NOTTINGHAM
TRENT UNIVERSITY

Investigation into the Feasibility of the Utilisation of Renewable Energy Resources in Libya

Ahmed Mohamed Ayad Mohamed

BSc, MSc

A thesis submitted in partial fulfilment of the requirements of the Nottingham Trent University of the degree of Doctor of Philosophy

2016

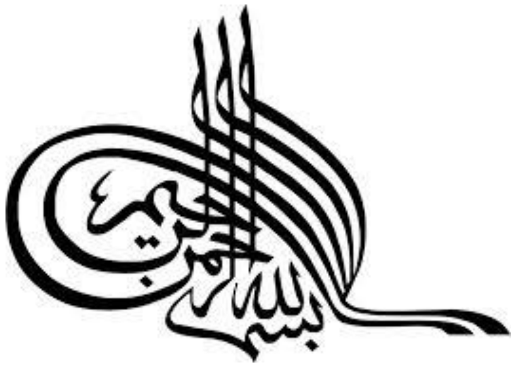
Copyright statement

Declaration

I hereby, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Doctorate of Philosophy and entitled "Investigation into the Feasibility of the Utilisation of Renewable Energy Resources in Libya" represents my own and original work and that, to the best of my knowledge and belief, except where otherwise referenced or acknowledged in the text. I also declare that the document has not been submitted, either in whole or in part, for any other award at this or any other university.

Signature: ………………….

Data: ……………………….



رَبَّنَا افْتَحْ بَيْنَنَا وَبَيْنَ قَوْمِنَا بِالْحَقِّ وَأَنتَ خَيْرُ الْفَاتِحِينَ

صدق الله العظيم

Dedication

الإهداء

إلى أعز الناس على قلبي

أبي الأستاذ محمد عياد البرغثى وأمي الرؤوم فاطمة سليمان بوقعيقيص

إلى كل إخوتي سالم وناصر وطارق وسليمان

وكل أخواتي أسماء ورجاء وأماني ومروى

إلى حياتي وعمري زوجتي الغالية الدكتورة شريفة موسى ابراهيم العبار

إلى كل أولادي وفلذات كبدي فاطمة ومصعب ولمار ولين

إلى الحنونة جدتي عائشة حمد الحداد

وخالي الغالي محمد سليمان سالم امبارك بوقعيقيص

إلى كل أقاربى وأصدقائي

إلى كل الأحبة وإلى من رحلوا وأنا بعيد عنهم ولم تسنح لي الفرصة لأودعهم:

أهديهم هذا العمل المتواضع الذي هو ثمرة جهدي.

ابنكم

احمد محمد عياد محمد عبدالقادر حسين امحمد عامرالبرغثى العقورى

Acknowledgements

I am exceedingly grateful to Almighty Allah, the creator, who gave me the opportunity and the ability to complete this work.

My sincere acknowledgement goes to my director of studies and principle supervisor Professor Amin Al- Habaibeh, who has provided and guided me with endless support, inspiration, and friendship throughout the period of my study, his kindness, understanding, encouragement and critically constructive discussions have supported me greatly and contributed to constructing and completing this dissertation. His clear insight and knowledge has opened my mind to comprehend the complex ideology of the phenomenon and research methodologies. I am also thankful to Dr Hafez Abdo, my associate supervisor, for his advice and comments during the research stages of this thesis. His support, friendship, kindness, understand and encouragement to finish my study. I also wish to thank my associate supervisor Professor Daizhong Su, for his support, constructive feedback and suggestions especially in the early stages of this work. I also would like to acknowledge and thank all the members of both academic and general staff at School of Architecture, Design and the Built Environment and Nottingham Business School, for their help, kindness, fruitful discussions and valuable advices. My gratitude must also go to Professor Abdulgader Amer, Dr Mustafa Graisa, Mr Bubaker Shakmak, Mr Wail Ali Elhawari and Dr Milad Elgargni for their support during the early stages and period of this thesis, as well as colleagues and friends who provided me with support during my period of study. Last but not least, I am indebted and thankful to my neighbour Goddard's family Julie, Dan, Joel and Ruth for their help, kindness and support.

Abstract

Renewable energy in Libya, in particular solar and wind energy, can partly cover current local energy demands. It can also, through connections to the Middle East, Africa and Europe, provide neighbouring countries with electricity. Additionally, with the increase in energy demand around the world, and the international effort to reduce carbon emissions from fossil fuels, there has been a drive in many oil-rich countries to diversify their energy portfolios and resources. Libya is currently interested in utilising its renewable energy resources in order to reduce the financial and energy dependency on oil reserves. This research investigates the current utilisation and the future of renewable energy in Libya, and the challenges and opportunities for investment in renewable energy in Libya. This study has explored the possibility of utilising the available renewable energy resources in Libya to offer the Libyan government a strategy for providing sustainable energy resources. This is expected to reduce carbon emissions, and help achieve an economically, socially and environmentally sustainable energy future. Interviews have been conducted with managers, consultants and decision makers from different government organisations, and have included energy policy makers, energy generation companies and major energy consumers. A comprehensive survey has been conducted to evaluate several characteristics of domestic energy demand and energy consumption in Libya.

The findings have indicated that, despite the recent political changes and the challenges that face the implementation of renewable energy technologies in Libya, renewable energy opportunities are still strategically of high importance. Solar and wind energy are considered the main sources of renewable energy for Libya. It has been found that energy demand is increasing in Libya and that renewable energy could be a solution to cover some of this demand. In addition, the results have indicated that there are no clear policies that support the implementation of renewable energy projects within Libya, and no clear legislation aimed at the types of technical, commercial and environmental issues which must be addressed for the implementation of renewable energy projects in Libya. Legislations governing the legal support for facilitating the spread of renewable energy in Libya are also limited. Moreover, there is a need to attract investors in renewable technologies by enhancing the country's infrastructure and improving the existing investment regulations.

List of Publications

During the research period a total of six academic papers were published, comprising three journals and three academic conferences as detailed below.

1. Ahmed M. A. Mohamed, Amin Al-Habaibeh, Hafez Abdo and Sherifa Elabar, (2015) “Towards exporting renewable energy from MENA region to Europe: An investigation into domestic energy use and householders’ energy behaviour in Libya”, **Applied Energy** Journal, vol. 146, p 247–262.
2. Ahmed M. A. Mohamed, Amin Al-Habaibeh and Hafez Abdo, (2013) “An Investigation into the Current Utilisation and Prospective of Renewable Energy Resources and Technologies in Libya”, **Renewable Energy** an international journal, vol. 50 , p732-740.
3. Ahmed M. A. Mohamed, Amin Al-Habaibeh, Hafez Abdo and Juma R. Abdunnabi, (2013),“The significance of utilising Renewable energy options into the Libyan an energy mix,” **Energy Research** Journal, vol. 4, (1): p 15-23.
4. Ahmed M. A. Mohamed, Amin Al-Habaibeh and Hafez Abdo, (2012), “The importance of renewable energy in Libya: historical overview”, third Annual ADBE Research Conference and Festival in the NTU, 28 June 2012.
5. Ahmed M. A. Mohamed, Amin Al-Habaibeh, Hafez Abdo and Abdelsalam Elhaffar, (2013), “An Investigation into the Importance of Developing the Renewable Energy Sector in Libya,” vol. 113, International conference on Electrical and Computer Engineering (ICECE). 26-28 March 2013, Benghazi-Libya.
6. Ahmed M. A. Mohamed, Amin Al-Habaibeh and Hafez Abdo, (2015), “Future prospects of the Renewable Energy Sector in Libya,” vol. 132 SBE16 Dubai International Conference, January 17-19, 2016.

List of Research Publicity

The researcher publications in Renewable energy journal, Energy Research Journal and Applied energy journal have attracted massive international publicity, below some of these links:

- Libyabusiness.tv. **Libyans could save a power station-worth of energy with basic eco measures, say UK academics**. March 11 2015.
- Nottingham Trent University News. **Libyans could save a power station-worth of energy by introducing basic eco measures.** March 19 2015.
- Libya Herald, **Libyan could save a power station-worth of energy with basic eco measures, say UK academics**, 09 March 2015.
- Thomson Reuters Foundation, **Libya could save energy with simple measures, study finds.** 11 March 2015.
- Libya today, **Libya could save energy with simple measures, study finds**, 11 March 2015.
- Wn.com. **Libyans could save a power station-worth of energy by introducing basic eco measures (Nottingham Trent University)**, 26 March 2015.
- African Review, **Libya can produce more energy from solar power than oil, says research.** February 27 2013.
- Africanseer, **Libya: Could Libya Be a Top Solar Energy Producer?** 8 March 2013.
- Afrol News, **Libya 'Could Produce more Solar Power than Oil'**, 27 February.
- All Africa, **Libya: Climate Conversations-Could Libya be a Top Solar Energy Producer?** 7 March 2013.
- Circa. **Oil-rich Libya could get more energy from solar than petroleum,** March 5, 2013.
- Clean Technical, **Libya solar potential 5x larger than oil reserves (infographic)**, June 29th, 2013.
- Energy Matters, **Libya Could Generate more Energy from the Sun than Oil**, 13 March 2013
- Geop Litical Monitor. **Is Libya’s energy future green?**, April 14, 2013.

- Green Technology, **Libya Could Produce more Solar Energy than Oil, Study Says**,' 6 March 2013
- Libya Business.tv. **Libya Solar Potential 5x Larger Than Oil Reserves**. 01/07/2013
- Libya Herald, **UK University says Libya Could Produce more Energy through Solar Power than Oil**, 28 February 2013
- Libya-business news, **Libya Solar Potential 5x Larger than Oil Reserves, 2 July 2013.**
- Nts – advanced technology, **Libya Could Produce More Energy in Solar Power than Oil.** 17. March 2013 .
- NTU News, **Libya Could Produce More Energy in Solar Power than Oil**,1 March 2013
- Oil price. **Never Mind Oil, Libya could Supply Europe with Solar Power,** April 15, 2013.
- Penn energy, **Libya Could Produce 5x the Energy from Solar than Oil finds New Report**, 11 March 2013
- RECHARGE, **Libya cited as potential solar hotspot, 27/February/2013**
- Recharge, **Libya cited as potential solar hotspot**. February 27 2013.
- Renew Economy, **Solar power could produce 5x more energy than oil in Libya**. 12 March 2013
- RTCC. Responding to Climate Change, **Libya solar potential six times larger than oil reserves**, 28 February 20103.
- Solar Power Today, **Libya's Solar Energy Potential Outshines its Oil Resources**, 8 March 2013
- Technical Review, **Libya Could Produce 'More Energy from Solar Power than Oil**', 27 February 2013
- The energy collective**, Libya Could Produce More Energy from Renewables than Oil.** February 28, 2013.
- The Green Optimistic, **Libya could generate five times more energy from solar**.13 March 2013.
- Thomson Reuters Foundation, **Could Libya be a top solar energy producer?** 7 March 2013.

Table of Contents

Copyright statement ..... **I**

Declaration ..... **I**

Dedication ..... **III**

Acknowledgements ..... **IV**

Abstract ..... **V**

List of Publications ..... **VI**

List of Research Publicity ..... **VII**

Table of Contents ..... **IX**

List of Figures: ..... **XV**

List of Tables: ..... **XVIII**

List of Abbreviations: ..... **XXI**

Chapter 1. Introduction **1**

1.1. Background 1
1.1.1. Geographical location and population 2
1.1.2. Libyan facts and figures 2
1.1.3. Libya's people 3
1.2. Problem definition 4
1.3. Research aim and objectives: 7
1.3.1. Research aims 7
1.3.2. Research objectives 7
1.4. The significance of the study 8
1.5. Structure of the thesis 10
1.6. Recent political changes and renewable energy in Libya 10
1.7. Summary 11

Chapter 2. The state of energy and environment in Libya. **12**

2.1. Introduction 12
2.2. Libya's energy situation 12

2.2.1. Energy demand 15
2.2.1.1. Energy demand in the electrical sector 18
2.2.1.2. Energy demand in the water sector 23
2.3. Price of energy 26
2.4. Libyan's environmental situation 29
2.5. Summary 33

Chapter 3. Economic situation: investment opportunities and energy efficiency 34

3.1. Introduction 34
3.2. Renewable energy and green jobs opportunities 35
3.3. Global investment 36
3.4. Libyan investment requirements 38
3.4.1. Reforms of investment policy prior to the political change of 17 February 2011 38
3.4.2. Reforms of investment policy post to the political change 17 February 2011 41
3.4.3. Investment opportunities in the energy sector 43
3.4.3.1. Investment opportunities in current energy resource 43
3.4.3.2. Investment opportunities in renewable energy resources 44
3.4.4. Libyan policy of foreign investors 45
3.5. Energy efficiency 45
3.5.1. The significance of energy efficiency in domestic sector 46
3.5.2. Determinants of Libyan domestic energy Consumption 47
3.5.3. Household energy use and energy behaviour 49
3.6. Summary 51

Chapter 4. Global trend of renewable energy technology. 52

4.1. Introduction 52
4.2. Global market and industry overview 53
4.2.1. Global renewable power-generation sectors 56
4.2.2. Global heating and cooling sectors 57
4.2.3. Global transportation sectors 57
4.3. Market state and industry trends by technology 58

4.3.1. Solar PV technologies 58
4.3.1.1. Solar PV markets 58
4.3.1.2. Solar PV cell technologies/industry trends 60
4.3.2. Concentrating solar power (CSP) 61
4.3.2.1. CSP market 61
4.3.2.2. CSP industry 63
4.3.3. Solar thermal heating and cooling: 64
4.3.3.1. Markets 64
4.3.3.2. Solar thermal heating/cooling industry 66
4.3.4. Wind power 67
4.3.4.1. Wind power markets 67
4.3.4.2. Wind power industry 68
4.4. Renewable energy cost development 70
4.5. The research framework 71
4.6. Summary 72

Chapter 5. The research methodology 73

5.1. Introduction 73
5.2. Research design 73
5.3. Research methodology 75
5.4. Research methods 78
5.4.1. Secondary data 80
5.4.2. Primary data 80
5.5. Data collection 80
5.6. The design of research instruments 81
5.6.1. The interview design 82
5.6.2. The questionnaire design 84
5.7. Documentary sources 88
5.8. Research population of the study area 88
5.9. Research Samples 89
5.9.1. Interview sample 90
5.9.2. Questionnaire sample and response rate 92
5.10. Piloting the research questionnaire 98
5.10.1. First stage: The other Libyan colleagues’ review 98

5.10.2. Second stage: The experts' review 98
5.11. Preparation for data analysis 99
5.11.1. Interview data coding 100
5.11.2. Questionnaire data coding. 100
5.12. The research's initial stage and field work 101
5.13. Reliability and validity 101
5.14. Ethical issues 103
5.14.1. Permitting free choice 104
5.14.2. Confidentiality and anonymity 104
5.15. Summary 104

Chapter 6. Interview data analysis and discussion. 106

6.1. Introduction 106
6.2. Potential of renewable energy sources in Libya 106
6.2.1. Description of interviews and interviewees 107
6.2.2. The research interview 108
6.3. Part one: Information from the interviews institutions 108
6.3.1. Libyan renewable energy targets 108
6.3.2. Libyan wind energy 110
6.3.3. Libyan Solar Energy 113
6.3.4. Current projects in renewable energy 116
6.3.5. Current electric energy projects 118
6.3.6. Evaluated existing plants 121
6.3.6.1. Steam turbines (24 Units) 122
6.3.6.2. Gas turbines (23 Units) 122
6.3.6.3. Total power plants (8 plants) 122
6.4. Part two: The general interviews questions 123
6.5. Summary 146

Chapter 7. Analysis of the general energy consumers' questionnaire 148

7.1. Introduction 148
7.2. Characteristics and Features of the questionnaire Sample 148
7.3. The fourth objective 150
7.3.1. Energy consumption sector definition 150

7.3.2. Assessment of current energy supply, consumption and demand 156
7.4. The fifth objective 161
7.4.1. The current public energy services 161
7.4.2. Causes of power and water outages 170
7.5. The sixth objective 173
7.5.1. The public vision, government role and environmental issues 173
7.6. Summary 177

Chapter 8. Analysis of the householders' questionnaire 178

8.1. Introduction 178
8.2. Characteristics and features of the questionnaire sample 178
8.2.1. Demographic variables 178
8.2.2. General observations 180
8.3. Electricity demand and load variation in Libya 180
8.3.1. Cooling, heating and hot water supply systems 182
8.3.2. Domestic appliances 185
8.3.3. Householders' awareness of the energy ratings of appliances 188
8.3.4. Energy consumption behaviour in Libyan households 189
8.3.5. Domestic lighting 190
8.4. Energy behaviour and energy awareness 193
8.4.1. General awareness of energy issues 193
8.4.2. Views on energy-efficiency measures and associated investment 194
8.5. Adjustment in occupants' behaviour 200
8.6. Policy implications 205
8.7. Summary 206

Chapter 9. Conclusion findings and recommendations 208

9.1. Introduction 208
9.2. Thesis overview 208
9.3. Evaluation of the research aim and objectives 210
9.3.1. Theme 1: Importance of renewable energy 211
9.3.2. Theme 2: Type and availability of renewable energy 212
9.3.3. Theme 3: Market and industrial trends in renewables technologies 214

9.3.4. Theme 4: The identification and assessment of current energy sources 215
9.3.5. Theme 5: Supply and demand of current energy 215
9.3.6. Theme 6: Energy service utilities 216
9.3.7. Theme 7: Government role towards renewables technology 217
9.3.8. Theme 8: Public vision and environment issues 217
9.3.9. Theme 9: Domestic energy use 218
9.4. Answering the research questions 219
9.5. The significance of the results 224
9.6. Contribution to knowledge 225
9.7. Research Limitation 228
9.8. Recommendations for further research 229
9.9. Final conclusion 230

References …. 231

Appendices …. 247

Appendix A : The Interview (English version). 247
Appendix B :The Interview (Arabic version). 252
Appendix C : The Questionnaire (English version). 256
Appendix D :The Questionnaire (Arabic version). 271
Appendix E : Status of Renewable Energy Technologies: 286
Appendix F : Status of Renewable Energy Technologies: 287
Appendix G : Status of Renewable Energy Technologies: 288

List of Figures:

Figure 1-1: Map of Libya. 3
Figure 1-2: Structure of the thesis 10
Figure 2-1: Africa’s top countries by proven crude oil reserves, 2014. 13
Figure 2-2: Top African natural gas proven reserves, 2014. 13
Figure 2-3: Crude oil production in Libya, January 2010 to November 2014. 15
Figure 2-4: Total energy consumption in the generation of electricity, ... 17
Figure 2-5: Electricity generation development and forecasting 2000-2015. 19
Figure 2-6: Electrical peak load development and forecasting. 20
Figure 2-7: Libya - electric power consumption per capita. 21
Figure 2-8: The monthly load as of 2012. 22
Figure 2-9: Electricity consumption per sector (2012). 22
Figure 2-10: Energy produced in 2012 by type of technology. 32
Figure 3-1: Global new investment in renewable energy, 2004-2013. 36
Figure 4-1: Total world capacity of solar PV 1995- 2013. 58
Figure 4-2: Solar PV world capacity, shares of top six countries, 2013. 59
Figure 4-3: Market shares of top 15 solar PV module manufactures, 2012 61
Figure 4-4: Concentrating solar thermal power global capacity, 1984-2013. 61
Figure 4-5: Solar water heating global capacity, 2000-2012. 64
Figure 4-6: Wind power global capacity, 1996-2013. 67
Figure 4-7: Future development of investment costs for renewable energy technologies. 70
Figure 4-8: Expected development of electricity generation costs from fossil fuel and renewable options. 71
Figure 4-9: The research framework 72
Figure 5-1: Research flow chart. 74
Figure 5-2: Triangulation of quantitative and qualitative. 76
Figure 5-3: Research methodology. 79
Figure 5-4: Research techniques and organisations. 89
Figure 5-5: Map of Libya and the regions used in the survey of this study. 93
Figure 6-1: Estimated average solar energy in Libya in kWh/m² per annum. 107
Figure 6-2: Renewable energy sharing plan, data extracted from the Planning and Studies Department of REAOL 109
Figure 6-3: The readings from the wind station in Chat. 111
Figure 6-4: Wind data. 112

Figure 6-5: Average annual solar radiation in some areas in Libya. 113
Figure 6-6: Libya's network peak load, 2012. 118
Figure 6-7: Renewable energy is available for commercial utilisation in Libya. 123
Figure 6-8: The importance of renewable energy to the development of Libya. 125
Figure 6-9: Renewable energy will satisfy energy demand following the expiration of oil. 126
Figure 6-10: Type of renewable energy with the highest feasibility. 127
Figure 6-11: Energy sector that has the best investment opportunities. 128
Figure 6-12: The reasons behind the inability of electricity production to meet demand. 130
Figure 6-13: Adequate effort was put into promoting renewable energy by the Libyan government. 131
Figure 6-14: The expectation that renewable energy will be used in Libya. 132
Figure 6-15: Public opinion with respect to renewable energy in Libya. 134
Figure 6-16: The expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden in Libya. 135
Figure 6-17: The climate change resulting from environmental pollution should force a reconsideration of the continuing use of conventional energy. 137
Figure 6-18: The belief that the costs of energy production by renewable energy sources are more expensive than the current sources. 138
Figure 6-19: The expectation/knowledge that the Libyan government has planned to reduce carbon emissions from the use of traditional fuel in electricity and water production stations. 140
Figure 6-20: The Libyan government has a clear policy for renewable energy. 141
Figure 6-21: The requirement of technical, commercial and environmental study phases for the implementation of renewable energy projects in Libya. 142
Figure 6-22: Access to information or scientific studies about the use of any type of renewable energy Libya. 143
Figure 6-23: Renewable Energy plan has led to any significant accomplishments. 145
Figure 7-1: Respondents' categories. 149
Figure 7-2: Responses of energy type which used as energy source in each sectors. 156
Figure 7-3: The source of water used by each sector. 160
Figure 7-4: Residential housing responses based on Table 7-10. 162
Figure 7-5: Commercial Farm responses based on Table 7-11. 164
Figure 7-6: Non-commercial farm responses based on Table 7-12. 165
Figure 7-7: Public factory responses based on Table 7-13. 166

Figure 7-8: Private factory responses based on Table 7-14. 168

Figure 7-9: Public facilities responses based on Table 7-15. 169

Figure 7-10: Causes of power outage. 171

Figure 7-11: Causes of water outage. 171

Figure 7-12: Reasons for the lack of gas cylinders. 172

Figure 7-13: Reasons for the lack of street lighting. 172

Figure 7-14: Energy resources. 174

Figure 7-15: Environment issues. 175

Figure 7-16: Government role. 175

Figure 8-1: The monthly load and the average temperature in 2012. 182

Figure 8-2: The number of appliances (a comparison between the current 2013 survey and the previous 5 years). 186

Figure 8-3: Householders' thoughts of the ratings of their household appliances... 188

Figure 8-4: Weekly use of some appliances by households in Libya. 190

Figure 8-5: Percentage of homes with fluorescent, halogen and traditional lighting. 192

Figure 8-6: Location of energy-saving light bulbs in Libyan households. 192

Figure 8-7: Libyan householders' general awareness of some energy-saving measures. 194

Figure 8-8: Householders' views on general efficiency and energy saving measures. 194

Figure 8-9: Householders' views on energy saving issues. 196

Figure 8-10: Householders' behaviour regarding renewable energy resources and CO_2 reduction schemes. 198

Figure 8-11: Householders' possible future investments in energy-saving measures. 199

