Behaviour\White Box\Feedback\Perceing Behaviour Control\Goal Setting
Type: Associated
Direction: Associative