Figure 9-1: The layout of the current study, and how it meets the research aim and objectives. 210

Figure 9-2: Summary of research contribution 226

List of Tables:

Table 2-1: Libya's oil and natural gas production, ...14
Table 2-2: Libya – electric power per-capita consumption in Libya. 21
Table 2-3: Water and desalination capacity projections for Libya. 25
Table 2-4: Prices of some petroleum products to consumers. 26
Table 2-5: Historic development of fuel prices to the Libyan electricity sector between 2001-2009 (Dinar / m^3). 27
Table 2-6: Fuel prices (2006-2007 average). 27
Table 2-7: Libyan electricity tariff. 28
Table 2-8: The tariff and classifications for major 29
Table 2-9: Development of electricity prices to non-residential sectors 29
Table 2-10: CO_2 emissions from power generation in Libya 2012. 32
Table 4-1: Estimated renewable energy share of global final energy consumption 2009- 2012. 53
Table 4-2: Renewable energy share of global electricity generation 2010-2013. 54
Table 4-3: Average annual growth rates of renewable energy technologies capacity and biofuels production, 2007-2012. 55
Table 4-4: Global capacities of different renewable energies and 56
Table 5-1: Summary of face-to-face interviews. 91
Table 5-2: Summary of Telephone interviews. 92
Table 5-3: Total population of Libyan energy users. 93
Table 5-4: The population size and sample for each area. 93
Table 5-5: The sample size of Tripoli. 94
Table 5-6: The sample size of Benghazi. 95
Table 5-7: The sample size of Western. 95
Table 5-8: The sample size of Middle. 95
Table 5-9: The sample size of Southern. 95
Table 5-10: The sample size of Green Mountain. 96
Table 5-11: Distribution of questionnaires collected 96
Table 5-12: Summary of the questionnaires. 97
Table 6-1: The estimated average wind speed in different Libyan cities. 110
Table 6-2: Average wind speed in four cities. 111
Table 6-3: Monthly average of wind speed (m/s) from 1985 to 1995. 112
Table 6-4: Monthly average of wind speed (m/s) in 2011. 112
Table 6-5: Power Generation (Characteristics and Costs) 114

Table 6-6: Monthly average of total radiation (kWh/m^2/m) during 1982-1988. 115
Table 6-7: Total installed PV systems in communication systems. 116
Table 6-8: Total installed PV systems in Libya. 117
Table 6-9: Libyan power generation units. 119
Table 6-10: Plants by type, capacity and total cost. 119
Table 6-11: The quantity of fuel consumed to produce 1 MWh in 2012. 120
Table 6-12: North Benghazi plants' fuel consumption rate in 2012. 121
Table 6-13: Renewable energy is available for commercial utilisation in Libya. ...123
Table 6-14: The importance of renewable energy to the development of Libya. 125
Table 6-15: Renewable energy will satisfy energy demand 126
Table 6-16: Type of renewable energy with the highest feasibility. 127
Table 6-17: Energy sector that has the best investment opportunities. 128
Table 6-18: The reasons behind the inability of electricity production to meet demand. 129
Table 6-19: Adequate effort was put into promoting renewable energy by the Libyan government. 131
Table 6-20: The expectation that renewable energy will be used in Libya. 132
Table 6-21: The public opinion with respect to renewable energy in Libya. 133
Table 6-22: The expectation that the production of energy from renewable sources will provide affordable energy and reduce the energy expenses burden in Libya. 135
Table 6-23: The climate change resulting from environmental pollution should force a reconsideration of the continuing use of conventional energy. 136
Table 6-24: The belief that the costs of energy production by renewable energy sources are more expensive than the current sources. 138
Table 6-25: The expectation/knowledge that the Libyan government has planned to reduce carbon emissions from the use of traditional fuel in electricity and water production stations. 139
Table 6-26: The Libyan government has a clear policy for renewable energy. 141
Table 6-27: The requirement of technical, commercial and environmental study phases for the implementation of renewable energy projects in Libya. 142
Table 6-28: Access to information or scientific studies about the use of any type of renewable energy Libya. 143
Table 6-29: Renewable Energy plan has led to any significant accomplishments. .145
Table 7-1: Respondents' categories. 149
Table 7-2: Detailed characteristics of the RES sector sample. 151
Table 7-3: Detailed characteristics of the FMC and FMN samples. 153
Table 7-4: Detailed characteristics of the FTP and FTV samples. 154

Table 7-5: Detailed characteristics of the PFL sample. 155
Table 7-6: Energy types which are used as energy sources in each sector. 156
Table 7-7: The source of the electricity being used in each sector. 157
Table 7-8: The types of energy used (electricity and fossil fuel). 159
Table 7-9: The source of water used by each sector. 160
Table 7-10: Residential housing responses. 162
Table 7-11: Commercial farm responses. 163
Table 7-12: Non-commercial farm responses. 165
Table 7-13: Public factory responses. 166
Table 7-14: Private factory responses. 167
Table 7-15: Public facilities responses. 169
Table 7-16: Causes of power and water problems. 170
Table 7-17: Energy resources, the government's role and environmental issues. ...174
Table 8-1: Sample distribution. 179
Table 8-2: Occupancy characteristics of the surveyed houses. 179
Table 8-3: Air conditioning and heating systems in the 429 surveyed homes. 184
Table 8-4: Percentage of households with particular appliances. 186
Table 8-5: Percentages of appliances in different age brackets. 187
Table 8-6: Factors that affect the purchase of household appliances. 189
Table 8-7: Householders' views on energy-saving behaviour. 196
Table 8-8: Householders' views on the most suitable method of obtaining 200
Table 8-9: Estimated average energy (kWh) and cost (LD) to run appliances for one house. 201
Table 8-10: Improved average energy consumption and cost for one household....202
Table 8-11: Summary of improvement scenarios in total cost and MWh consumption (per annum). 205

List of Abbreviations:

Abbreviations and key words used in this thesis are as follow:

AD	………………	Anno domini
AME	………………	Africa and the Middle East.
ASU	………………	Arab Socialist Union
Bbl (S)	………………	Barrel (S)
BC	………………	Before Christ
bcf	………………	Billion Cubic FEET
CBL	………………	Central Bank of Libya.
CSERS	………………	Centre for Solar Energy Research and Studies Libya
CSP	………………	Concentrating solar power
DHI	………………	Diffuse Horizontal Irradiance
DNI	………………	Direct Horizontal Irradiance
EIA	………………	Energy Information Administration.
EU	………………	European Union
GDP	………………	Gross Domestic Product
GECOL	………………	General Electricity Company of Libya
GHG	………………	Greenhouse Gas Emissions
GHI	………………	Global Horizontal Irradiation
GMRP	………………	Great man-made river project
GPC	………………	General People's Congress
GW	………………	Giga Watt
GWh	………………	Giga Watt Hour
HDR	………………	Human Development Report
IEA	………………	International Energy Agency
IMF	………………	International Monetary Fund
KV	………………	Kilo Volt
KWh	………………	Kilowatt hour
LD	………………	Libyan Dinar
LEPGS	………………	Libyan Electrical Power Generation Sector
LFIB	………………	The Libyan Foreign Investment Board.
LFIB	………………	Libyan Foreign Investment Board
LIA	………………	The Libyan Investment Authority.

mBbls/d	………………	Million barrels per day
MENA	………………	Middle East and North Africa
MIGA	………………	The Multilateral Investment Guarantee Agency.
MW	………………	Mega Watt
NDP	………………	National Development Plan
NOC	………………	National Oil Corporation
NPC	………………	Nation Planning Council
NTC	………………	National Transitional Council
OC_2	………………	Carbon Dioxide
OGJ	………………	Oil And Gas Journal
OPEC	………………	The Organization of Petroleum Exporting Countries
PV	………………	Photovoltaic
RCC	………………	Revolutionary Command Council
REAOL	………………	The Renewable Energy Authority of Libya.
SAP	………………	Standard Assessment Procedure
SPSS	………………	Statistical Package for Social Science
SWF	………………	Sovereign Wealth Fund.
Tcf	………………	Trillion cubic feet
UAE	………………	United Arab Emirates
UK	………………	United Kingdom
UN	………………	United Nation
US$	………………	United State Dollars
USA	………………	United Stated America
WTO	………………	The World Trade Organisation.
LFO	………………	light fuel oil
HFO	………………	Heavy fuel oil

Chapter 1. Introduction

With the increase in energy demands and the international drive to reduce greenhouse gas (GHG) emissions, in particular carbon dioxide (CO_2) emissions from fossil fuel, there has been a drive in many oil-rich countries to diversify their energy portfolio and resources. This study investigates the current utilisation and future of renewable energy in Libya, with the objective of reducing the financial and energy dependency on oil and natural gas reserves. This chapter introduces a brief overview regarding the nature of the study. The chapter starts by providing background information about the subject of the study, which leads into an introduction of the definition of the research problem, and the research questions to be investigated.

1.1. Background

Utilisation of renewable energy is becoming important to sustain people's lifestyles, reduce carbon emissions and slow the depletion of limited energy resources (Al-Habaibeh et al., 2010). Renewable energy in Libya is not a well-investigated matter due to the availability of oil, of which Libya is one of the world's leading exporters. With the goal of maintaining oil resources for future generations, and of entering the renewable energy market and reducing pollution, there is now a drive to invest and develop further renewable energy resources. Renewable energy, such as solar and wind power, is widely available in Libya (the current total installation PV systems is 4475 kW, for more details see Section 6.3.4 Table 6-7). According to Tagouri, "I do not know a place better than Libya to be the centre of the world's resources in solar energy and high averages of wind motion rate. It is necessary to find various renewable energy sources and to invest in them in order to be able to break the dependency in Libya on the only income source, oil" (Tagouri, 2009).

The priority for development plans in Libya is to connect electrical power to all regions, a goal informed by the fact that the average power consumption of each individual is deemed to be one of the fundamental factors in measuring the growth level in modern societies (Faraj, 2009).

However, electricity is currently expensive, particularly in agricultural applications, because of the large area that the network needs to cover and the size of the investment in the infrastructure (Salah, 2006). The cost of electricity in Libya in the agricultural and industrial sectors has exhausted the state public budget during the previous thirty years, as indicated through the annual reports of auditors (GPCFAAL, 2007; Workshop, 2009).

The value of projects related to electricity distribution contracted or at the stage of contract conclusion amounted to 5,956 million Libyan dinars in the field of electrical power production (1.25 Libyan dinars being equivalent to 1 US dollar); 5,273 million dinars in the field of transportation and control, and 5,915 million dinars in the field of distribution (News, 2009).

This has led to the discontinuation of several projects related to food, textiles, fertilizers, milling due to rises in the cost of local production. Recent studies, see for example the 2007 Report of the Financial Audit Authority (GPCFAAL, 2007), and the 2008 Report of the Ministry of Electricity, Water and Gas (GPCEWGL, 2008), have shown the importance of investment in renewable energy for the future.

1.1.1. Geographical location and population

Libya is a key country in the MENA region, occupying a strategic location in North Africa and serving as a link between Southern Europe and the rest of Africa. Despite the fact that Libya is considered as one of the oil-rich countries, it is important to secure alternative resources of energy, especially as it has only one type of energy resources (oil). Growing alternative energy resources can in turn help to maintain oil resources for future generations, when the price of oil will go up, and to reduce current pollution.

1.1.2. Libyan facts and figures

Libya is a member of the Organization of Petroleum Exporting Countries (OPEC), and holds the largest proven oil reserves, and one of the largest proven natural gas reserves, in North Africa (Pak et al., 2009). It is located in the middle of North Africa. It has a large coast, 1,900 km along the Mediterranean Sea, and shares borders with six countries (see Figure 1-1): Tunisia (459 km), Algeria (982 km), Niger (354 km), Chad (1,055 km), Sudan (383 km) and Egypt (1,150 km) (Mohamed, 2005; Waniss and Karlberg, 2007). The country is situated between the latitudes of 19° and 34°N, and the longitudes of 9° and 26°E. It is extensively exposed to the sunlight throughout the year, and most of Libya's surface consists of coastal plains, plateaus and mountains.

The desert extends deep into the south, which contains scattered villages and small towns. The climate is Mediterranean: it is warm in summer and mild in winter. The desert climate in the south is very hot in summer with extreme diurnal temperature ranges. Average temperature is around 15°C throughout the winter and 35°C during the summer (Staff, 2013).

Currently oil is depended on as the main source of energy, and oil export revenues are very important to the economic development of Libya as they represent 75% of its total revenue (CBL, 2006; Komoto, 2009). Libya has a low population density: according to Central Bank of Libya, there are 5.6 million inhabitants (CBL, 2009) distributed in a large land area of over 1,759,540 km² (Government, 2005).

Figure 1-1: Map of Libya.

Source: (EIA, 2011).

1.1.3. Libya's people

Libya has a large land area and consequently a low average population density, although 90% of the people live along the coastline in less than 10% of this area. More than half the population are urban, mostly concentrated in the two biggest cities, Tripoli and Benghazi (Kezeiri and Lawless, 1987; Waniss and Karlberg, 2007). Native Libyans are primarily a mixture of Arabs, Berbers, Taboo and Toareq; the last two groups mainly nomadic or semi-nomadic, and distributed in many scattered places in the south of Libya. The first national census in 1954 showed that the population was 1.041 million, which had increased to about 5.67 million by 2006 (Bank, 2011). It is difficult to evaluate the accuracy of more recent estimates, mainly from organisations outside Libya, but they tend to indicate the population is growing at a steady pace. The central intelligence agency estimates that Libya’s population was 6,733,620 in 2012 (CIA, 2016). Additionally Libya’s annual rate of natural increase (birth rate less death rate) has been on average one of the highest in Africa. In this respect, Libya is one of the twenty-six countries in the developing world whose population could conceivably double in the next twenty-five years (Waniss and Karlberg, 2007).

1.2. Problem definition

OPEC countries will face a rise in demand for oil and gas in line with international economic growth, which reflects changes in lifestyle accompanied by an increase in energy consumption for cooling and space heating. However, a situation where we are close to the peak of oil and gas exploration and production in many places, and with significantly rising energy prices over the last few years, every government will be forced to encourage more efficient energy use to overcome increasing energy costs and ease energy security concerns (Grein et al., 2007).

It is believed that Libya’s electric energy demands are expected to grow extremely rapidly (7% - 13% per year) which increased to 41.286 GWh in 2014 compared to only 20.202 GWh in 2004 (for more details see Section 2.2.1.1 page 18) (Goodland, 2013; Khalil et al., 2009; Mohammed, 2010). The Libyan government expects that electrical energy consumption will increase more than two and half fold by the end of 2020 (Georgy et al., 2007; Khalil et al., 2009), driven mainly by rapid increase in both population (see Section 1.1.3 page 3) and economic growth (see Section 2.2.1 page 15) and change in energy consumption behaviour (see Section 3.5 page 45) (IEA, 2005; Workshop, 2009). Currently the dependency is on oil and natural gas, as the main sources of energy for generating the country’s growing demands for electricity/energy (El-Osta and Kalifa, 2003; Keiichi et al., 2009; Mohamed et al., 1998). Electricity distribution is difficult and expensive in Libya's vast area, in which there are about 200 scattered and remote villages with populations ranging between 25 and 500, each not less than 25 kilometres away from the grid (Hassin, 2009; Hiba and Jibril, 2010; Ibrahim, 2010). Although electricity generation has doubled in Libya between the years of 2000 and 2010, increasing power demand above the production capacity has led to electricity shortfalls; therefore the country suffers from power outages, both in the main cities and the other provinces (Mohamed et al., 2013a).

High energy demand in Libya is driven mainly by domestic energy use, which accounts for about 36% of the total energy consumption (GECOL, 2013). Consumption of domestic energy depends on family size, lifestyle, environment (location and climate), the types of appliance in use, ownership, the physical characteristics of the house and human behaviour (Brandon and Lewis, 1999; Koen and Geun, 2011; Missaoui and Mourtada, 2010; Schipper et al., 1982; Yohanis, 2012). Because the consumption of energy for domestic purposes is so high, an investigation of the effects of these characteristics on overall energy consumption and demand in Libya, and the possibility of altering them to reduce that consumption, is worth undertaking.

The Libyan energy sector has undergone development in the area of design, materials and installation. Research on energy use and energy-consuming behaviour is relatively new in Libya, and the construction of energy-efficient houses which can limit heat transfer because of improved thermal insulation and improved construction is not a priority in Libya (Mohamed et al., 2013a). Furthermore, there seems not to be much interest in the establishment of the average Standard Assessment Procedure (SAP) rating of houses, either in the Libyan government or amongst the Libyan people. The energy performance of a building depends on a number of factors, and overall life-cycle domestic energy consumption is lower in a housing stock constructed with low-embodied energy materials (Koen and Geun, 2011; Yohanis and Norton, 2002).

Utilising renewable energy alternatives may be the ideal solution to a number of energy problems in Libya and a useful instrument for keeping a sustainable stream of revenue for the country from the international market. This is also supported by the local legislation that was established within the frame of protecting the environment for example

- Law No. 7 in 1982 concerning the protection of the environment.
- Law No. 13 in 1984 on provisions relating to general hygiene.
- Decision No. 263 of 1999 of General People's Committee regarding the establishment of the Environment Public Authority.

- Law No. 15 in 2003 of protecting and improving the environment. Regarding the aspects of the environment that are addressed by this law, the following notes have been summarized: (Protection of atmospheric air, the seas and marine resources, water resources, food, soil and plants and wildlife (Ali, 2013; Ibrahim, 2014).

It has been argued that Libya is rich in renewable energy resources such as wind and solar (Al-karaghouli et al., 2009). However, in Libya there are very limited published references and no clear comprehensive scientific studies have been undertaken on the utilisation of the renewable energy resource area which can give local and foreign investors the information to enable them to make reliable decisions. In addition, the government department that is in charge of renewable energy is new.

With the purpose of studying renewable energy in Libya, an empirical process was undertaken to explore the current situation in Libya's energy sector in January, 2011. This was done with the aim of taking a provisional view of the population, and of the available information resources. Evidence from the data-collection process revealed that there is still a need (1) for research in the renewable energy field; (2) to explore the current situation of Libyan energy; (3) to explore with their managers the expected barriers to and difficulties of implementing renewable energy in the relevant authorities and companies; (4) to identify the relevant institutions and whether they are prepared to participate in this research; (5) to conduct an initial field study in Libya to explore the financial and technological challenges and opportunities facing the utilisation of renewable energy resources.

During this initial stage of the study, the researcher has conducted several face-to-face interviews with the chairman of the Renewable Energy Authority, and the deans of the Engineering Schools of Al-Fatah University (Tripoli) and Garyounis University (Benghazi). Other senior people in these universities and others at various managerial levels were also interviewed. The interviews were designed to establish the argument of this study, and to explore the current situation of energy generation and consumption in Libya, and the challenges and opportunities of implementing new renewable energy systems in Libya in the future. During this, the author obtained documents and reports related to the current situation in the Libyan energy sectors from a range of different organisations and institutions.

The empirical evidence, as discussed in chapters six, seven and eight, reveals the current situation of the energy and renewable energy sectors in Libya. Based on the initial stage exploring the Libyan energy sectors, the researcher believes that there is a need for carbon and pollution emission reductions, and to maintain conventional energy resources for future generations. Overall, this thesis investigates the problems and conditions on the ground: it investigates the current energy generation and consumption situation, and the challenges and opportunities for investment in and the implementation of new renewable energy systems in Libya in the future. Therefore, the main goals of this research are to answer the following research questions:

1. What is the possibility of sustaining Libya's position in the current international energy market after oil and natural gas depletion?
2. What are the challenges to and opportunities for the utilisation of renewable energy resources in Libya?

1.3. Research aim and objectives:

1.3.1. Research aims

The main aim of this study is to investigate the feasibility of the utilisation of renewable energy resources in Libya, by studying the challenges and opportunities for the investment in renewable energy in Libya.

The goal is to find a way to achieve an economically, socially and environmentally sustainable energy future.

1.3.2. Research objectives

The main objectives of the thesis can be summarised as follows:

1. To study the importance of investing in renewable energy resources in Libya.
2. To investigate the types and availability of renewable energy resources in Libya.
3. To study the global situation of renewable energy technologies in order to identify the market and industrial trends.
4. To identify and assess the current energy supply, consumption and demand in Libya.
5. To investigate to what extent the current public energy service is appropriate and sufficient.

6. To study the attitude of the Libyan government and institutions towards renewable energy technology, the public vision in each sector regarding renewable energy, and environmental issues.
7. To investigate the effect of domestic energy consumption and householders' awareness of, and attitudes and behaviour towards, overall energy consumption in Libya, and how this could affect peak demand, capacity and the government's energy budget.

These objectives are achieved by using secondary data analysis which includes relevant documents and annual reports from the energy sector, and primary data analysis which includes two main methods: questionnaires and interviews (both face-to-face and via telephone).

1.4. The significance of the study

Libya has been selected as the area of the fieldwork because it satisfies all the research requirements. It has limited energy resources and it is difficult and uneconomical to connect electrical power to all regions and scattered villages. Other important issues are the reduction of carbon emissions, maintaining the traditional energy resources for future generations, and the fact that the cost of electricity in many sectors has exhausted the state public budget and several projects have been discontinued. On the other hand, Libya has a huge area, 1,759,540 km^2 and a large coast, 1,900 km along the Mediterranean Sea, with 88% of its area considered to be desert where there is a high potential for solar energy such as thermal, photovoltaic and other solar energy conversions which can be used for electricity.

Whilst Libya is an oil-rich country it also has great potential for the exploitation of renewable energy sources. Its location allows the easy export of clean energy to Europe, and its financial situation gives it the opportunity to implement clean energy technology. Libya is interested in investing in renewable energy because the international and national challenges and availability of renewable energy sources in Libya make it worth studying the possibility of sustaining Libya's position in the current international market through renewable energy when oil and gas may be fully depleted in the country. Moreover, most of the needed information about renewable energy there is obtainable, and this in fact increases the generalisability of this study.

The results and recommendations of this study can be extended to countries in similar situations to Libya, such as, Saudi Arabia, Algeria, Nigeria, Iran, and Iraq.

With regard to power generation, the importance of energy comes from its contribution to the quality of daily life and industrial development (Hassin, 2009). The reasons behind the choice of this sector for this study are, firstly, that the conventional and main sources of energy are oil and natural gas, not only for energy supply, but also for revenues to finance the development of the society, and secondly that the researcher has access to data and information on energy in many sectors in Libya. Furthermore, given that this is one of the first studies researching renewable energy in Libya – according to the database of the Centre for Research and Information and Documentation in Libya (Blunch, 2008) – it is expected that its results will contribute to the development of Libyan government, managers and organizations. It is also believed that these results can be communicated to other countries in similar situations.

This study has explored the possibility of utilising the available renewable energy sources in Libya. It offers the Libyan government a strategy for providing sustainable energy resources, and sustaining their position in the current international energy market.

Since this study can be considered one of the first research works conducted on the effects of energy consumer behaviour on the overall Libyan energy position, the results of this study should be of particular importance to a number of stakeholders. The largest category of these stakeholders is the general Libyan public, who should be aware of the effects of energy consumption behaviour on energy issues and who have a right to a sustained and affordable energy supply. Other stakeholders include energy analysts, energy planners, policy makers, and current and potential investors in the Libyan energy sector, all of whom should also be able to benefit from this study in one way or another. Whilst this study has tackled the effects of energy consumption behaviour on overall energy consumption and demand in Libya and offered a scenario of reduced energy consumption, it has not touched on the effects of different policy measures on changing the consumption behaviour of Libyan households.

Although the focus of this research is on Libya, it has significant relevance to other countries regarding applied energy practices and implementations. Libya is similar in culture and style of living to many other countries around the world, particularly within the Middle East and North Africa (MENA) region. This research will be important for those countries, and for researchers in the field of applied energy.

1.5. Structure of the thesis

The thesis has been divided into nine chapters, which are formulated as follows:

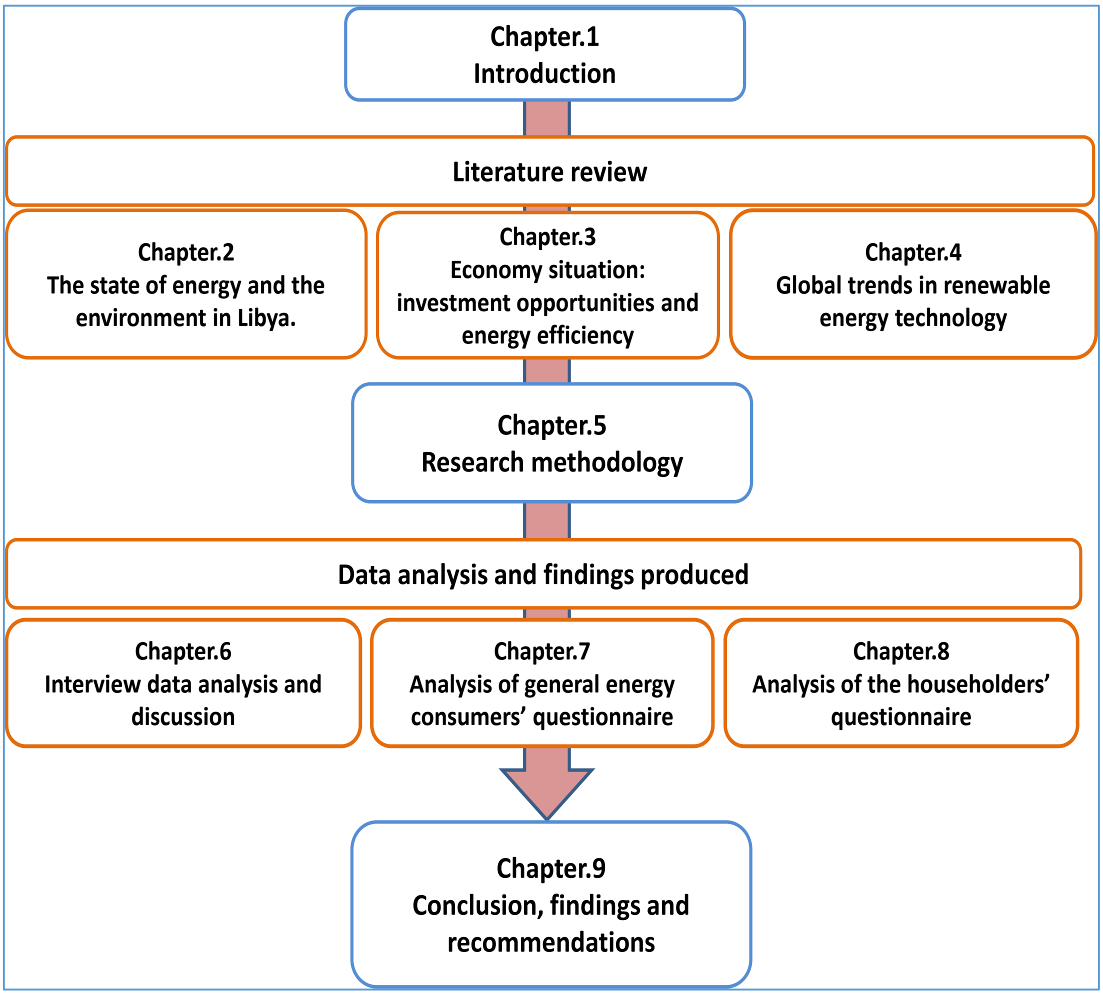


Figure 1-2: Structure of the thesis

Source: Author's own.

1.6. Recent political changes and renewable energy in Libya

The research work for this study has been performed both prior to and following the recent political changes in Libya. As such, some data was collected prior to the recent change in the government in 2011. The changes in the Libyan government after the data of this research was collected are considered an important factor due to the potential possibility of uncertainty in how the government views the strategic importance of renewable energy. In all of the Libyan interim governments, there has been a senior member who is responsible for the electricity, water and renewable energy sector. This reveals the importance of the renewable energy sector in the new Libyan governments and the continuity of the strategic importance of renewable energy. Therefore the author has contacted and interviewed some of the energy policy makers in the new and previous governments, such as the head of the Thermal Energy Conversion Department in the Centre for Solar Energy Research and Studies in the previous government and the head of the Thermal Energy Conversion Department in new ones, the dean of the Engineering faculty at Garyounis University in Benghazi in the previous government, the head of the Department of Electrical and Electronic Engineering at Al-Fatah University in Tripoli, and others, all of whom expect that there will be further and significant activity in the sector of renewable energy, not least because of the Libyan National Transitional Council (NTC)'s decision to create a think tank for the Libyan people, which is still working to investigate new revenue resources in Libya (NTC, 2011).

1.7. Summary

This chapter has provided an overview of the thesis. After highlighting the background to the study, the research problem is stated, and the aim and objectives of the study are outlined. Based on those objectives, two research questions have been proposed and a research method designed to answer those questions and fulfil the research objectives has been outlined. The chapter ended by discussing the significance of the present study and outlining the thesis structure.

With the purpose of achieving the research objectives and completing the requirements of the proposal of this thesis, a discussion and review of the Libyan energy and environmental situation, along with the literature related to this study, will be the subject of the next chapter.

Chapter 2. The state of energy and environment in Libya.

2.1. Introduction

This chapter covers the current energy supply and the environmental issues in Libya, based on a description of the Libyan energy situation, and energy demand in the electricity and water sectors.

The growth in greenhouse gas (GHG) emissions, particularly CO_2 emissions, has led to the so-named global warming phenomenon and climate change. GHG emissions are fastest growing in developing countries (Graisa and Al-Habaibeh, 2011; SAMI, 2012).

A further purpose of this chapter is to familiarize the reader with the historical context of energy and environment in Libya, as well as to lay a foundation for a later discussion of the findings of this thesis.

This chapter is divided into two main sections: Libya’s energy situation, and Libya's environmental situation. The first section includes the energy demands in the electricity sector and in the water sector, and the price of energy. The second section of this chapter explores the current environmental situation and the expected changes in Libya.

2.2. Libya’s energy situation

The main objective of this section is to explore the current and the future energy situation in Libya. No country’s current energy supply can be considered as indefinitely sustainable, as energy costs are exponentially increasing due to environmental issues and the limitation of resources (Salah, 2006).

With regard to Libya, the conventional and main resources of energy are oil and natural gas (Ekhlat et al., 2007), not only for the supply of energy, but also for revenue to finance the country’s development (Gibril, 1995). Libya has the highest proven oil reserves of any country in Africa (EIA, 2013, 2012). Figure 2-3 displays the countries in Africa’s with the largest proven crude oil reserves as of 2014.

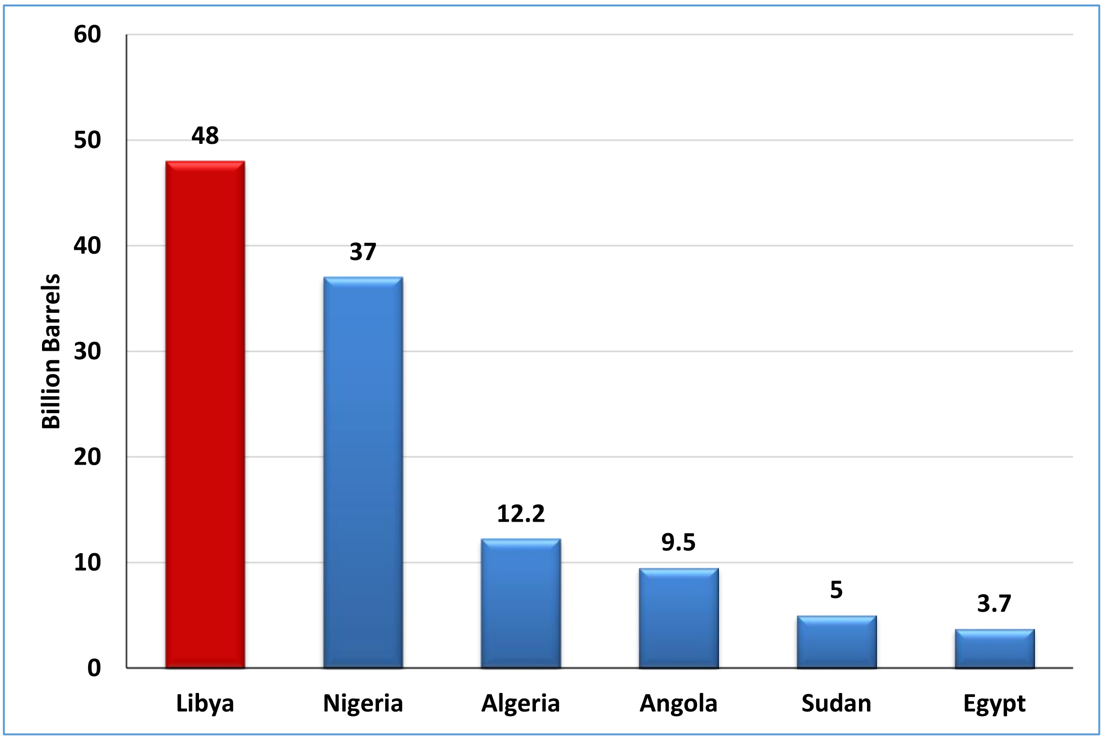


Figure 2-1: Africa's top countries by proven crude oil reserves, 2014.

Data source: (EIA, 2014): p. 3.

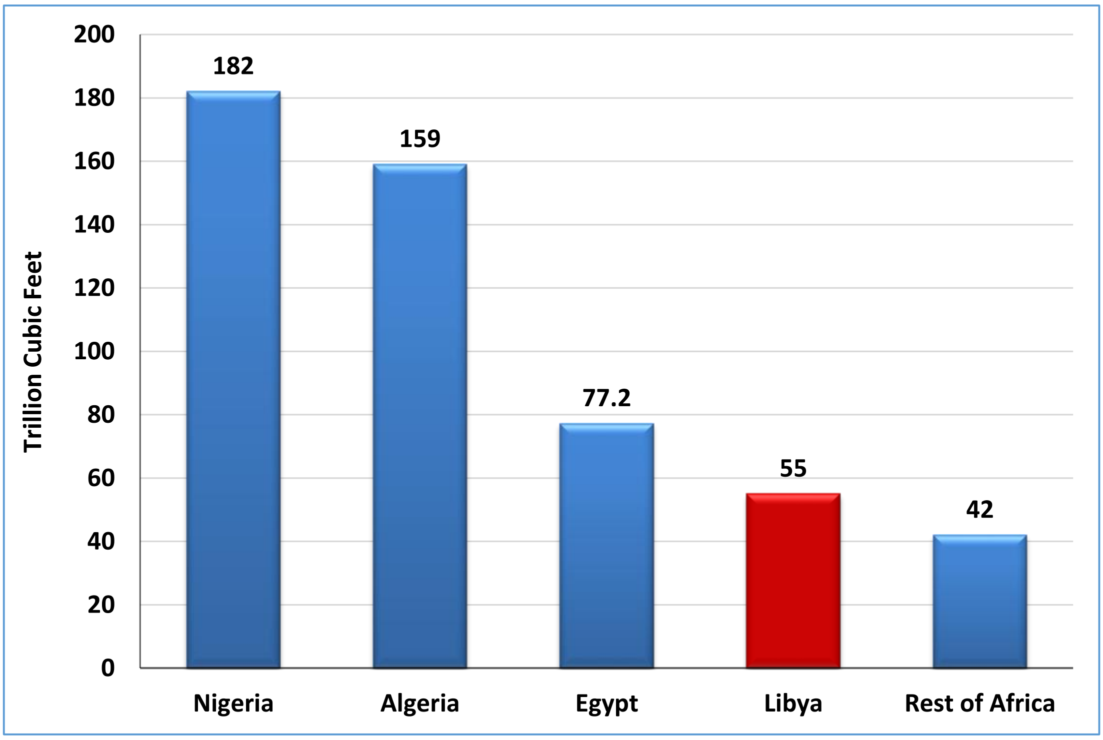


Figure 2-2: Top African natural gas proven reserves, 2014.

Data source: (EIA, 2014): p. 9.

1. Oil: According to the Oil and Gas Journal (OGJ), Libyan proven reserves were estimated at 48 billion barrels as of January 2014, as shown in Figure 2-1 (EIA,

2014, 2013, 2012; European Commission, 2010), which is equivalent to 80 years of production based on an estimated production of 1.65 million barrels per day (mBbl/d). The production capacity of Libya has risen from 1.4 mBbl/d in 2000 to 1.8 mBbl/d in 2010 (EIA, 2013, 2012; European Commission, 2010). At the beginning of 2014, the country's crude oil production was at an average of 450,000 bbl/d, approximately 500,000 bbl/d lower than that of 2013 and about 900,000 bbl/d lower than that of the 2012 average (EIA, 2014).

2. Gas: According to the same source as above, proven reserves of natural gas were estimated at 55 trillion cubic feet (Tcf), which equals 51 years of production, which was 1,069 billion cubic feet (Bcf) as indicated in the EIA report. Natural gas production averaged 227 Bcf in 2011, which means there was more than a 50% fall in comparison with the previous year, and recovered to an average of 430 Bcf in 2012, unchanged in 2013. Figure 2-2 shows the African countries with the largest proven natural gas reserves, 2014 (EIA, 2014, 2013, 2012; European Commission, 2010).

Oil and natural gas have continued to play a major role in the country's economy, since they are an important feedstock for many industries and more than half of the energy production of oil and natural gas are exported (Gibril, 1995). Table 2-1: Libya's oil and natural gas production, consumption and export averages for the year 2012 (EIA, 2013).

Table 2-1: Libya's oil and natural gas production, consumption and export averages for the year 2012.

Type	Production	Consumption	Export	Storage
Oil (2012) mBbl/d	1,37	0.12	1,25	-
Natural Gas (2012) Bcf	431	172	209	50

mBbl/d: million barrels per day. Bcf: billion cubic feet.
Data source: (EIA, 2014, 2013).

The exportation of Libyan oil and natural gas suffered near-total disruption in the months of political unrest in the early months of 2011, as the minimal and irregular oil generation that did occur was mostly exhausted domestically. In September 2011, Libyan oil production started its recovery. After the gradual consolidation of control over most cites of the country by the TNC by May 2012, crude oil production was estimated to have recovered to at least 1.65 mBbl/d, as the impressive pace of the sector's recovery exceeded the expectations of most industry analysts. On the other hand, during the second half of 2013 the most important oil fields and export terminals had to be shut down due to the political tension. Therefore the production of oil declined to 300 thousand bbl/d in May 2014 from its long term position of 1.65 million Bbl/d (Chamberlin, 2014; EIA, 2014), as shown in Figure 2-3. The EIA have indicated that the production of Libyan oil was interrupted for much of 2011-2014 because of the conflict, but started to recover comparatively rapidly after the cessation of most hostilities by the end of 2014 (EIA, 2013).

With 95% of Libyan revenues tied to petroleum sales, the Libyan Ministry of Economy estimates that the continuous disruption cost it over $10 billion or about 12% of its GDP in 2013 (Chamberlin, 2014). The fact that the economy of Libya is dependent on hydrocarbons suggests that the sustained recovery of the energy industry will be a main factor in the country's near-term economic fortunes (IRENA, 2013; Yohanis, 2012).

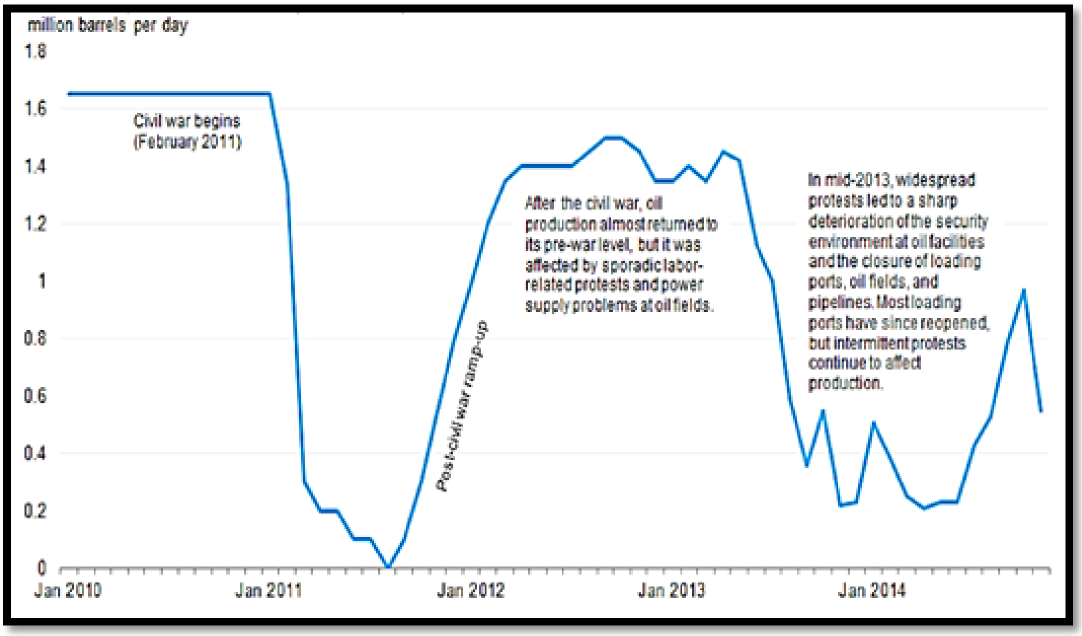


Figure 2-3: Crude oil production in Libya, January 2010 to November 2014.
Source: (EIA, 2014): p. 7.

2.2.1. Energy demand

The average economic growth in the period from 1995-1999 in Libya was 1.6%, and the corresponding value in 2005 was 8.5% (Grein et al., 2007). In addition, the IMF states that the economy increased by only 1.8% in the year 2009. This was below the 3.4% increase in the year 2008 and was the worst performance since 2002, where the oil prices rebounding caused the economy to shrink by 1.3% (more details in chapter two). The IMF and EIA believe that the economy will gather momentum and is forecasting a 5.2% increase in 2010 and 6.1% in 2011 (EIA, 2012). However, the economic growth in the Organization of the Petroleum Exporting Countries (OPEC) countries will be dependent on changes in energy consumption. Consequently, the government will be forced to a more efficient usage of energy, to overcome the growing energy cost (more details in chapter four). As such, renewable energy and a changing energy mix will be a challenge for the countries in the area (Grein et al., 2007). Libyan total principal energy demands are expected to grow at an average yearly rate of 3.3% over the forecast period, and are expected to reach 43 Mtoe in 2030 (Mandil, 2005).

At the end of the first decade of the 21st century, the international situation of spiralling oil prices is driving an important change around the world (Hassin, 2009).

In North Africa, oil is one of the main sources of energy. In Libya, oil is still the main energy source, although recently a growing use of natural gas can be observed (Grein et al., 2007).

With energy demand on the increase, most of Libya's existing power stations are being changed from oil to natural gas, and new power plants are being established to run on natural gas. This in turn frees up more oil for export and reduces GHG emissions. Moreover, the Libyan government is planning to expand the production of natural gas and to substitute oil-fired power plants with natural gas-fuelled units, to maximize the quantity of oil available for export, and is also looking to increase its natural gas exports, to Europe and elsewhere (Affairs, 2010; Hassin, 2009). Libya's natural gas production was enhanced by 180% to reach about 30 bcm per year between 2000 and 2007 (Tanaka, 2009).

Libya's energy consumption composition has remained comparatively steady during the decade, with about 74% of energy demand being met by oil and 26% by natural gas in 2009, and 62% of oil against 38% of natural gas in 2010. In contrast, energy produced in 2012 was 61% natural gas, 30% oil (9% HFO and 21% LFO) and 9% No Fuel (Steam), as illustrated in Figure 2-4 (EIA, 2012; GECOL, 2014). Before the year of 2012, Libya generated more than 50% of its electricity using oil. The share of natural gas in the electricity generation mix has been rising substantially only since 2004.

With its geographical location between Tunisia, Algeria and Egypt, Libya is an essential country in the development of the Mediterranean electricity circle. The Libyan network is very long (2500 km) but not very powerful (GECOL, 2014). From an energy perspective, further expansion of the electricity grid and its integration in the region seem to be the country's major challenges (European Commission, 2010; GECOL, 2014).

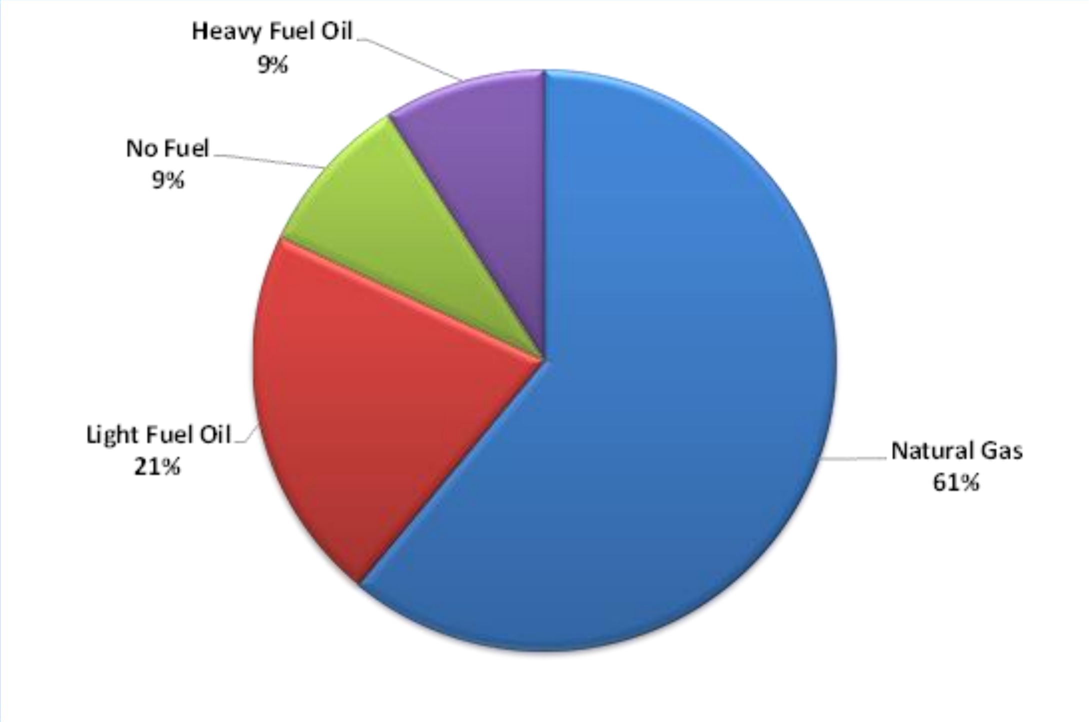


Figure 2-4: Total energy consumption in the generation of electricity, by fuel type (2012).

Data source: (GECOL, 2014): p. 4.

Despite the fact that gas rose from supplying 28% of the total energy demand in 2009 to 61% in 2012, oil will continue to be the dominant fuel. However, with electricity demand on the increase, the Libyan government is planning to expand the use of natural gas to meet domestic requirements, and also the use of solar and wind potential in more rural areas or scattered villages (EIA, 2012). The next sections include more information about energy demands in the electrical and water sectors:

2.2.1.1. Energy demand in the electrical sector

Prior to the discovery of oil and the changes which this brought about to the economic status of Libya, electrical power was very poorly established, the unit cost of supply very high, and the service undependable. Even in 1965, Libya's total installed electricity capacity for electrical power amounted to only 70,000 kilowatts (kW). In Libya, total electricity production stood at 157 million kilowatt hours (kWh) in 1965, while the per capita yearly consumption was estimated at 101 kWh. Capacity consumption stood at only 29%, and the average annual rise in production between 1950 and 1965 amounted to the low figure of 11% (Waniss and Karlberg, 2007). In 1970 the peak demand was 150 MW, by 2003 per capita consumption rose to 2,798 kWh while at the end of 2003 peak demand was 3,340 MW. In the meantime, installed capacity also rose, to more than 4,710 MW by the end of 2005 (Hassin, 2009).

Libya's current electrical energy demands are expected to grow considerably: the Libyan government expects that power generation will be increased by more than two and half times by the end of the year 2020 (Ekhlat et al., 2007). The Libyan government expects that the country will require approximately 70 million barrels of oil per year for its electricity requirements, and that this will cost around 14 billion dollars a year (Gibril, 1995). At the same time, according to Zervos, the underlying oil price will be increasing throughout the next 50 years (Zervos et al., 2010).

The overall number of customers in the electrical system in Libya is approximately 1.2 million (GECOL, 2013), distributed between six categories: the commercial and uncommercial agriculture sectors, the residential sector, the private and public industrial sectors, and public utilities (more details will follow in chapter five) (Ekhlat et al., 2007; Khalil et al., 2009).

The Libyan government expects that the energy sector will play an essential role in attaining its ambitious infrastructure and economic development plans (Hassin, 2009). The General Electric Company of Libya (GECOL), which is a state-owned vertically structured power utility in Libya with a monopoly over generation, is responsible for power generation, transmission and distribution of electrical energy in Libya (Mohammed, 2010; Rose, 2004). GECOL is an agency below the Ministry of Electricity and Renewable Energy (Affairs, 2010). While Libya's power sector requires crucial investment, GECOL has suggested that it may allow private investment in Libya's generation and distribution sectors to be able to meet the demand (Rose, 2004).

GECOL is planning to construct a number of power plants. This plan has been influenced by the rapid growth of electricity demand, which is occurring due to the fact that electricity in Libya is deeply subsidized, at about one-third per kilowatt-hour of the selling price to the consumer. Although GECOL receives its fuels at very highly subsidized prices, an operating loss is still made. Indeed, the problems of managing the high growth rate in demand and financing the necessary heavy investments give GECOL a strong motivation to manage demand (Affairs, 2010).

Currently, Libya's energy network involves approximately 8,000 miles of 220-kilovolt (kV) lines and 13,000 miles of 66kV and 30kV lines (Affairs, 2010; EIA, 2012; Hassin, 2009). The total electricity production of GECOL, which comes from fourteen main power plants, was 25.415 gigawatt hours (GWh) in the year 2007 (Affairs, 2010), which increased to 28.666 GWh in 2008, 32.558 GWh in 2010, and 41.286 GWh in 2014, compared to only 18.943 GWh in 2003 (Khalil et al., 2009; Mohammed, 2010). There are plans to have a total installed capacity of 10 GW by the year 2015 (Affairs, 2010; Mangement Commission, 2010). This signifies an average annual growth of 7%-13% as shown in Figure 2-5, which shows electricity generation development during the period 2000-2014 and electricity demand forecasting for the year of 2015.

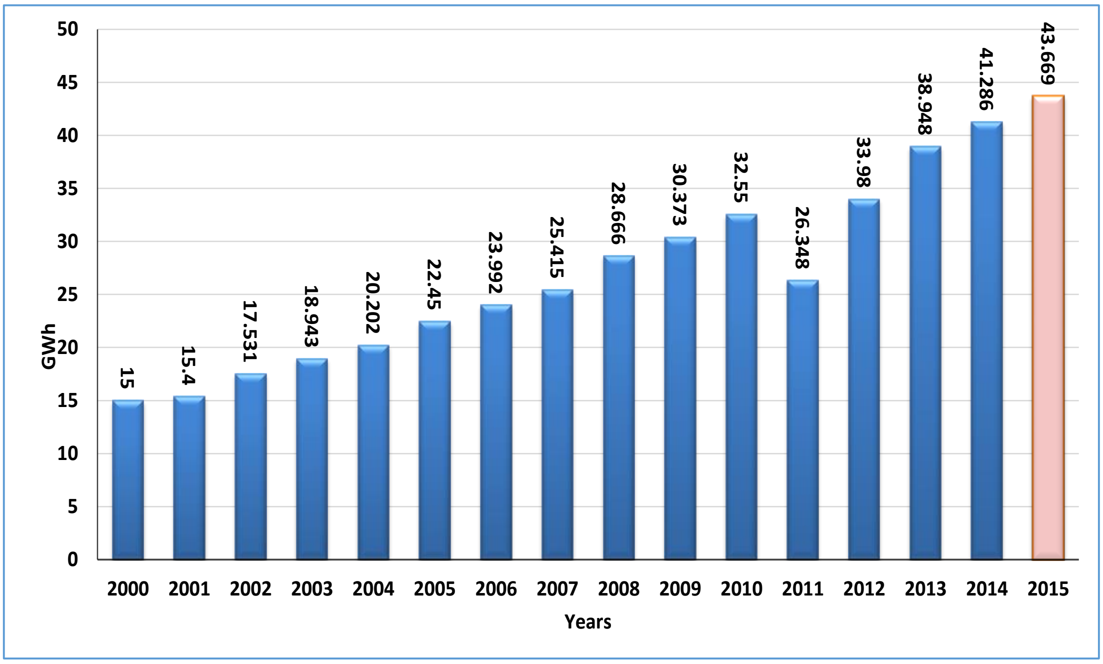


Figure 2-5: Electricity generation development and forecasting 2000-2015.
Data source: GECOL Report 2014 (latest Report) (GECOL, 2014).

The annual peak load of the general grid was only 2,630 megawatts (MW) in the year 2000, increasing to 6,389 in the year 2014 (GECOL, 2014). This represents an average annual growth rate of between 8% and 10%. Figure 2-6 shows the electrical actual annual peak load trends development during the period 2002-2014 and demand forecasting during the period 2015-2020.

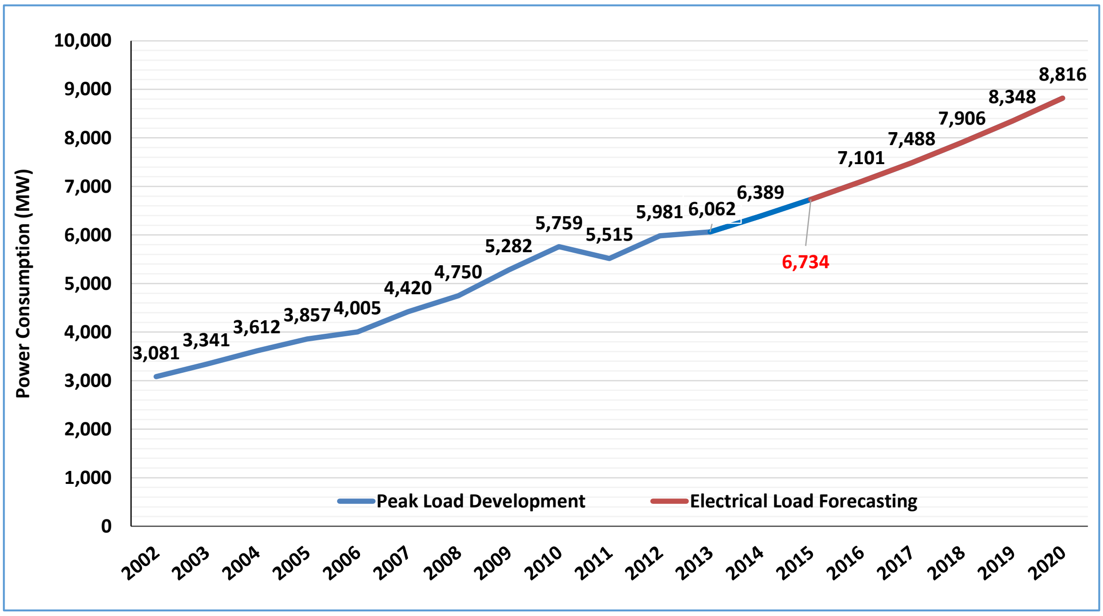


Figure 2-6: Electrical peak load development and forecasting.

Data source: (GECOL, 2014).

Energy consumption has increased steadily over recent years and Libya seems to have high per-capita electricity consumption. The per-capita electricity consumption in Libya almost doubled between 2000 and 2012, part of the high increase is a combination of poor insulation and people’s behaviours. In this context 4,850 kWh in the year 2012 compared to only 2,650 kWh in the year 2000, as shown in Table 2-2 (Khalil et al., 2009; Mangement Commission, 2010, 2009).

Table 2-2: Libya – electric power per-capita consumption in Libya.

Year	Per-Capita Consumption
2000	2650 kWh
2001	2664 kWh
2002	2809 kWh
2003	2953 kWh
2004	3039 kWh
2005	3259 kWh
2006	3939 kWh
2007	4158 kWh
2008	4360 kWh
2009	4602 kWh
2010	5000 kWh
2011	- kWh
2012	4850 kWh

Data source: (GECOL, 2014, 2013).

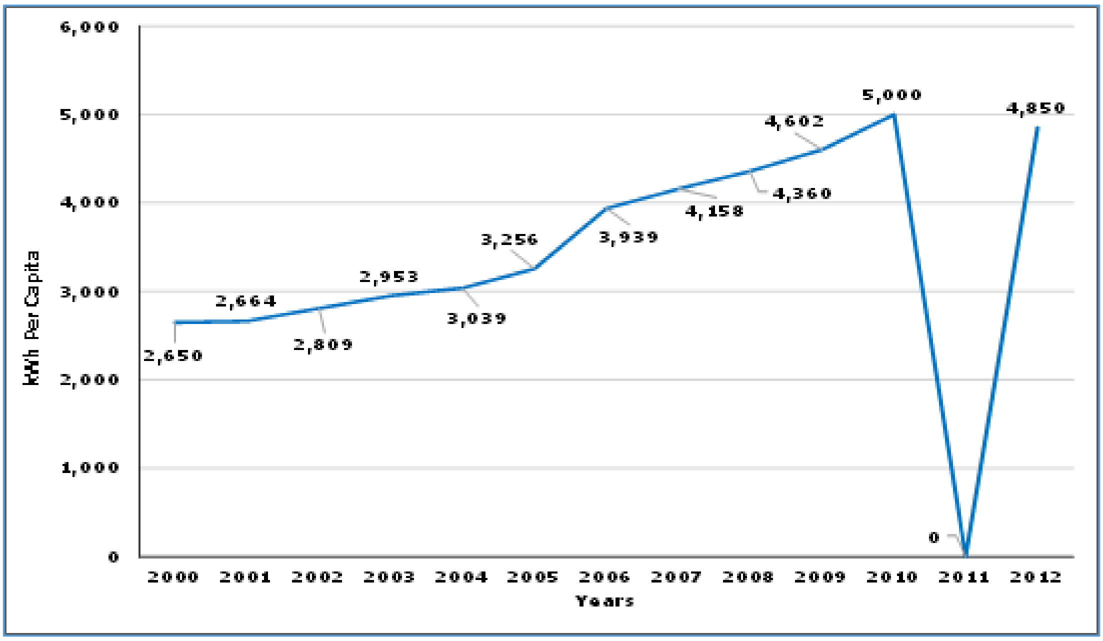


Figure 2-7: Libya - electric power consumption per capita.

Data source: (GECOL, 2014, 2013).

This growth is expected to continue as a result of the several new infrastructure projects which are planned, it will also continue to increase as the economy expands. GECOL has difficulties in meeting this demand with a commensurate expansion of capacity (Affairs, 2010).

Figure 2-8 shows the monthly load curves for usual working months for the year 2012.

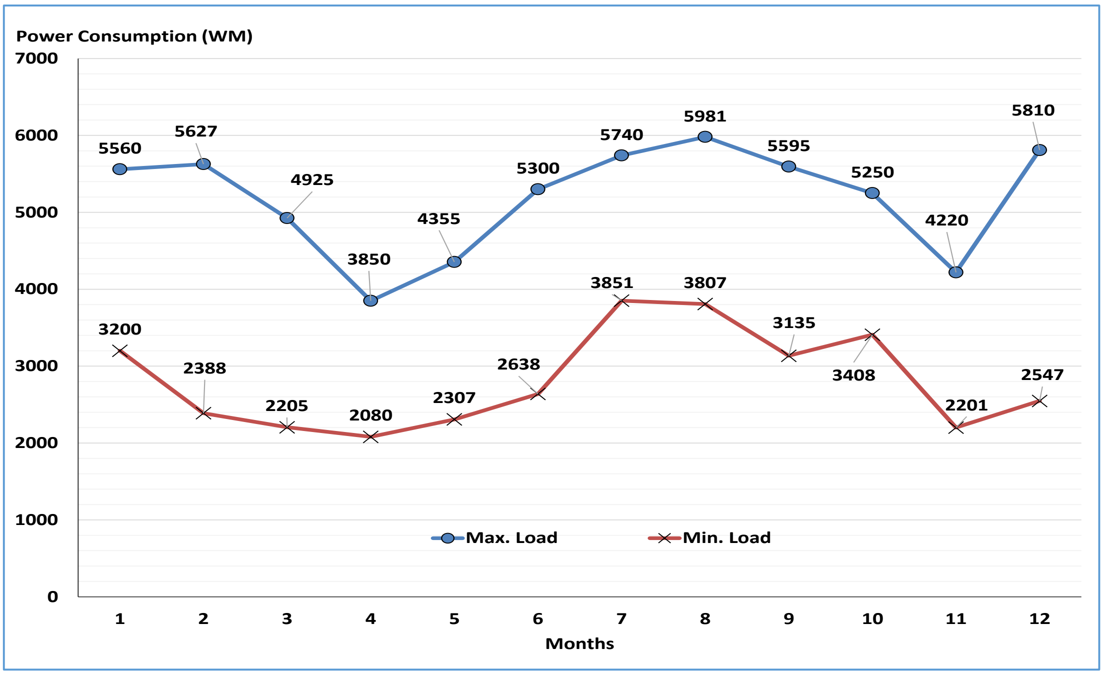


Figure 2-8: The monthly load as of 2012.

Data source: (GECOL, 2013).

In 2012, the electrical sector distribution of energy consumption was approximately 36% for the residential sector, 11% for the industrial sector, 26% for the agricultural sector and 27% for public utilities. Figure 2-9 shows these classifications (Abdulwahad, 2012; GECOL, 2014, 2013; Khalil et al., 2009).

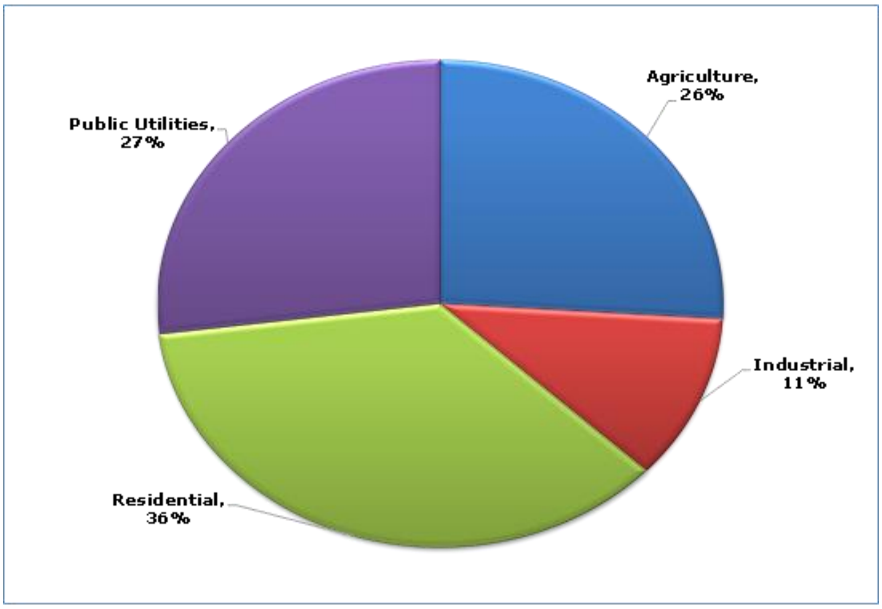


Figure 2-9: Electricity consumption per sector (2012).

Data source: GECOL Report 2013 (GECOL, 2013).

The figure above illustrates that the domestic sector accounts for the highest share of electrical energy demand in Libya. The residential load share is approximately 36% of the overall peak load of electrical power system in Libya (the next chapters include more details about domestic energy efficiency) (Ekhlat et al., 2007).

2.2.1.2. Energy demand in the water sector

The requirement for water is rising in many regions of the world due to domestic, industrial, agricultural and tourist pressures. The exponential growth of the world's population is situated predominantly in the dry areas of the world such as Africa and India, which leads to a growth in food demand, causing additional concentrated stress on water resources that are already scarce. Every year, the groundwater level is dropping by several metres in many of the regions, leading to losses or high salt disturbance, thereby making the water unhealthy for consumption (Komoto, 2009). In fact, many scientific studies have stated that several countries have faced serious water shortages; although the water cover over 70% of the Earth's surface (Lawgali, 2008).

In the past few decades, local water consumption has risen worldwide due to the growth of population, increasing water consumption in the agricultural, domestic and industrial sectors, and increasing living standards. Libya is not different from all other countries worldwide in respect of the reasons which lead to the rise of water deficiency. In addition, water demand with very little recharge has strained the resources of the groundwater in Libya. This has in turn led to a serious drop in both water levels and quality, particularly at the Mediterranean coast, along which most of the industrial, agricultural and domestic activities are located (Lawgali, 2008).

A. Water supply situation

In Libya, annual precipitation is less than 150 millimetres per year and surface water sources are limited: approximately 95% of Libya is covered with desert. In addition, non-traditional sources such as the desalination of brackish water and seawater are also limited (Bindra et al., 2003; Kershman, 2001). In fact, Libya's dependence is primarily on fossil groundwater, which is extracted at a rate of eight times that of its renewal. While the coastal aquifers are being renewed by rainfall, the unrestrained extraction of groundwater from these aquifers exceeds the yearly replenishment (Mandil, 2005).

B. Energy requirements in the water sector

One option for creating new fresh water resources is distilling seawater, which is effectively an inexhaustible source. While a deficiency of energy sources can complicate the use of standard desalination technologies in some regions, in arid and semi-arid regions, the lack of drinkable water often occurs together with high solar irradiation, allowing solar energy to be used as the driving force for water treatment systems. One very promising option, therefore, is to produce the energy necessary for large-scale desalination through solar power (Komoto, 2009). A worldwide survey indicates that Libya is the largest operator of both thermal and membrane desalination plants in the Mediterranean basin and North Africa. Furthermore, it was the sixth country in the world to utilise desalination as a source of water for urban consumption (Kershman, 2001; Wheida and Verhoeven, 2004). The General Electricity Company of Libya, which is also responsible for the water desalination system (Kershman, 2001), planned to install desalination technology with a capacity of one million cubed meters per day (mcpd) prior to the year 2016. This quantity will require approximately 1.8 TWh/year of electricity, and as such water desalination technology in Libya will be a major driver for energy demand (Ekhlat et al., 2007).

Water desalination requires fuel, which will increase from 0.6 Mtoe in 2003 to 2.8 Mtoe in 2030, and this means that the total primary energy demand will be accounting for about 6% of total Libyan demand (Mandil, 2005). In addition, industrial water demand is predicted to rise to 425 million m^3 in 2025. The fuel which is required for water desalination will account for 23% of the rise in energy demand in the power and water sectors (Affairs, 2010).

Desalination plants and non-renewable groundwater resources essentially fulfil presently rising industrial water demand. Since water resources are limited, the current availability of energy sources, including electricity, petroleum and natural gas, have assisted in resolving the challenge of fulfilling a rapid and considerable rise in water demand for industrial, agricultural and domestic purposes (Bindra et al., 2003). The International Energy Agency (IEA) (2005) has stated that about one third of the total electricity capacity additions will be for new combined water and power (CWP) plants with desalination units in Libya. At the end of the projection period, desalinated water is expected to account for 11% of the total water demand (Mandil, 2005).

C. Water production and desalination demand for Libya

The implementation of the Great Manmade River[1] (GMMR), which was started in 1984, has been chosen by Libyan government to address water shortages. The GMMR is designed to transfer 2300 Mm^3/year of fossil water thousands of kilometres to the Northern region (urban population centre) from the Nubian aquifers in the Southern region. Even if the GMMR were to achieve expectations, however, the transported water would address only 40% of predictable demand (Mandil, 2005).

Libya is also planning to increase desalination capacity to enhance the water capacity of the GMMR. Thermal desalination was first introduced in late 1996s (Wheida and Verhoeven, 2004). The total installed desalination capacity had reached 272 Mm^3 by 2003, although real production was estimated to be some one-third of this because most of desalination plants were not in the best operating condition. The desalination sector suffered from unsuitable technical designs and deficiency of spare parts and materials during the twenty years. In 2003, desalinated water supply accounted for only some 2% of the total water supply. The consumption of water is projected to rise to 5,713 Mm^3 in the year 2030 (Mandil, 2005). Therefore, GECOL has been implementing a one-billion-dollar programme in order to install desalination capacity of 307 Mm^3 by 2030 (see Table 2-3) (Mandil, 2005).

Table 2-3: Water and desalination capacity projections for Libya.

Items	2003	2010	2020	2030
Water consumption (Mm^3)	4 867	5 051	5 383	5 713
Desalination capacity (Mm^3)	272	465	532	772
Oil and gas requirements for desalination (Mtoe)	0.6	1.4	1.9	2.8

Data source: (IEA, 2013).

[1] The Great Manmade River Project is a network of pipes that supplies water from the Sahara Desert in the south of Libya to the north.

2.3. Price of energy

The main objective of this section is to demonstrate the current price of energy supplies in Libya, including the prices of petroleum product and electricity to consumers, due to its impact on both the financial and economic positions of Libya and in turn on the Libyan people's standard of living. It could be argued that energy supplies and prices are the main financial and economic factor in all countries. Energy demand is price sensitive, in particular for electricity. A long-term price increase will save huge energy quantities and reduce greenhouse gases emissions in countries with distorted prices. Subsidies have placed massive pressure on public funds and indeed overcome them and state-owned enterprises are normally a victim of the practice (Affairs, 2010).

Subsidisations are well-known throughout the economy of Libya. Energy, water and agriculture receive wide state funding through input subsidies and price. The Libyan government also subsidises oil through customer subsidies. As such, in Libya the price of oil products to customers is less than the international price for similar products. This is a distortion on the market price and represents an implicit subsidy of oil products (Affairs, 2010).

Several efforts have been made to try to reduce the high level of subsidies, but they are still at the same high level. Diesel is sold at 17 Dirhams/litre and gasoline at 20 Dirhams/litre (1000 Dirham = 1 Dinar; £ pound = 2 LD at present exchange rates). Table 2-4 includes the latest sale price to Libyan consumers.

Table 2-4: Prices of some petroleum products to consumers.

Fuel	Sale price to consumers Dirhams / litre	Transfer sale price to consumers £ Pound / litre
Diesel	17	0.08 pence / litre
Gasoline	20	0.10 pence / litre

Data source: (GECOL, 2013).

Table 2-5 shows the development of fuel prices to the electricity sector from 2001 to 2009. The attempts to bring prices closer to the global prices are visibly. In Libya, inflation was subdued and there have been long deflation periods. Consequently the price increases are actually effectively larger.

Table 2-5: Historic development of fuel prices to the Libyan electricity sector between 2001-2009 (Dinar / m^3).

Fuel type	2001	2002-2005	2006	2007	2008	2009
Heavy Fuel Oil	18.4	18.4	18.4	18.4	18.4	36
Light Fuel Oil	26	36	56	66	86	150
Natural Gas	0.008405	0.008405	0.008405	0.008405	0.008405	0.02

Source: (GECOL, 2013).

The Libyan government has been subsidising electricity prices in two ways, and as illustrated below the General Electricity Company of Libya (GECOL) receives fuel input at prices lower than the international prices (see Table 2-6). This kind of support is known as an implicit subsidy, which does not appear in the government accounts. In the last few years, it has also received capital that was free: this is an explicit subsidy which does appear in the government budget.

Table 2-6: Fuel prices (2006-2007 average).

Name	GECOL (subsidized)		International	
	$/Mbtu	Cents/GCal	$/Mbtu	Cents/GCal
Heavy Fuel Oil	1.390	549.88	11.59	4598.83
Light Fuel Oil	0.358	142.03	5.47	2169.58
Natural Gas	0.160	63.49	7.00	2777.78

Mbtu = million British thermal units. GCal= Giga calorie.
Source: (GPEWGL, 2013).

Table 2-6, indicates that the average price of HFO supplied to GECOL between 2006 and 2007 was 1/12 of the international HFO price. NG was much cheaper and the average supplied price was just 1/44 of the international price (GPEWGL, 2013). If we consider the recent hikes in international oil prices, these gaps must have widened further. The reason that the average prices of 2006-2007 were used is that there is not enough information about GECOL prices after this period.

The sales revenues of electricity are inadequate to cover the costs of production, so the government also compensated the deficit by a direct financial transfer (GPCEWGL, 2010). GECOL estimates its average cost per unit of electricity sold at around 64

Dirham/kWh. This takes into account the large commercial losses (about 25%) and also the technical losses (13-14%), for which no income is received (GECOL, 2013).

Table 2-7 shows the domestic consumers' tariff according to the Regulation on electric energy services, issued by the General People's Committee Decision No. 82 of the year 2007, and so far still in force.

The Regional Centre for Renewable Energy and Efficiency stated in 2010 that the average revenue from a local customer was 23.6 Dirhams/kWh; this value is near to the smallest tariff due to the majority of customers being in the lowest band (REN21, 2011). A point of significance arising from the high threshold for the definition of the lowest tariff group is that the majority of consumers receive the subsidy; it is by no means confined to the poor. The tariff is unchanged since 2008 as shows in Table 2-7.

Table 2-7: Libyan electricity tariff.

Residential (According to General Electricity Company)	
Consumption level (kWh)	Tariff (Dirham/ kWh)
1 to 1000	20
1001 to 1400	30
Over 1400	50

Note: 1 LD = 1000 Dirham ≈ 0.5 £ pound.
Data source: (GECOL, 2013).

The other major consuming groups' tariffs are also well below the unit producing cost, for example heavy industry (average revenue equivalent 31 Dirhams/kWh) and light industry (42 Dirhams/kWh). Except the sales to commercial enterprises, public facilities including street lighting and government, the selling price exceeds the average cost of production (Affairs, 2010).

Table 2-8: The tariff and classifications for major costumer groups for electricity.

Classifications costumers	Unit price (Dirhams/kWh)
Public facilities	0.068
Heavy industry	0.031
Light industry	0.042
Small agricultural	0.032
Large agricultural	0.032

Data source(Affairs, 2010; GECOL, 2013).

Despite the tariffs currently being heavily subsidised, they were even further from cost in the past. Table 2-9 shows the development of costs over the past 30 years for consumers other than those in the residential sector. In several cases prices have increased. This is not accurate for the domestic sector, where average revenues have persisted at about 20 Dirhams/kWh over the whole period. Local customers have therefore been protected from this partial improvement (Affairs, 2010).

Table 2-9: Development of electricity prices to non-residential sectors (Dirhams / kWh).

Sectors	Before 1981	82-95	96	97	98-03	04-05	06-08	09-12
Small agriculture	5	15	20	25	30	30	30	32
Large agriculture	5	15	21	27	32	32	32	32
Light industrial	15	15	24	33	42	42	42	42
Heavy industrial	7	10	17	24	31	31	31	31
Public facilities	15	30	35	40	45	68	68	68

Data source: Several GECOL reports.

2.4. Libyan's environmental situation

The main motivation of this section comes from the strong global desire to reduce the risk of GHG emissions, whether in the current time or in the future. Specifically, it will examine the arguments around implementing emission reduction policies that can help to reduce GHG emissions and their economic and environmental implications on both advanced developing and industrialised countries (FE, 2009; UNFCCC, 1997). The discussion has asserted that the impact of a changing climate will affect environmental, social and economic sustainability. Several experts have debated and warned against the risk of worldwide climate change deriving from the rise of GHG emissions in the atmosphere. The United Nations Framework Convention on Climate Change (UNFCCC) adopted the Kyoto Protocol in 1997 (see www.unfccc.int), signed by 84 states, under which all the major industrialised countries must limit their GHG emissions and bring them back down to 1990 levels (UNFCCC, 2003).

The Human Development Report (HDR) 2007/2008 indicates that the annual change of CO_2 emissions was 4.2% throughout the period of 1999-2004[2]. Furthermore, the same report found that Libya accounts for 0.2% of international emissions: an average of 9.3 tonnes of CO_2 per person (Watkins, 2008). In respect of the various environmental conventions, Libya has signed and ratified numerous agreements such as the Vienna Convention in 1990, the United Nations Framework Convention on Climate Change in 1999 and the Kyoto Protocol in 2006 as a Non-Annex I party (UNFCCC, 2003; Watkins, 2008). Thus, the country has the opportunity to implement emissions reduction policies such as an emissions trading mechanism. Well-defined emissions reduction policies and environmental regulations are one of the key elements that can positively treat the problem of climate change.

Libya is the world's 11th largest oil producer (Pratten and Mashat, 2009), and as a result of rising petroleum production and its substantial revenues (accounting for about 95% of export earnings and contributing more than 54% of the Gross Domestic Product (GDP[3]), as mentioned earlier in this chapter), the country has seen a significant increase in GHG emissions, particularly CO_2 emissions (Elhage et al., 2008; SAMI, 2012). Oil and the manufacture of cement dominate GHG emissions in Libya (Elhage et al., 2008; Khalil et al., 2009).

Most countries have seen considerable growth in CO_2 emissions, which is often related to both economic and industrial growth. High levels of urbanisation also contribute towards the current situation in large urban centres in Northern Africa. Libya has the

---

[2] GO_2 emissions are now believed to be primary greenhouse gas responsible for the problem of global warming (REN21, 2013).

[3] GDP: Gross Domestic Product, which is the total value of all goods, services, agricultural produce and minerals extracted in a country or area, usually in one year. Often the GDP divide by the population is used as a measure of relative prosperity. GDP=C+I+G+(X-Im). C= Consumption Expenditure, I= Investment, G=Government Expenditure, X=Export, Im= Import.

highest per capita share of CO_2 emissions in comparison to its neighbours. CO_2 emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include CO_2 produced during the consumption of solid, liquid, and gas fuels and gas flaring (Mohammed, 2010).

The main sources of air pollution in Libya are related to the use of petroleum derivatives as fuel in many artisan, industrial and transport fields (Abdul-Hakim, 2006). The emissions of CO_2 mostly originate from fuel burning in the power production sector (38%), in the transport sector (20%) and in industry (8%), with other sectors representing the remaining 34% (Lawgali, 2008; Mangement Commission, 2010). Oil factories are one of the major causes of atmospheric pollution because of the harmful gas emissions, primarily carbons, hydrocarbons, sulphurs and nitrogen oxides which are released from the burning of petroleum in refineries and oil fields (Abdul-Hakim, 2006; Votano et al., 2006), and they also have adverse effects on the surrounding residential and maritime areas. In 2003, petroleum was responsible for more than 60% of CO_2 emissions in Libya and natural gas accounted for around 40% (Salah, 2006).

In 2010, two thirds of electricity in the world were produced from the burning of fossil fuels, which leads to the release of CO_2 and other GHG emissions into the atmosphere. In the same year, Libya produced about 60 million tons (Mt) of CO_2 emissions in comparison with 50 million tons (Mt) of CO_2 in 2002: that is, approximately 0.2% of world CO_2 emissions. In general, power-related emissions are responsible for a large proportion of CO_2 emissions in the country. Libya‘s energy-related CO_2 emissions rose by more than 78%, from less than 18.7 million tonnes of oil equivalent (Mtoe) in the year 1980 to about 50 Mtoe in 2003, mostly because of increased power supply (Ekhlat et al., 2007). The emission amount differs from one fuel type to another (coal, oil and natural gas) and therefore the growing use of natural gas should work to lower CO_2 emissions (Mohammed, 2010). Table 2-10 shows the value of CO_2 emissions from power generation:

Table 2-10: CO_2 emissions from power generation in Libya 2012.

Fuel type	Power generation MWh	Fuel consumption m³	Conversion factor	Kg CO_2 / year
Gas	20,727,800	6,013,482,065	0.185	3,834,643
Light fuel	7,135,800	2,388,932	2.518	17,967,944.4
Heavy fuel	3,058,200	805,472	2.674	8,177,626.8
No fuel	3,058,200	-	-	-

Data source: (GPEWGL, 2013). Source of conversion factor (Khalil et al., 2009).

As a consequence of rising energy demand, CO_2 emissions will more than double over the projection period, and are expected to reach 104 Mt in 2030. In addition, the annual average growth in emissions is 3.3% over the outlook period, although this will be slower than the forecast 3.6% growth in demand due to the change to gas in power production (Mandil, 2005). The daily data of CO_2 emissions includes fuel intake and energy production from different producing units, particularly combined cycle units, which account for about 37% of the total energy produced in the Libyan network (see Figure 2-10), and increase energy productivity and improve environmental conditions by reducing CO_2 emissions (Khalil et al., 2009).

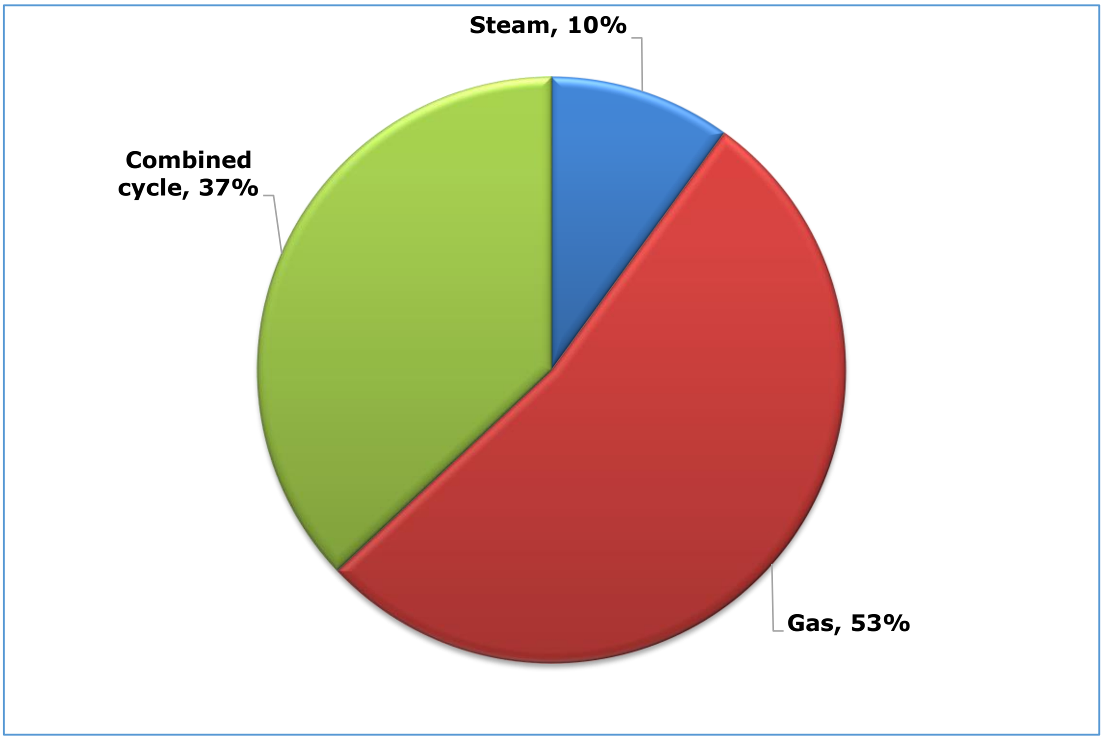


Figure 2-10: Energy produced in 2012 by type of technology.

Data source: (GPEWGL, 2013).

2.5. Summary

This chapter presented a situational analysis of energy and the environment in Libya, focused on the current and future energy situation, energy demand in the electrical and water sectors, and current energy prices, as well as the Libyan environmental situation. There is significant evidence of continuous increase in energy demands and the effect of fossil fuel on the environment in a negative way. However, with the purpose of achieving the research objectives and completing the requirements of the proposal of this thesis, a discussion and review of the renewable energy jobs, global investment flows and Libyan investment is required in the next chapter. Furthermore, the next chapter includes a section on energy efficiency (saving energy), with related literature for this study. These will be the subjects of the next chapter.

Chapter 3. Economic situation: investment opportunities and energy efficiency.

3.1. Introduction

In the recent past, the effects of continuing climate change and abnormal weather conditions have resulted in a negative impact on overall development efforts. Economic sectors that largely depend on weather conditions directly or indirectly – for instance fisheries and agriculture – are increasingly subject to the effects of climate change (IPCC, 2012). Additionally, the natural resource depletion experienced as a result of increased demographic and environmental pressures tends to raise the severity of the impact of climate change. There are increasing concerns about the rising threats to the consumption patterns and existing income of households and individuals that earn their incomes from these sectors (Foresight, 2011; IPCC, 2012).

It could be argued that facing environmental challenges provides opportunities for employers and workers which can lead to economic growth. As such, some modern industries address climate change, such as those at the forefront of the clean-technology sector and the global efforts to make shifts in patterns of use and invest in the green economy (Eco-economy). In addition, these challenges can lead to the establishment of large numbers of green jobs in sectors such as renewable energy, agriculture, environmental protection, industry, research, development, management, activities and services, and jobs focused on, for example, the energy efficiency of buildings and sustainable transport systems (Presence, 2012).

This chapter is divided into four main sections. Renewable energy job opportunities are explored in the first section. Sections two and three discuss global investment and Libyan investment, and Libyan economic reforms. Energy efficiency (saving energy), which is the fourth section in this chapter, examines the effects of Libyan domestic characteristics and the possibility of altering them on the overall energy consumption and demand in Libya, and this in fact represents the objectives of this research study.

3.2. Renewable energy and green jobs opportunities

This section examines the role of environmental challenges in providing opportunities for jobs, which can be reflected as economic growth for a country. It will show how renewable energy can generate more job opportunities and new investment challenges.

Libya as a country is facing environmental challenges and lack of opportunities for work. According to the Ministry of Libyan Labour the percentage of unemployed in Libya at 15%, this percentage represents approximately 400 thousand unemployed people in Libya. 149 thousand of them have university qualifications: 43% of the total unemployed (Mangement, 2012).

In terms of job opportunities in the renewable energy sector, there has been a significant increase in the 21st century. The International Renewable Energy Agency Report (IRENA) 2013, which was based on an extensive range of studies, principally from the period 2009–2012, showed that 5.7 million people worldwide work directly or indirectly in the renewable energy area. The international renewable energy workforce involves a broad diversity of occupations and jobs, ranging from low to very high skilled. Though a growing number of countries are investing in renewable energy, the majority of employment remains concentrated in a relatively small number of countries, including China, Brazil, India, the United States of America and the EU member states. Employment is growing in other countries as well, and there are rising numbers of jobs (technicians and sales staff) in the off-grid sector of the developing world such as selling, installing, and maintaining small photovoltaic (PV) solar panels (REN21, 2013).

Sorted by technology, globally, the largest number of jobs, about 1.38 million, is now in the biofuels value chain, mostly in cultivating and harvesting feedstock, where jobs vary seasonally. Brazil's sugarcane-based ethanol industry is the largest biofuels employer, although growing mechanisation of feedstock harvesting has decreased the number of direct jobs in sugarcane and ethanol processing to 579,000 in 2011. The estimates for employment in biomass heat and power are quite soft and dated with the exception of the EU data. *"For solar heating/cooling, there are important discrepancies among available sources, and estimates range from 375,000 jobs internationally to 800,000 for China alone. Growth of jobs in the wind industry has reduced somewhat globally, while employment in solar PV has surged in recent years.*

Yet solar PV is facing turbulence, as huge overcapacities and tumbling prices have caused layoffs and bankruptcies on the manufacturing side, while allowing significant increases in the ranks of installers. Hit hard by the economic crisis and adverse policy changes, Spanish renewable energy employment fell from 133,000 jobs in 2008 to 120,000 in 2011. The concentrating solar power (CSP) industry at first offset a portion of the job loss, however it is in trouble itself currently because of policy changes, with employment dropping below 18,000 in 2012. In France, renewable energy jobs decreased by 17% between 2010 and 2012, mainly in solar PV and geothermal heat pumps. In 2012, Germany lost 23,000 solar PV jobs, but also added 17,000 wind power jobs. In the USA, solar employment associated with installations is increasing, while the number of wind and biofuels jobs varies in response to policy changes. For instance, U.S. biofuels employment dropped from 181,300 to 173,600 in 2012 owing to soaring feedstock prices, a drought-induced drop in yield, and lower demand. Generally, aggregate international renewable energy employment remains in growth in a dynamic albeit somewhat tumultuous process that involves both gains and losses in different parts of the world" (IRENA, 2013):p.53.

3.3. Global investment

Global new investment throughout 2013 in renewable energy and fuels was USD ($) 214.4 billion, a drop of 14% from the previous year's record amount of $250 billion (see Figure 3-1).

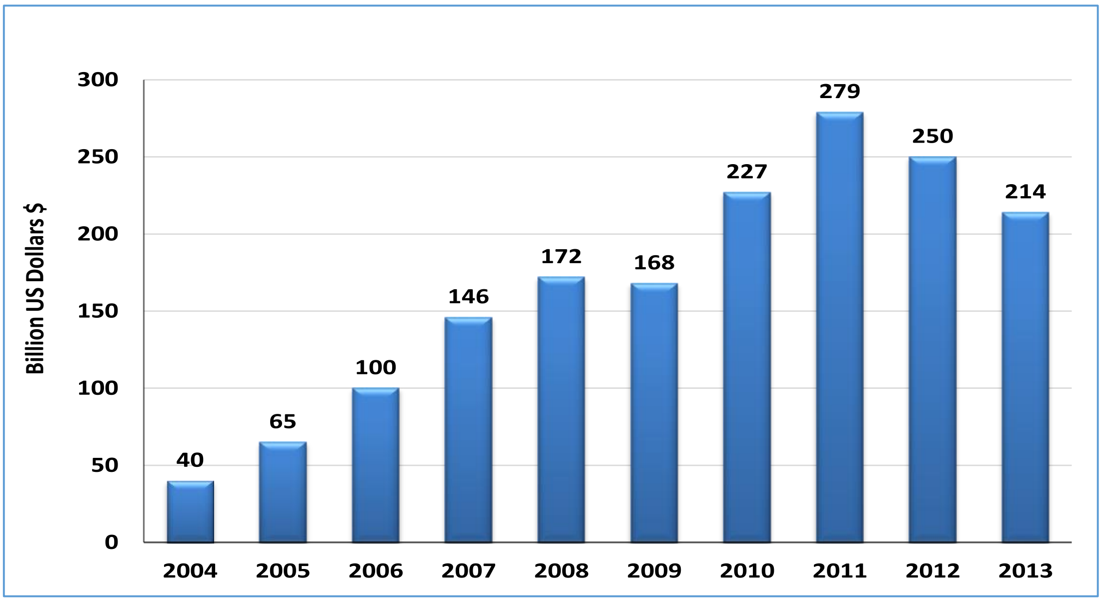


Figure 3-1: Global new investment in renewable energy, 2004-2013.
Data source: (Brower et al., 2014): p. 67.

2012's total was the second highest ever and 8% above the 2010 (Brower et al., 2014; Teske et al., 2013), though less than the corresponding value for 2011. The reduction in investment after many years of growth was caused by uncertainty over support policies in Europe and the USA, as well as retroactive reductions in support. On a more positive note, it is also in part the result of sharp reductions in technology expenses (REN21, 2013; Teske et al., 2013).

A significant factor in 2012 was an extra movement in activity from developed to developing economies, though the previous group still accounted for more than half of global investment. In 2007, developed economies invested two and a half times more in renewables (excepting large hydro) than developing countries did; in 2012, the difference was only 15%. China was the chief country for renewable energy investment. The other main trend of 2012 was a further, significant reduction in the costs of solar PV technology. Indeed, the continued improvements in price competitiveness for solar and wind power helped to support requirements in several markets (REN21, 2014).

The year 2012 experienced the largest shift yet in the balance of investment activity between developed and developing economies. Expenditures in developing countries reached $112 billion, or 46% of the world total; this was up from 34% in 2011, and continued an unbroken eight-year growth trend. On the other hand, investment in developed economies fell 29% to $132 billion, the lowest level since 2009. The alteration was motivated by reductions in subsidies for solar and wind project development in Europe and the USA; improved investor interest in developing markets with growing power demands and attractive renewable energy resources; and falling technology expenses of wind and solar PV. Europe and China accounted for 60% of global investment in 2012 (Brower et al., 2014).

Solar power was the most significant sector by far in terms of money expended in 2012, receiving 57% of total new investment in renewable energy (96% of which went to solar PV). Despite that, the $140.4 billion for solar was down 11% from 2011 levels, because of a drop in financing of CSP projects in Spain and the United States, in addition to severely lower PV system prices. Solar was followed by wind power ($80.3 billion) and hydropower projects larger than 50 MW (estimated at $33 billion) (REN21, 2013; Teske et al., 2013).

3.4. Libyan investment requirements

The main objective of this section is to explore the reforms of the Libyan economy before and after the political change of 17 February 2011 and investment opportunities in renewable energy. Moreover, this section includes an examination of the history and the future of Libya's investment situation and structure.

3.4.1. Reforms of investment policy prior to the political change of 17 February 2011

Historically, the Libyan economy has suffered from many negative factors. In the early 1990s, the government introduced a series of reforms to allow an expansion of the base of ownership and the direct participation of the private sector in economic activities in order to restructure the economic sectors. The government issued a number of laws in order to regulate economic operations such as:

- N 5, 1997 encouragement of foreign capital investment – amended by law 7, 2003;
- N 9, 2000 regulation of transit commerce and free zones;
- N 21, 2001 governing the practice of economic activities for individuals and public companies;
- N 1, 2005 concerning banking;
- N 2, 2005 combating money laundering.

In addition, the Libyan government issued several economic regulatory decisions, such as:

- N 178, 2001 organising the work of agencies;
- N 2, 2002 organising import and export;
- N 21, 2002 organising foreign capital investment;
- N 8, 2005 organising the opening of offices for representatives of foreign companies in Libya;
- N 737, 2005 organizing the registration of branches and offices representing foreign companies.

Libya witnessed a number of economic developments post 2000. These are:

1. In 2001, companies and corporate bodies to practice economic activities.
2. In 2003, the requirements for the export and import licences were cancelled in order to offer facilities for individuals.
3. In 2005, to incentivise trade, the country was made a free trade area. Libya also lifted all duties (except for cigarettes) and these duties were replaced by a 4% tax, the Service Import Tax (Khaled, 2007).
4. In 2007 the EU is Libya's main trading partner, both for exports and imports. The EU's share of Libyan exports is nearly 80%, while its share of Libyan imports reached about 55% (EN, 2013).

These laws, decisions and statutes increased the size of commercial operations and competition, improved the role of banks in economic activities and encouraged local and international foreign investors.

The government of Libya has displayed a growing interest in foreign private investments since 1997. It issued Law No. 5/1997 and its amendment, Law No. 7/2003, which offered several incentives and abundant guarantees to attract foreign business and investment to assist economic development in Libya (Khaled, 2007). The laws' aims, as stated by article 1, included: diversification of income sources; achieving regional development; building up Libyan technical cadres; contribution to development of national products to assist in entry thereof into the international markets; and transference of modern technology.

Article 8 of Law No. 5/1997 states that foreign investment is permitted in Libya in the following sectors: health, tourism, industry, services, and agriculture. The Libyan Foreign Investment Board (LFIB) is a government body established by article 5 of Law No. 5/1997. The LFIB is an independent autonomous body attached to the Ministry for Economy and Trade which aims to attract and support foreign investors (LFIB, 2007).

After UN sanctions were raised in 2003, Libya made considerable progress on economic reforms and amended some laws as part of a broader campaign of international reintegration (CIA, 2007), which has encouraged Libyan international trade. After the lifting of the UN sanctions, Libya applied to become a member of the

World Trade Organisation (WTO)[4], and has been in membership negotiations (it presently holds observer status) since 2004 (EN, 2013). Libya first applied to be accepted as a member of the WTO in December 2001, but failed repeatedly to implement the reforms required (EIA, 2012). This once-closed economy is recently attracting foreign investments, and it has taken great steps in rebuilding relationships with the international community. As such, Libya's place in a concurrently emerging and fast-growing Arab market makes this an especially interesting focus for the study (Busnaina, 2010).

The LFIB granted approval for the construction of 220 projects between 1998 and 2007 in many fields. Of these approved projects, a total of 156 projects were actually undertaken with a total investment cost of DL 9,386 million, including $6,184 million from foreign investors and DL 1,347 million from local investors (LFIB, 2007). Despite relaxation of the barriers to entry, Libya is still seen as a changeable business location, and this has served to stifle regional commercial ambitions (Busnaina, 2010).

The government established the Libyan Investment Authority (LIA) in 2006, a sovereign wealth fund (SWF) that combined the assets of the Libyan Foreign Arab Investment Fund, the Libyan African Investment Portfolio and the Oil Investment Company. It is the receiver of "excess" oil funds and invests mainly through a number of external money managers. LIA is one of the main SWFs, with assets of about $70 billion. In February 2006 the Libyan African Investment Portfolio was established; it now has significant holdings in Oil Libya, the Sahel-Saharan Investment and Trade Bank, and the Libyan Arab African Investment Trade Company (EIA, 2012).

Libyan economic activity is predominantly managed by the state, which controls about 80% of the economy. Almost all of the main industrial concerns, including the National Oil Corporation, are state-owned. Most of the food required by Libya has to

[4] The WTO is the legal and institutional foundation of a multilateral trading system of member countries. It includes 148 countries, and was created in January 1995, with 76 original members then followed by a further 72 members joining in the following years.

be imported due to the inappropriate climate and the limited amount of arable land. There is a serious need to expand the economy, spur the private sector to decrease unemployment, slim down an over-employed state sector, release the economy, and encourage foreign investment outside of the infrastructure and energy sectors. The government still holds price, credit, trade, and foreign exchange controls, although some new modest reforms have been done, including the partial privatization of two banks and a decrease in some subsidies (EIA, 2012).

According to Barkawi, the latest Libyan Foreign Investment Law, 9/2010, opens up new sectors that were previously closed to foreign investments and to the private sector. This law offers exemption from company tax and various stamp and customs duties for a period of five years which, subject to conditions, might be extended for a further three years. The law includes not only pure foreign investment, but Libyan private capital overseas as well (Barkawi, 2014). These economic reforms and others will have a positive impact by encouraging local and foreign investors, with more detail provided in the following sections.

3.4.2. Reforms of investment policy post to the political change 17 February 2011

After 17 February 2011 Libya experienced a dramatic rise in construction activity, with a range of determined development programmes, mainly in relation to housing, education, tourism and infrastructure. In spite of the country being presently well-placed to fund these development programmes, there is still a huge demand for foreign investment to provide project capital. The input of much-needed knowledge-transfer, training and professional expertise should improve on what is perceived to be a lack of due industry and transparency in Libyan projects and also make an attractive proposition for foreign investors (Umar, 2013).

With regard to transparency, the new Libyan government has made it clear that accountability, openness and transparency will be dominant in all future dealings. This is a positive response and if it can be met, foreign investors will be much more motivated to become involved in Libyan construction. An additional mechanism to provide confidence to foreign investors is for Libyan customers to use the services of construction consultancy practices controlled by internationally recognised professional bodies (Umar, 2013; Waddah, 2013).

Internal and external experts have suggested that Libya's economic development strategy should expand to decrease dependence on hydrocarbons. Development of Libya and its economic growth depend on expanding, improving and renovating the country's infrastructure. Prior to 2011, the requirements of Libya's infrastructure were clear. Years of sanctions and underinvestment had left the country in considerable disorder. In this respect, the Arab spring of 17 February led to further disappointments, leaving services damaged and disturbed, coupled with a lack of expatriate expertise and skills. Prior to the political change, Libya had already embarked on a development programme of over $120 billion, and new spending is predicted to run into billions of dollars. Libya is an undeniably attractive country for investors, giving an opportunity to contribute to the development of the economy of North Africa's richest nation, although confirming that standards are recognised and sustained and that strategic management plans are in place may be a challenge (Umar, 2013).

The economic sector requires the setting out of a background for infrastructure growth to both monitor and protect investors. There is likely to be the possibility for business between public and private sectors. Rewards to Libya as a country will comprise the stimulation of the economy and enhanced confidence through fast establishment of local employment. It is a period of opportunity made still stronger by the chance to utilise low construction prices while other countries in the region continue in a state of economic collapse. In Libya almost all sectors are suitable for investment, particularly energy, services, industry, tourism, and agriculture. Libya could capitalise on projected growth with further investment in these sectors, ports sites and internal transport networks (Waddah, 2013).

The Multilateral Investment Guarantee Agency (MIGA), a member of the World Bank Group, signed its first investment agreement contract in Libya, assuring a $9.8 million investment in the expansion of a beverage and harissa plant outside Tripoli in September, 2012. This is the first time any World Bank Group offering or guarantee instrument has been made in the country. A growth in international investment guarantees and political risk assurance would increase international investors' confidence in discovering new opportunities in Libya (Stephen, 2013). Confidence in public financial management is a basic requirement for investors. Some significant measures have already been defined by international financial organisations, specifically concerning macro-economic management and a transparent rules-based approach to budget planning and expenditures in the public sector. In particular, development systems and integrated procurement are essential to detect projects opportunities, assess offers and initiate project management. Transparency, accountability and results-based performance measurements are the foundations upon which investor confidence will rest. To attract the best foreign investment it is essential that procurement systems are transparent and payments reliable and timely (Waddah, 2013).

Regulation and implementation of standards are similarly vital to investor confidence. While a suitable legal system supporting private sector activity has been in place since before the Arab spring, confidence needs to be recovered in reasonable legal processes for everyone in project investment, management and development. A reliable legal system, independent, and efficient is important for building confidence between investors. In the coming years, infrastructure will be the most interesting sector in Libya's economy. Informed by national priorities, supported by the rule of law, and undertaken with transparency, there will be no barriers to confidence amongst investors in this huge and active sector (Stephen, 2013; Waddah, 2013).

In July 2012 the Libyan Minister of Economics issued decrees Nos. 207/2012 and 103/2012 which organise the legal framework for foreign investment in Libya. Laws 207 and 103/2012 are applicable in most economic sectors except certain areas which are strictly limited to the Libyan people. As for foreign companies, the laws also detail the form of legal entities, i.e. limited liability, branches of foreign companies, joint ventures and representative offices (Karbal, 2014).

3.4.3. Investment opportunities in the energy sector

This section explores the opportunities available to the Libyan government and the implementation barriers to be overcome in order to utilise the opportunities available in both conventional power plants and renewable energy.

3.4.3.1. Investment opportunities in current energy resource

The Libyan government plans to raise crude production capacity from 1.8 million barrels a day (bbl/d) in 2009 to 3 million bbl/d by the year 2013. The country has an additional 5 billion barrels of oil unused that are difficult to develop or too remote, accounting for 12% of its total oil reserves (Teketay, 2010). The National Oil

Corporation (NOC) has controlled the oil industry and manages investments in Libya through Exploration and Production Sharing Agreements (EPSA). National refining capacity totals approximately 378 thousand bbl/d, being provided by five domestic oil refineries, all possessed by the NOC (Affairs, 2010). In Libya, oil refineries require urgent repairs and improvement. In addition, because Libya was unable to import new refining technologies through the period 1993-1998 due to trade sanctions, its refining capacity is lower than the design capacity (Affairs, 2010; Mandil, 2005).

The NOC is also the producer of natural gas and has control of all new discoveries. Libya has proven natural gas reserves equivalent to 55 trillion cubic feet (tcf). This amount has risen significantly over the past 20 years since large investments have been started to investigate new deposits. The International Energy Agency (IEA) predicts a marked rise in gas production from 6 billion cubic meters (bcm) in 2003 to 12 bcm in 2010, and then a surge to reach 57 tcf by the year 2030 (Affairs, 2010).

With energy demand on the increase, most of Libya's existing power stations are being changed from oil to natural gas and new power plants are being established to run on natural gas. Moreover, the Libyan government is planning to expand the production of natural gas, to maximise the quantity of oil available for export by replacing oil-fired power plants with natural gas-fuelled units, and to increase its natural gas exports to Europe and elsewhere (Affairs, 2010; Hassin, 2009). Natural gas production was increased by 180% to reach about 30 bcm per year between 2000 and 2007 (MEREL, 2005; Tanaka, 2009), but the work on this investment plan has been stopped due to the conflict.

3.4.3.2. Investment opportunities in renewable energy resources

Although with few tangible results, Libya has been talking about expanding its economy away from hydrocarbons for years. It could become a significant solar- and wind-power producer for export to Europe, and improve the country's infrastructure through the building of its long-planned railway network. This could also make Libya a communications core between Europe and Sub-Saharan Africa.

The new government of Libya will be producing draft legislation to boost the renewable energy sector in Libya. It will cover the purchasing, rental or letting of land for renewables, and will also work to promote the general public to produce solar energy on their rooftops. However, there are some barriers, such as the reduction of energy subsidies and increased energy prices to customers. The main problem in this regard which is currently facing Libya is the disincentivising low price of electricity, which does not motivate people and the government to consider investing in renewable energy. Local consumers pay LD 0.03 per kW for power that costs Libya around LD 0.30 per kW to produce; the international average price of generation is about €0.17 per kW which equals approximately LD 0.29. The Libyan government must take this difficult political decision as the expectation of energy demand increases in the future. Renewable energy supply on a large scale is inevitable; therefore the government must have a long-term strategy. Libya should be at the centre of renewable energy (Sami, 2013), while at the same time it should work on other factors such as energy efficiency which can save both energy and the funds of the public state budget (Waddah, 2013).

3.4.4. Libyan policy of foreign investors

The Libyan government goals to encourage the foreign investment (foreign capital) by enforcing the right legislation (leaving the door open for the local capital to participate) particularly in relation to projects that incorporate state of the art technology, which can contribute to the development of local market to bring it in line with worldwide standards (Article No. 1 of Law No. 7 of 2003).

It has worked to reassure foreign investors by developing a number of guarantees, in order to encourage Foreign Direct Investment inflows. The guarantees include dispossession, seizure, immunity against the risks of nationalisation, freezing or reservation or any other procedures with a similar effect unless by law or a court order in which case the victim will be entitled for prompt and fair compensation. Otherwise prompt and fair compensation should be paid according to the market price of the project. These guarantees or procedures should be applied indiscriminately. Moreover, investors have the right of appeal against any inconvenience or any decision that caused as a result of the application of the law, within 30 days from the time of first being informed in writing of the measures (Articles No. 20, 23 of Law No.7 of 2003, and Article No. 39 of the Executive Regulation).

3.5. Energy efficiency

Energy efficiency has increasingly become an important issue in balancing the energy security equation for any given country (Abdo, 2011). Energy efficiency works on the demand side by reducing the consumption of energy, so increasing the opportunity of providing enough energy to consumers. Energy efficiency has become one of the most pressing issues in modern society.

Renewable energy in the MENA region can be closely linked to Europe. Several ideas have been raised in the past to power Europe from the renewable energy available in Africa, particularly from North African countries including Libya. Scientific studies have demonstrated that the desert sun could meet the increasing power demands in the MENA region while powering desalination plants to provide freshwater to the MENA region and helping to provide clean energy to Europe, and in so doing reduce carbon emissions across the EU-MENA region. For this vision to become reality, it is important to understand the local energy demands and consumption in the MENA region, if sufficient renewable energy is to be generated and exported to Europe. This section is aimed at investigating the effects of domestic energy consumption and householders' awareness of and attitudes and behaviour towards the overall energy consumption by Libyans, and how this affects the peak production, capacity and state budget.

3.5.1. The significance of energy efficiency in domestic sector

The domestic sector is an important contributor to energy consumption across the world. In the USA domestic electricity use accounts for more than half of the energy consumed, while in Sweden approximately 20% of the total annual consumption of electricity is in fact domestic in nature (appliances, lighting, etc.) (Andreas et al., 2014). A significant body of research has been undertaken in the UK on domestic electricity consumption (Kilpatrick et al., 2011). In the MENA region, energy production continues to increase, but not as fast as local energy demand. In 2006 energy output in Libya was about 47% higher than in 1990, while the use of energy in the area, which in many countries is subsidised, more than doubled. The growth of energy use (about 4.3% a year) was the highest of any region in the MENA. In 1990, domestic energy use constituted 34% of the region's production, while by 2006, 47% of production was used for domestic consumption (Fact et al., 2009). Approximately one half of total energy subsidies in MENA are accounted for by petroleum products, while the remainder represents subsidies on electricity and natural gas. There is a wide disparity of subsidies in the region, with subsidies being more prevalent in oil exporters (Africa and States, 2013).

Since the oil crisis in the 1970s domestic energy conservation has been an area of investigation for applied social and environmental studies (Andreas et al., 2014). In particular, according to the results of Koen and Geun, there are close links between occupants, the building, appliances and behavioural factors and household energy consumption. In addition, the study confirms that there are relationships between demographic and economic factors and household energy use (Koen and Geun, 2011).

3.5.2. Determinants of Libyan domestic energy Consumption

This section discusses the main determinants, or factors. That influence the Libyan domestic energy consumption. Libya plays a major role in connecting petroleum and electricity international networks (Mohamed et al., 2013b). Electricity generation has doubled in Libya between 2000 and 2010. Increasing power demands over the production capacity have led to electricity shortfalls, and the country consequently suffers from power outages in the major cities and other provinces. Libyan energy officials and producers expect that demand for electrical power will increase in the future (Mohamed et al., 2013a).

Libya's petroleum sector has also been affected by power supply issues and the current political instability in the country, which have both had significant effects on production levels from some of the country's largest oil fields (EIA, 2012).

This study introduces, almost for the first time, a scientific investigation into the effects of Libyan consumer behaviour on the overall consumption and demand of energy in Libya, and this is of interest for local and foreign investors.

Domestic energy use in Libya accounts for about 36% of the total energy consumption (GECOL, 2013). Consumption of domestic energy depends on family size, lifestyle, environment (location and climate), types of appliance in use, ownership, physical characteristics of the house and human behaviour (Brandon and Lewis, 1999; Koen and Geun, 2011; Missaoui and Mourtada, 2010; Schipper et al., 1982; Yohanis, 2012). Investigating the effects of these characteristics and the possibility of altering them on the overall energy consumption and demand in Libya is worth undertaking; and these are in fact the objectives of this research study.

Over the years, the Libyan energy sector has undergone development on different fronts such as design, materials and installation. However, research on energy use and energy consuming behaviour is relatively new in Libya. To date, building energy efficient houses which can limit cold and heat transfer due to improved thermal insulation and improved construction is not a well-investigated matter in Libya (Mohamed et al., 2013a).

Moreover, there does not seem to be much interest in the establishment of the average SAP rating of houses from either the Libyan government or most of the Libyan people. The energy performance of a building depends on a number of factors such as the climate, insulation of ceiling and walls, infiltration, efficiency of cooling and/or heating systems (which is a function of the type of air-conditioning systems, boilers and boiler fuel types), type of glazing, home or floor area, orientation, type of construction, age of the house, number of windows and shading on the home's structure. The overall life-cycle domestic energy consumption is lower in a housing stock constructed with low-embodied energy materials (Koen and Geun, 2011; Yohanis and Norton, 2002), and orientated for solar gain by windows and heavily insulated fabric in a moderate climate (Shanks et al., 2006).

Home energy use is a function of the structure and intensity of energy use in that home (Schipper et al., 1982). Energy intensity is affected by the use of energy-intensive appliances, cooling and heating demands, standards of living, occupancy and work patterns, comfort expectations, energy use behaviour, types and frequency of use of appliances and cultural habits (Cathy, 1999; Jaber, 2002; Schipper et al., 1982; Westergren and Hogberg, 1999).

Domestic energy use can be reduced by natural ventilation and lighting, minimising cooling and heating loads, efficient domestic appliances, and promoting energy-conscious behaviour (Westergren and Hogberg, 1999). Such a reduction can lead to a reduction in the peak load of the country. Domestic energy use is increasing in Libya due to the increase in the number of dwellings which in turn leads to an increase in electricity usage. Energy-saving measures have not been adopted and this can affect significantly household energy efficiency in Libya (Wood and Newborough, 2003). As such, CO_2 emissions have continuously increased without a suitable appraisal of new energy-saving measures (GECOL, 2011).

While this energy-efficiency section takes into consideration previous international studies that have been conducted in other countries (Andrade, 2001; Brandon and

Lewis, 1999; BRANZ, 2005; CTNI, 2005; Mansouri et al., 1996; Nilssen, 2003; Yohanis, 2012), it differs from them as it is focused on Libya: an oil and natural gas producing country.

3.5.3. Household energy use and energy behaviour

In the UK, as well as in other countries, many surveys have been conducted to investigate the factors that affect domestic energy efficiency (Andrade, 2001; Brandon and Lewis, 1999; BRANZ, 2005; Mansouri et al., 1996; Nilssen, 2003; Yohanis, 2012).

Both government agencies and energy utilities in the UK have been conducting investigations into domestic energy consumption behaviour (DEFRA, 2003; DTI, 2002; Millward, 2003; Yohanis, 2012). The techniques used to conduct these studies have included questionnaires (Leach et al., 2000), temperature measurements, electricity meter readings and personal interviews (Palmborg, 1986; Yohanis et al., 2008) gathering information from utility bills, monitoring of individual household appliances (Lam, 1998; Yohanis, 2012), self-recording energy diaries (Wilhite and Wilk, 1987) and energy audits (Goldman, 1985; Lee, 2000).

In this section 'energy behaviour' refers to actions taken by occupants in their use of energy in their houses. Energy behaviour plays an important role in determining the magnitude and pattern of domestic energy use, and has been used as such by a number of researchers representing a number of disciplines including economics, science, environmental psychology, business and social policy (Abrahamse and Steg, 2009; Carrico et al., 2011; Poortinga et al., 2003; Seligman et al., 1977). Total consumption of domestic energy can be reduced by 10 to 30% by changing householders' energy consumption (Owens, J., Wilhite, 1988; Yohanis et al., 2008)**.** According to Firth et al., a study related to dwellings in the UK has demonstrated that overall electricity consumption is accounted for a 10.2% increase in consumption by standby appliances (e.g. consumer electronics and TVs) and almost 4.7% increase in consumption of active appliances (e.g. electric showers, lighting and kettles) (Naief et al., 2014). Seeking behavioural modifications with the aim of reducing energy consumption involves some interactions of technical and social phenomena (Firth et al., 2008; Hitchcock, 1993).

With regard to energy use and behaviour, three aspects are worth mentioning here: purchase usage, maintenance and behaviour-related (Hitchcock, 1993; Yohanis, 2012).

Education level and awareness of energy efficiency and climate change also contribute to energy-saving behaviour, while on the other hand many people do not understand their energy bills, and others do not know how and where they may save energy.

Purchase-related behaviour concerns the energy characteristics of the products chosen and explores why householders change their criteria, for example, by adding thermal insulation, installing low-energy light bulbs, energy-efficient glazing, preventing draughts, monitoring energy consumption and/or generating their own energy.

A strong relationship has been established by Yohanis (2008) between floor area and average annual electricity consumption, the study concluding that more floor area leads to greater electricity usage (Yohanis et al., 2008).

Druckman and Jackson (2008), studied domestic energy usage at all levels of society; they have identified factors that contribute to determining energy usage, such as type of house, household composition, tenure and location (whether rural or urban) (Druckman and Jackson, 2008). Income is a significant factor affecting energy use, however the relation of income to education and awareness of environmental matters is not straightforward, making the relationship between income and energy use complex (Druckman and Jackson, 2008; Firth et al., 2008). One main factor in the reduction of household energy consumption is the availability of suitable information.

Dietz (2010) explores matters related to the narrowing of the energy-efficiency gap in the USA, where householders are unable to benefit from the opportunity to save energy and show their part in conserving the environment (Dietz, 2010). Jaffe and Stavins (1994) state that there is a gap between real and ideal energy use. They use the ideas of ‘market failure’ and ‘non-market failure’ to clarify the slow distribution of energy-efficient technologies; ‘market failures’ being defined as market barriers that may need a policy intervention to be overcome. Their effort is an indication of the complexity of household energy analysis, which includes technical, economic and social disciplines, and the assumptions policy makers are required to make (Jaffe and Stavins, 1994).

Gillingham et al. (2009) define a requirement to establish an economically effective level of energy efficiency, and whether a particular policy is essential to accomplishing it. They identified behavioural and market failures that might assist to clarify the gap (Gillingham et al., 2009). Carrico et al. (2011) have noted the absence of available brief summaries for policy makers of the key results of social and behavioural science studies on household energy behaviour. They stipulate that to maximise the potential for achievement, policy makers must combine multiple approaches to behaviour alteration, such as measures to decrease cognitive costs, raise motivation, and offer more actionable and related information. In the vast majority of cases, a single approach to altering behaviour, such as increasing the availability of information, is not adequate to induce meaningful levels of behavioural change, and consequently, a number of strategic tools are required to be in place in order to target a wider audience and to boost rates of acceptance (Carrico et al., 2011).

3.6. Summary

This chapter discusses environmental challenges, how they provide opportunities for jobs and how this can be reflected as economic growth, and renewable energy's effects on the Libyan economy. This uncovered how renewable energy can make more job opportunities and new investment challenges. This chapter also discusses Libya's comprehensive economic reforms for local and foreign investment. This chapter states the opportunities which are available to the Libyan government and the implementation barriers which must be overcome in order to utilise these opportunities in both conventional power plants and renewable energy.

The second part of the chapter contains an investigated domestic energy use and householders' energy behaviour in Libya. The chapter has outlined the expected annual increase of electricity demand in Libya and the yearly fluctuation. This expected increase would mean that Libyan has to invest in a new infrastructure that could cost significant amount of money, or households will face programmed power cuts.

The previous chapter has highlighted renewable energy's positive effects on the global economy energy efficiency of Libya, and, with the purpose of achieving the research objectives and completing the requirements of the proposal of this thesis, has discussed and reviewed the renewable energy jobs, global investment flows and Libyan investment requirements. The second part of this chapter includes a survey of literature on energy efficiency related to this study. The global situation of the renewable energy technologies market and industry will be the subject of the next chapter.

Chapter 4. Global trend of renewable energy technology.

4.1. Introduction

This chapter discusses the global situation of renewable energy technologies, as it is necessary information considering the main aim of this study, to investigate the feasibility of the utilisation of renewable energy resources in Libya by studying the challenges and opportunities for investment in renewable energy in Libya. A description of the global context in general requires a preliminary understanding of the capacity for development of different renewable energy technologies in the world. Over the last few decades there have been some dramatic changes to the global energy market. In fact, the world has seen several important developments in renewable energy technologies. The current global economic recession has been marked by extensive public finance crises that led many European governments to introduce incentives for solar energy. In the meantime, global developments have highlighted the economic, security and human costs of relying greatly on nuclear and fossil energy (Carrico et al., 2011). For example, on April 20, 2010 the BP oil spill occurred in the Gulf of Mexico, causing massive damage and having significant negative effects on the economy and welfare of people in the area (BBC, 2012; Russell, 2010). Moreover, Japan's Fukushima nuclear disaster due to the earthquake and tsunami has led several countries to rethink the role of nuclear energy in supplying electricity (Froggatt, 2011). The "Arab Spring" revolutions have led to oil-price instability worldwide, and the global demand for oil is outpacing the capacity for production.

In the year 2010 the average global surface temperatures were recorded at the highest levels since 2005. GHG emissions have also been rising: in May 2013, CO_2 levels in the atmosphere exceeded 400 parts per million for the first time in many hundred millennia, making the international goal to limit the increase in global temperatures to 2˚C above preindustrial levels even harder to reach (IEA, 2013; REN21, 2011).

These many changes have collectively required a move towards a more sustainable source of energy, and an exploration of renewable energy options. This chapter aims to familiarise the reader with the concepts of renewable energy technologies and with trends and existing capacities in global markets, and to lay a foundation for a later discussion of the findings of this thesis. Therefore, this chapter is divided into three main sections: a general market overview, an examination of renewable energy technologies, and a summary of renewable energy cost development. The first section includes an introduction to several important developments in renewable energy technologies that have had an impact on both direct and indirect uses. The second section looks at renewable energy technologies and the global market state, focused on analysis of the concepts of solar photovoltaic energy technologies, solar thermal energy technologies and global trends in renewable energy technologies. The last section provides a summary of renewable energy cost development.

4.2. Global market and industry overview

This section provides an overview of recent market and industry developments in the heating and cooling, transport fuels, and power generation sectors. The section that follows provides technology-specific coverage of market and industry developments and trends. During 2011-2013, the international demand for renewable energy continued to grow (REN21, 2014, 2013). The international performance of renewable energy has had positive continuous growth. Renewables supplied approximately 16.7% and approximately 19% of global final energy consumption in 2009 and 2012 respectively (El-ashry, 2011; REN21, 2014, 2013, 2012, 2011). Table 4-1 illustrates the consumption of global energy in 2012.

Table 4-1: Estimated renewable energy share of global final energy consumption 2009- 2012.

Type	2009	2010	2011	2012
Fossil fuels	81%	80.6%	78.2%	78.4%
Nuclear	2.8%	2.7%	2.8%	2.6%
Renewables	16%	16.7%	19%	19%

Data source: (El-ashry, 2011; REN21, 2014, 2013, 2012, 2011). (The latest year for which data are available.)

Certain renewable sources such as solar photovoltaic (PV) (0.7%), wind (2.9%), hydropower (16.4%), geothermal, concentrating solar power (CSP) and oceanic (0.4%) accounted for approximately 22.1% (16.4% and 5.8%) of the total final global electricity production share with fossil fuels and nuclear in 2013 (REN21, 2014, 2013). Table 4-2 illustrates the renewable energy share of global electricity generation in 2010-2013.

Table 4-2: Renewable energy share of global electricity generation 2010-2013.

Type	2010	2011	2012	2013
Fossil fuels and nuclear	80.6%	79.7%	78.3%	77.9%
Hydropower	16.1%	15.3%	16.5%	16.4%
Other renewable (non-hydro)	3.3%	5%	5.2%	5.8%

Data source: (REN21, 2014) (REN21, 2013).

Renewables can replace nuclear and fossil fuels in four distinct markets: countryside (off-grid) energy services, transport fuels, heating and cooling, and power generation. This section provides an overview of recent developments in the transport fuels, heating and cooling, and power generation sectors (REN21, 2014, 2011, 2010; UK, 2014).

Installed capacity of many renewable energy technologies has grown rapidly during the period 2009-2013. This includes wind, solar PV, solar water heating systems, CSP and biofuels (REN21, 2014, 2013, 2012). The total capacity of solar PV has risen most rapidly of all renewable energy technologies, growing by about 60% yearly, this was followed by CSP capacity which has grown from a small base at more than 40% per year on average, and wind power, which has increased 25% yearly over this period (REN21, 2013).

Geothermal and hydropower growing rates have been more modest, in the range of 3-4% per year (see Table 4-3). Biomass capacity is mature but with steady growth in solid and gaseous biomass, rising at an average of 8% yearly.

In this context, demand has increased rapidly in the cooling/heating sector, especially for solar thermal systems, some biomass fuels and geothermal ground-source heat pump systems. Over the past five years, glazed solar water heater capacity has risen by an average of more than 15%.

In the transport sector, the growth of liquid biofuels has been mixed in recent years. The average yearly growth rate over the period from the end of 2007 to 2012 was almost 11% for ethanol and 17% for biodiesel. However, although biodiesel production continued to develop in 2012, it was at a much slower rate of growth, while ethanol production peaked in 2010 and has since dropped.

Table 4-3: Average annual growth rates of renewable energy technologies capacity and biofuels production, 2007-2012.

Technology	Growth rate (%)	
	2012	Last five years
Solar PV	42%	60%
Wind power	19%	25%
Concentrating solar thermal power	61%	43%
Geothermal power	2.6%	4%
Hydropower	3.1%	3.3%
Solar hot water / heating	14%	15%
Ethanol production	-1.3%	11%
Biodiesel production	0.4%	17%

2012 only – End 2007 through 2012 five-year period.
Data source: (REN21, 2013).

During 2012, renewable energy industries experienced continued growth in equipment manufacturing, installation, and sales. Onshore wind power and solar PV saw dramatic price reductions during the year due to technological advances and decreasing expenses due to economies of scale, uncertainties or reductions in policy support such as policy reversals and retroactive alterations affecting investment climates in a number of established markets, and reduced momentum in Europe, China, and India (REN21, 2013, 2012).

Solar PV manufacturing in renewable energy industries has been challenging following the dropping prices, combined with the international financial/economic crisis, and continuing tensions in international trade. These developments have created new challenges for some renewable energy industries and, especially, equipment manufacturers.

In term of investment the United Nations Environment Programme (UNEP) report ‘Global Trends in Renewable Energy Investment 2011’ states that the total renewable energy global investment broke a new record in 2010, in spite of the recession. In the same year global investment in renewable fuels and power increased by 32%: about \$211 billion in comparison with \$160 billion in 2009 (Bloomberg, 2012; REN21, 2011). In 2012 the total global renewable energy investment was \$244 billion for fuels and renewable energy (including electric and small hydro projects), which was 12% down from the previous year’s record where it was \$279 billion, though the total was still the second highest year ever for renewable energy investments. There was a continuing rising trend in developing countries, with investments in the Southern

Hemisphere topping including South Africa, Chile and Kenya $112 billion versus $132 billion in developed countries, a dramatic change from 2007, when developed economies invested 2.5 times more in renewables (excluding large hydro) than developing countries (Bloomberg, 2011).

4.2.1. Global renewable power-generation sectors

A summary of the global power capacities of different renewable energy technologies and biofuel production in 2011 and 2012 is shown in Table 4-4. This table demonstrates the increase in global power generation and biofuel production from the existing capacity at the end of year 2011 to 2012. In 2012 total global renewable energy power capacity exceeded 1,470 GW (gigawatts). Hydropower increased internationally, wind power accounted for about 39% of renewable power capacity added in 2012, to an estimated 990 GW, while other renewables rose by 21.5% to exceed 480 GW (Bloomberg, 2013). For more information about the status of power generation (characteristics and costs) with regard to renewable energy technologies, see Appendix A.

Table 4-4: Global capacities of different renewable energies and biofuel production in 2012.

Technologies type	Added through 2012	Existing capacity at end of year 2012
Power Generating	GW	
Hydro power	+ 30	990
Wind power turbines	+ 45	283
Biomass power	+ 9	83
Geothermal power	+ 0.3	11.7
Solar PV	+ 29	100
Concentrating solar thermal power (CSP)	+ 1	2.5
Ocean (tidal) power	0	0.5
Total non-hydro renewables other renewable		480.7
Total renewable energy capacity		1470.7
Hot water/ space heating	(GW_{th})	
Modern biomass heating	+ 3	293
Solar collectors for hot water/space heating (glazed system)	+ 32	255
Geothermal heating	+ 8	66
Transport fuels	(billion litres/year)	
Biodiesel production	+ 0.1	22.5
Ethanol production	- 1.1	83.1

Data source: (REN21, 2013).

GW_{th}: The data is expressed in Gigawatt thermal, rather than in square meters of installed collector area. A factor of 0.7 KW_{th}/m^2 is used to derive the nominal capacity from the area of installed collectors (Bertoldi and Atanasiu, 2010; Madomercandy, 2007; REN21, 2013).

4.2.2. Global heating and cooling sectors

Solar thermal collectors, geothermal power and modern biomass presently supply hot space and water heating (in addition to some cooling with the use of heat pumps and absorption chillers) for tens of millions of commercial buildings and domestic internationally. Solar thermal collectors and other resources are also used to supply heat for agricultural applications and industrial processes. Passive solar building designs deliver a significant quantity of light (and heat), and their numbers are on the increase. Modern biomass accounts for the majority of renewable heating globally. Solar collectors are used in more than 56 states for water and increasingly for space heating in households, hospitals, hotels, schools, commercial buildings and government. Geothermal energy is used by at least 78 states for heating purposes, including bathing, district heat systems and swimming applications, agricultural industrial purposes and among others. Ground-source heat pumps can both cool and heat space and represent the largest and historically fastest-growing section of geothermal direct use. Use of renewable energy technologies for cooling and heating is still limited relative to their potential for meeting international demand (REN21, 2014).

Trends in the cooling (and heating) sector include the use of larger systems, the feeding of renewable heat and cooling into regional schemes, the increasing use of combined heat and power (CHP), and the rising use of renewable heat for industrial purposes. Furthermore, some EU states are starting to see hybrid systems that link solar thermal and other heat sources, for example biomass. Some are using district heat systems (often based on renewable sources) to balance electricity generation from variable sources, such as by using excess power generation on very windy days to heat water directly or via heat pumps. For more information about the status of renewable-energy-based hot water/ heating/cooling (characteristics and costs) (REN21, 2013), see Appendix F.

4.2.3. Global transportation sectors

Renewable energy is presently used in the transport area in the form of liquid and gaseous biofuels, in additional to electricity for electric road vehicles and trains, and potentially fuel-cell vehicles powered through renewably produced hydrogen. Currently liquid biofuels supply over 2.5% of international transport fuels (3.4% of road transport fuels and a very small but growing share of aviation fuels), and account for the largest share of transport fuels derived from renewable energy sources (REN21, 2013).

Electricity is used to city transit, power trains, and a rising number of electric passenger road motorised cycles and vehicles, scooters, and motorbikes. There are limited but increasing initiatives to tie electric transport systems with renewable electricity. In some sites, particularly at the local level, electric transport is linked directly to renewable electricity through policies and specific projects (Daily Times Report, 2014). For more information about the technological status of renewable energy use as transport fuels (characteristics and costs), see Appendix G.

4.3. Market state and industry trends by technology

There are different renewable energy generation methods for domestic and commercial use, with direct uses such as solar PV and solar thermal technologies or indirect uses such as wind, wave, hydropower and bioenergy. Most of the initial-stage interviewees and the literature reviews confirm that only two sources of renewable energy (solar and wind) are available and potentially exploitable in Libya. In order to achieve the research objective, therefore, this section will focus on solar PV, thermal and wind technologies.

4.3.1. Solar PV technologies

4.3.1.1. Solar PV markets

The market of photovoltaic power saw an additional year of extraordinary growth. Since increasing overall global capacity to 139 GW, another 39 GW of operating capacity was added through the year of 2013 (Brower et al., 2014).

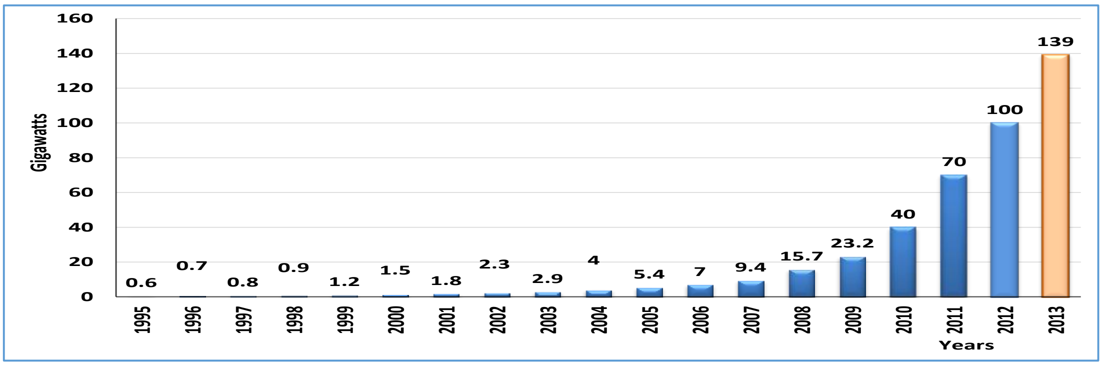


Figure 4-1: Total world capacity of solar PV 1995- 2013.
Data source: (Ingmar, 2011; REN21, 2012, 2011).

As demonstrated in Figure 4-1, the period from the end of 1995 through 2013 saw the overall global installed capacity of several renewable energy technologies grow at very rapid rates. PV power developed the fastest of all renewable technologies during the last five-year period, with operating capacity rising at an average of 60% yearly. It was followed by concentrating solar thermal power (CSP), which increased almost 43%, growing from a small base, and wind power, which increased 25%. Global solar photovoltaic capacity reached 139 GW in 2013, representing a growth rate of 60% over the year. The top markets, China, the United States, Germany, Spain, Italy and India were also the leaders for total capacity (REN21, 2013). Asia dominated the global market, led by China, while markets expanded in other regions, and at the same time Germany was the dominant player in European Union (Angelis, 2013). Figure 4-2 shows the global solar PV capacity of the top six countries:

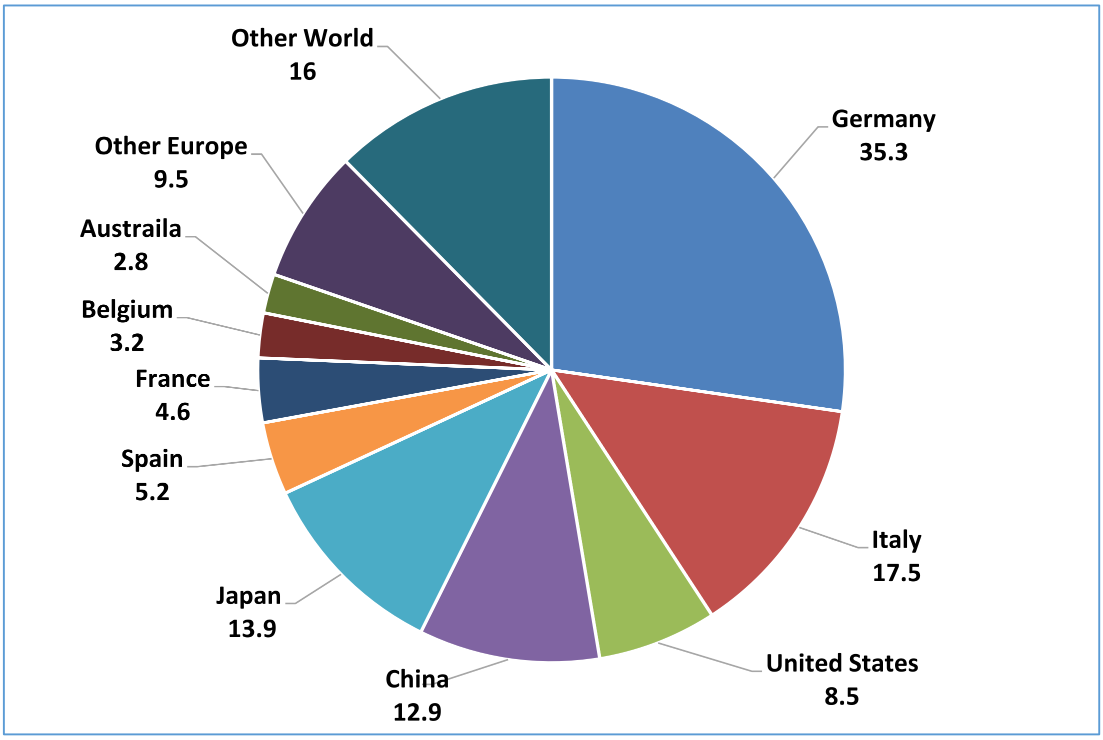


Figure 4-2: Solar PV world capacity, shares of top six countries, 2013.

Source: (Brower et al., 2014; REN21, 2013).

In some countries, solar PV has been starting to play a substantial role in electricity production: in 2013, it covered 5.6% of the national electricity demand in Italy and about 5% in Germany, with far higher shares in both countries during sunnier months. By the year's end, PV capacity in the EU was enough to cover 2.6% of total consumption, and world capacity in operation was enough to produce at least 110 TW h of electricity every year. Each year these PV installations save more than 53 million tons of CO_2 (Masson et al., 2013; REN21, 2013).

4.3.1.2. Solar PV cell technologies/industry trends

In terms of power technology, the most significant measure is the energy cost per kWh provided. With photovoltaic power, this cost mainly depends on two factors: the capital cost per watt of capacity and the PV power-conversion efficiency. These factors dictate the economic competitiveness of photovoltaic electricity. The conversion efficiency of a PV cell is defined as follows:

$$\text{Conversion efficiency} = \frac{\text{Electrical power output}}{\text{Solar power impinging the cell}}$$

The continuing developmental attempts to generate more efficient low-cost cells has resulted in the different kinds of PV technologies available in the market nowadays (REN21, 2013).

In terms of the conversion efficiency and the module cost (REN21, 2013), 2012 was a good year for solar PV installers, distributors and consumers, but module and cell manufacturers struggled to survive, let alone make a profit (Patel, 2006), with excess production capacity and supply that, alongside extreme competition, drove prices down further in 2012, yielding smaller margins for manufacturers and encouraging continued industry consolidation. Low prices have also challenged many thin-film companies and the concentrating solar industries, which are struggling to compete (REN21, 2013). In 2012 the average price of crystalline silicon solar modules dropped by more than 30% while thin-film prices fell by approximately 20%. Costs of installed systems are also dropping, although not as quickly, and with considerable variance from one location to another (Monitor, 2013).

Figure 4-3 shows that the top fifteen solar PV module manufacturers accounted for half of the 35.5 GW produced internationally, with eleven of these companies based in Asia. Yingli (China) jumped ahead of both Suntech (China) and First Solar (USA) to land in first position. First Solar held its number two spot, and Suntech fell to fourth after Trina Solar (China). There was also much fluctuation in rank among the other top players.

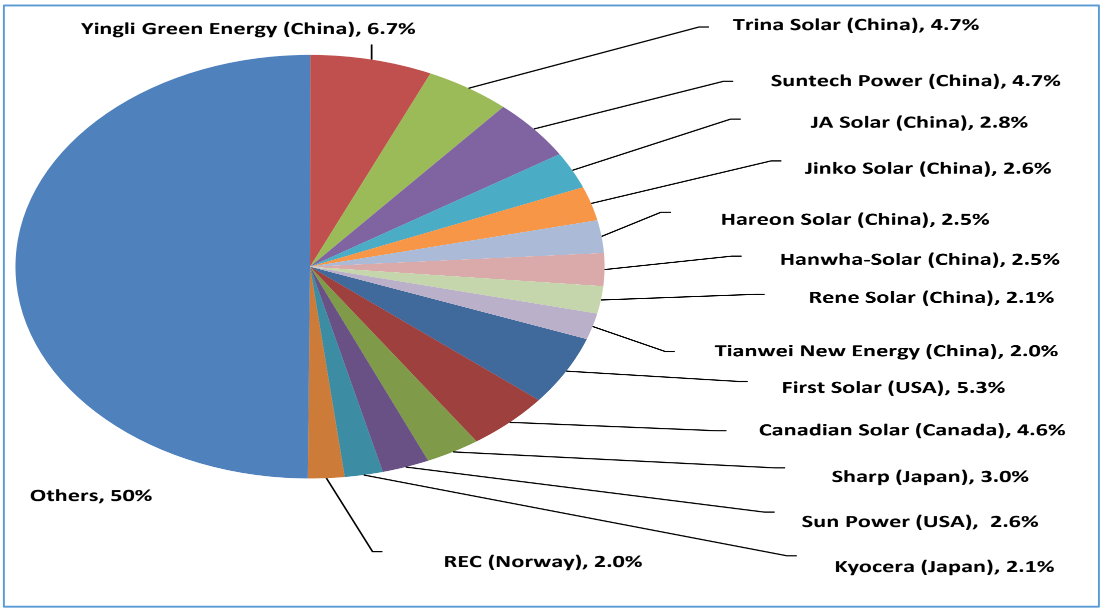


Figure 4-3: Market shares of top 15 solar PV module manufactures, 2012
Source: (REN21, 2013).

4.3.2. Concentrating solar power (CSP)

4.3.2.1. CSP market

In 2013, the market for concentrating solar thermal power continued to advance, with total global capacity up to more than 36%, equal to about 3,425 GW. In comparison to 2011 the market has doubled (Brower et al., 2014; REN21, 2013).

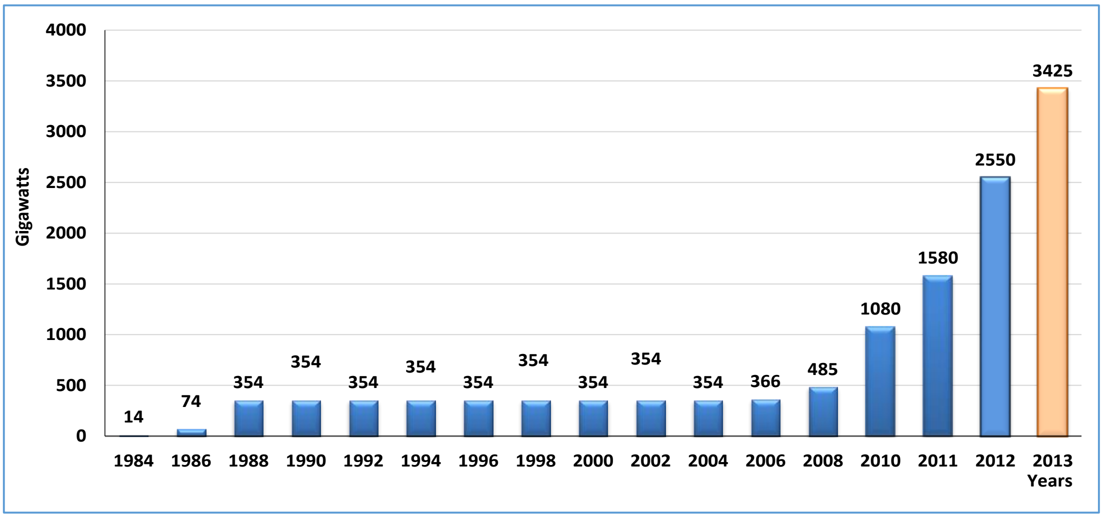


Figure 4-4: Concentrating solar thermal power global capacity, 1984-2013.
Source: (REN21, 2013).

As demonstrated in Figure 4-4, since the end of 2007 and through 2013 total worldwide capacity rose at an average annual rate approaching 43%. The most mature technology is the parabolic trough, which continues to dominate the market and at the end of 2011 represented about 95% of facilities in operation and by mid-2012 represented 75% of plants under construction. Towers/central receivers accounted for 18% of plants under construction by mid-year and are becoming more common, followed by parabolic dish technologies and Fresnel (6%), which are still under development (REN21, 2013). Many countries, such as India, Germany, France, China, Italy, Israel, and South Korea, have small experimental stations in operation. In March 2013, the United Arab Emirates (UAE) joined the list of countries with CSP, with the 100 MW capacity Shams 1 plant (the first full-sized pure CSP station in the MENA area to begin operation) (Power, 2010; SCSP, 2013). Interest in CSP is growing mainly in developing countries, across Africa, the Middle East, Asia, and Latin America, with investment spreading. In 2012 one of the most active markets was South Africa, where construction started on a 50 MW solar power tower and a 100 MW trough station. Namibia declared plans for a CSP station by 2015 (Brief, 2013).

A number of development banks have dedicated funds towards projects planned in five MENA countries (Algeria, Egypt, Jordan, Morocco and Tunisia). In the next few years, the ambitious targets for domestic use and export could give rise to more than one GW of new capacity in North Africa (REN21, 2013). The UAE and Saudi Arabia plan to install CSP to meet rapidly developing energy demands and to allow the allocation of more oil for export. Jordan is assessing possible projects. In early 2013, Saudi Arabia launched a competitive bidding procedure that contains important CSP capacity. India planned by the end of 2013 to complete 500 MW, but some projects have been cancelled and only one third were ready on time; phase two of the National Solar Mission has been postponed. In Australia, a 44 MW station is under construction to feed steam to an existing coal facility. Several other countries, including Israel and China, Argentina, Chile and Mexico in Latin America and many countries in Europe, have declared their intentions to install CSP stations (CTF, 2013; Imen, 2012).

Experts have expressed concern that the window of chance for CSP (PV) is closing as solar PV prices continue to fall and utilities become more familiar with PV. On the other hand, CSP has a number of characteristics that are expected to remain attractive to utilities. These include CSP's ability to offer thermal storage and thus to be dispatchable and to allow an increased share of variable renewables, and its capability to provide low-cost steam for present power plants (hybridisation). Furthermore, CSP has the potential to supply heating and cooling for industrial desalination and other processes (José et al., 2013; REN21, 2013).

4.3.2.2. CSP industry

In spite of continued activity being concentrated in the United States and Spain, the CSP industry has further extended its focus in several countries such as China, India, Australia, Chile, South Africa and the MENA region. There was an overall trend of diversification of employment in these countries and international manufacturing capacity rose slightly during 2012. Dropping natural gas and PV prices, the international economic recession, and policy changes in Spain all created uncertainty for both CSP manufacturers and developers (S.C, 2014). Wide supply chains are evolving in Spain and the United States, with a rising number of companies involved in the CSP business. To reduce costs or raise product value, companies have also begun to expand development efforts to include a diversity of CSP technologies. A small number of manufacturers have started to market solar concentrator technologies for industrial heating and cooling, as well as desalination, including the Solar Power Group (Germany), Sopogy (USA), and Abengoa. Thermal energy storage is becoming an increasingly significant feature for new plants as it permits CSP to dispatch electricity to the grid at night or during cloudy periods, provides firm capacity and ancillary services. The most extensively used system for storing thermal energy is molten salt, however other types, including steam, chemical, thermocline (use of temperature variances), and concrete, are also in use or being tested and developed. To decrease costs through economies of scale, the size of CSP projects is growing (REN21, 2014).

Although plants in Spain have been limited to 50 MW due to regulatory restrictions, new projects in the United States and elsewhere are in the 150–500 MW range and even greater. As noted, increasing size helps to decrease costs through economies of scale, but suitable plant size also depends on technology. Some projects are also adding dry-cooling solutions that considerably decrease water demand, a progression that is essential in the arid, sunny areas where CSP offers the greatest potential. CSP costs have dropped considerably in recent years, for systems with and without thermal storing. Although subject to alterations in commodity prices, the main components of CSP facilities (including aluminium, concrete, glass, and steel) are in general not in tight supply (REN21, 2014; S.C, 2014).

4.3.3. Solar thermal heating and cooling:

4.3.3.1. Markets

Solar thermal technologies contribute significantly to hot water production in several countries and progressively to space heating and cooling along with industrial processes. In 2011, the world added approximately 51 GW_{th} (more than 72 million m^2) of solar heat capacity, for a year-end total of 247 GW_{th}. 49 GW_{th} (>96%) of the market were glazed water systems; the remainder were unglazed water systems for swimming pool heating, as well as unglazed and glazed air collector systems (REN21, 2014).

With regard to glazed water systems only, the market expanded 15%, and total global capacity in operation by the end of 2011 (223 GW_{th}) supplied an estimated 193 TWh (696 PJ) of heat yearly. China, Turkey, Germany, India, and Brazil were the 2011 market leaders for newly installed glazed water collector capacity; the same countries led for total capacity, with Brazil ahead of India (see Figure 4-5). By the end of 2012 global solar thermal capacity reached an estimated 282 GW_{th}, of which the global capacity of glazed water collectors reached 255 GW_{th} (José et al., 2013).

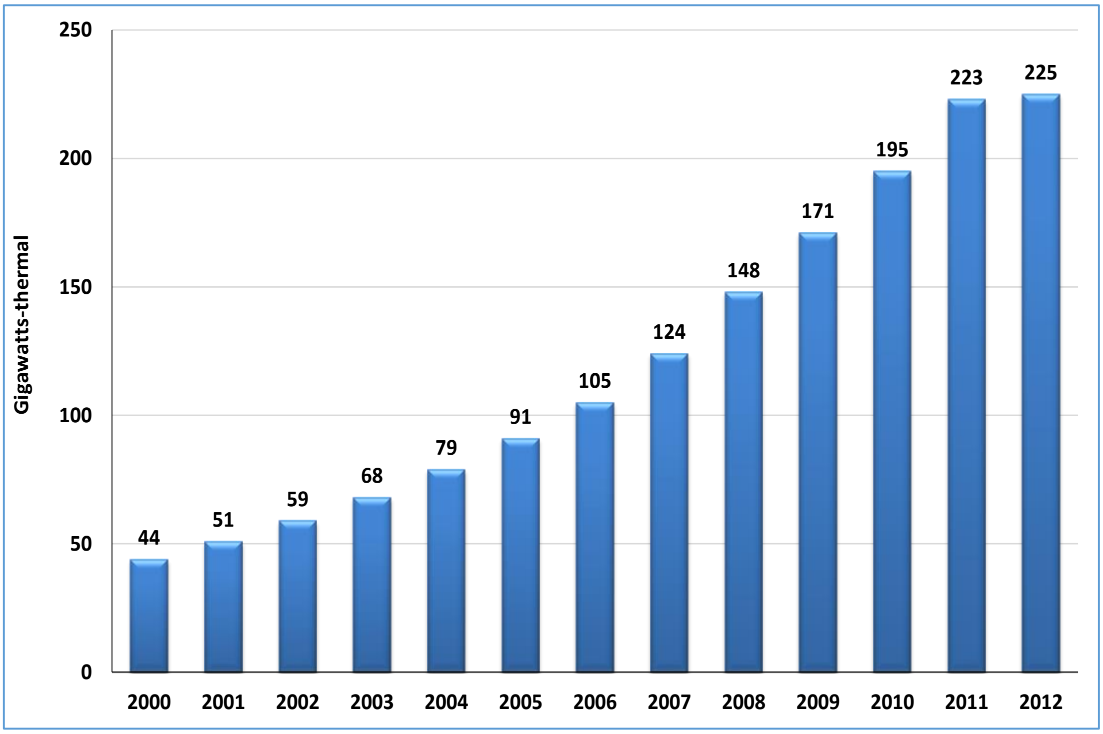


Figure 4-5: Solar water heating global capacity, 2000-2012.
Data source: (José et al., 2013).

Many countries in Africa use solar thermal, including Egypt, Mozambique, Tunisia, Zimbabwe, and South Africa, the greatest mature market in Sub-Saharan Africa. The

PROSOL project in Tunisia has increased annual installations more than thirteen-fold over five years, to more than 64 MW_{th}. In the Middle East, Israel leads for installed capacity, followed by Jordan and Lebanon, where penetration is 13% in the residential sector and the market is motivated by national subsidies, zero-interest loans, and municipal mandates (REN21, 2014).

Solar space heating and cooling are also gaining ground. Globally, the market share of systems that offer both water and space heating is about 4% and growing, with installations in established markets in South America (Brazil, Mexico) and Asia (China, India, Japan). District heating systems that use solar thermal technology (often related to other heat sources such as biomass) are cost competitive in Austria, Denmark, Germany, and Sweden (José et al., 2013; Teske et al., 2013).

The worldwide solar cooling market rose at an average annual rate above 40% between 2004 and 2012, ending the period with about 1,000 solar cooling systems installed, most commonly in Europe. Large-scale systems are creating interest because of their extra favourable economics, whereas the availability of small (<20 kW) cooling kits for residential usage has improved interest in the residential sector, mainly in Central Europe and sunny, dry climates such as Australia, the Mediterranean islands, and the Middle East. An additional driver, mainly in countries with significant cooling requirements, is the potential for solar cooling to decrease peak electricity demand. Solar heat and steam can also supply process heat and cooling for industrial uses. In 2010, about 200 process heat systems were working internationally, totalling approximately 42 MW_{th}. By share of worldwide capacity, India was on the top (with 10%), followed by Brazil (7%) and Israel (6%) (REN21, 2014; Teske et al., 2013).

First-hand projects in 2012 involved a leather tannery in China, and a U.S. turkey processing company, and plans were declared for three Heineken beer-producing facilities in Europe. Process heat accounts for the principal share of large-scale solar thermal capacity in Austria and for the greatest of Thailand’s commercial solar heat subsidies. On the other hand, solar air conditioning, district heating networks, and solar process heat for industrial purposes still account for less than 1% of international solar thermal capacity (REN21, 2014).

4.3.3.2. Solar thermal heating/cooling industry

Through 2012 the solar thermal heating/cooling industry managed to meet the challenges it faced, mostly in Europe. Large European heating companies have done well, although the expansion of solar specialists has been slower. Slow but steady expansion continues in Eastern Europe, but market deceleration in several central and south European countries has forced companies to increase emphasis on maintenance or replacement of present systems, and to close production capacity or to build new production facilities to face increasing demand outside Europe. The industry has also seen a number of acquisitions and mergers between leading players (Teske et al., 2013).

From country to country price developments diverge. with installed system prices reliant mainly on employment costs and where systems are installed (e.g., age of the buildings). In 2012 the automation of manufacturing processes continued to grow, with ongoing innovation from adhesives to materials and beyond. These advances have pulled down production costs over the years, although these decreases have been mostly offset by growing materials costs (copper, aluminium alloys) (REN21, 2014; Teske et al., 2013).

As the market for solar air collectors expands, the number of manufacturers and products is also increasing. Whereas the main markets are in Europe and North America, where most suppliers concentre on air-based systems, manufacturers in China and India are increasingly supplying water-based systems as well (Teske et al., 2013).

Increasing interest in solar cooling is attracting new companies to the solar thermal sector, for example Hitachi and Mitsubishi in Japan. The technology has commonly seen little competition owing to its higher investment costs, however costs dropped 50% between 2007 and 2012, and the potential remains for additional reductions. There are also efforts under way to grow system quality, such as the current adoption of an Australian standard for solar cooling (REN21, 2014).

4.3.4. Wind power

4.3.4.1. Wind power markets

Through 2013, there was a rise in global wind capacity to about 318 GW (see Figure 4-6), where an additional 35 GW of wind power capacity was added and began operation.

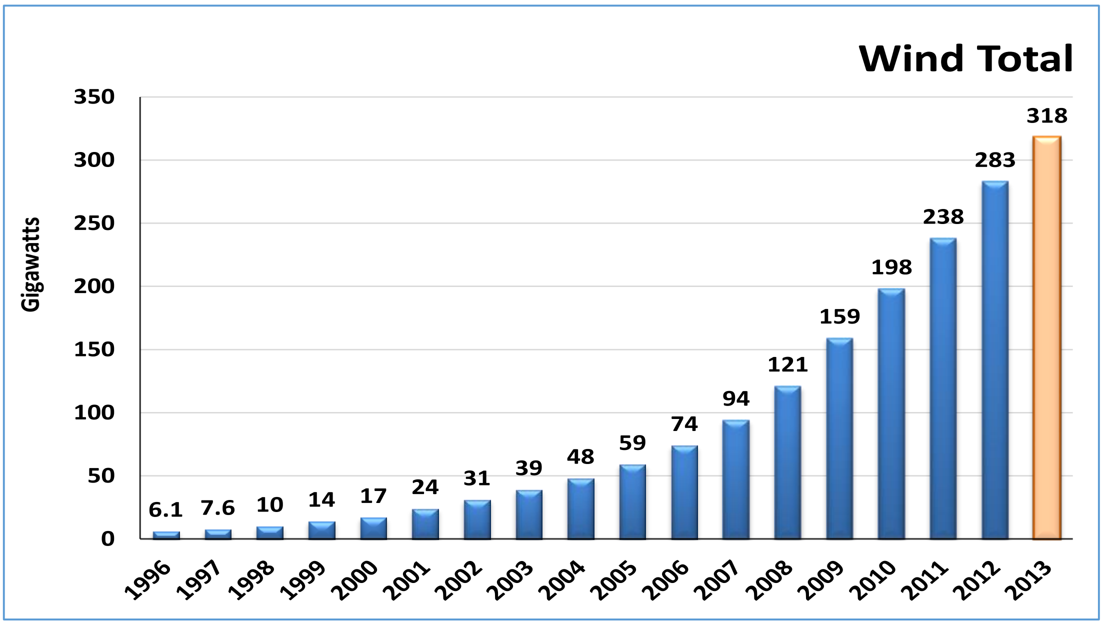


Figure 4-6: Wind power global capacity, 1996-2013.

Data source: (REN21, 2013).

Although in terms of global capacity it was another record year for wind power, the rate of growth of the market dropped nearly 10 GW compared to 2012, reflecting mainly a steep drop in the U.S. market. The ten top countries accounted for more than 85% of the year-end global capacity, but there are dynamic and emerging markets in all regions. By the end of 2013, at least 85 states had seen commercial wind activity, at least 71 had more than 10 MW of stated capacity by the year's end, and 24 had more than 1 GW in operation (REN21, 2014; Teske et al., 2013).

Since the end of 2008 yearly growth rates of cumulative wind power capacity have averaged 21.4%, and international capacity has risen eightfold over the past 10 years. Africa and the Middle East (AME) demonstrate little development aside from Morocco (0.2 GW), and Ethiopia. which joined the list of countries with commercial-scale wind farms by completing Africa's largest individual wind farm (120 MW). Other countries in the region have also moved ahead with new projects, and several have announced long-term plans with the aim of mitigating the impact of dry seasons on national hydropower output (REN21, 2014).

Wind power is playing a major role in power supply in a growing number of states. In the EU, the wind power capacity operating at the end of 2013 was enough to cover approximately 8% of electricity consumption in a year with normal wind (up from 7% in 2012), and several EU states met higher shares of their demand with wind. Wind was the top power source in Spain (20.9%, up from 16.3%) during 2013, and met 33.2% of electricity demand in Denmark (up from 30%). Four German states had enough wind capacity at the year's end to meet over 50% of their electricity needs. In the USA, wind power represented 4.1% of total electricity production (up from 3.5% in 2012) and met more than 12% of demand in nine states (up from 10% in 2012), with Iowa at over 27% (up from 25%) and South Dakota at 26% (up from 24%). Wind power accounted for 2.6% of China's electricity generation. Globally, wind power capacity by the end of 2013 was enough to meet an estimated 2.9% of total electricity consumption (REN21, 2014, 2013).

4.3.4.2. Wind power industry

The available wind power is a function of the cube of the wind speed. Therefore if the wind blows at twice the speed, its energy content will rise eight fold. Turbines at a site where the wind speed averages 8 m/s produce about 75-100% electricity more than those where the average wind speed is 6 m/s (Briefi, 2005). However, there are several elements that can make an impact on the amount of energy which can produce by wind including wind speed, height (due to the heights can easily reach to tap the wind energy) and Rotor or Turbine Model (the size of the rotor used)(AENews, 2016)

In terms of turbine, the prices grew in response to increasing international demand, increasing material costs, and other issues throughout 2005–2009. Since then, increasing scale and superior efficiency have combined to increase capacity factors and reduce the cost of turbines, as well as maintenance and operations. Overflow in the international turbine markets has further reduced prices, facilitating developers by improving the cost-competitiveness of wind power comparative to fossil fuels. During 2013, however, the industry faced challenges, from downward pressure on prices combined with improved competition between turbine manufacturers, competition with low-cost gas in some markets, and a drop in policy support motivated by economic severity. Compared to their 2008 peak, turbine prices fell by as much as 20–25% in western markets and more than 35% in China before stabilising in 2012 (Marconi, 2014; REN21, 2014).

As a result, improvements have been developed to reduce the costs of wind farms. These include maintenance, operations, strategies and technologies to improve the economics of wind power in a varied range of operating conditions. Turbine designs continue to evolve to reduce costs and increase yield, with trends towards larger machines (higher hub height, longer blades, and greater nameplate capacity).

In 2013, the average size of wind turbines provided to market was 1.9 MW, in comparison to 1.8 MW in 2012. Average turbine sizes were 1.8 MW in the USA, 2.7 MW in Germany, 1.7 MW in China and 1.3 MW in India. The biggest commercially available wind turbine (German company Enercon's E-126, up to 7.6 MW), is used in onshore areas, while the average size of an installed turbine in the offshore sector remained at approximately 4 MW in Europe (REN21, 2014, 2013).

New machines for offshore use in Europe and Asia within the 5–8 MW range are being tested, while leading Chinese manufacturers are competing to develop turbines of 10 MW and larger, spurred on by government grants. In addition to bigger turbines, the offshore industry is undertaking larger projects, and moving farther out into deeper waters. To date, deep-water offshore wind has focused on foundations adapted from the oil and gas industry, but new designs are under development around the world (REN21, 2013).

These trends have pushed up prices in recent years. As of early 2014, the levelised cost of offshore wind power was nearly USD 240/MWh (EUR 172/MWh), but the potential for lowering costs through reductions in lifecycle financial costs is considered significant. The small-scale (<100 kW) wind industry also continued to mature in 2013, with hundreds of manufacturers worldwide, expanding dealer networks, and increasing importance being placed on turbine certification (REN21, 2014).

The world's top ten turbine manufacturers captured about 70% of the international market in 2013 (down from 77% in 2012). Vestas (Denmark) regained the top spot from GE Wind (United States), which suffered from the poor U.S. market and fell to fifth. Goldwind (China) climbed four steps to second, followed by Enercon and

Siemens (both Germany), which switched spots. Other top manufacturers were Gamesa (Spain), the Suzlon Group (India), United Power and Mingyang (both China), and Nordex (Germany) (Marconi, 2014).

4.4. Renewable energy cost development

Figure 4-7 shows the cost trends for renewable energy technologies derived from the respective learning curves. It is important to note that the predictable cost reduction is not a function of time, but of cumulative capacity (unit production), and consequently dynamic market development is required. Most renewable energy technologies will be able to reduce their particular investment costs to between 30% and 60% of current prices, once they have attained full maturity after the year 2040.

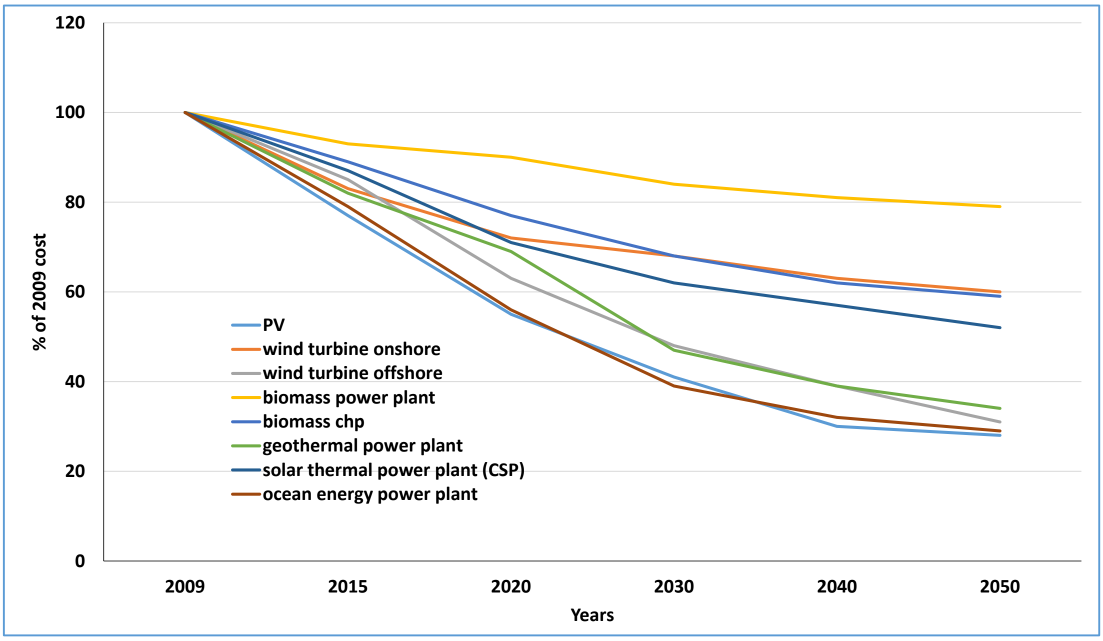


Figure 4-7: Future development of investment costs for renewable energy technologies.

Data source: (REN21, 2014).

Figure 4-8. Production costs nowadays are approximately 8 to 35 cents/kWh for the most significant technologies, including PV. In the long term, the costs are predicted to converge at about 6 to 12 cents/kWh. These approximations are based on site-specific conditions, for example the local wind regime or solar irradiation, the availability of biomass at reasonable prices, or the credit granted for heat supply in the case of combined electricity and heat production (Teske et al., 2013, 2008).

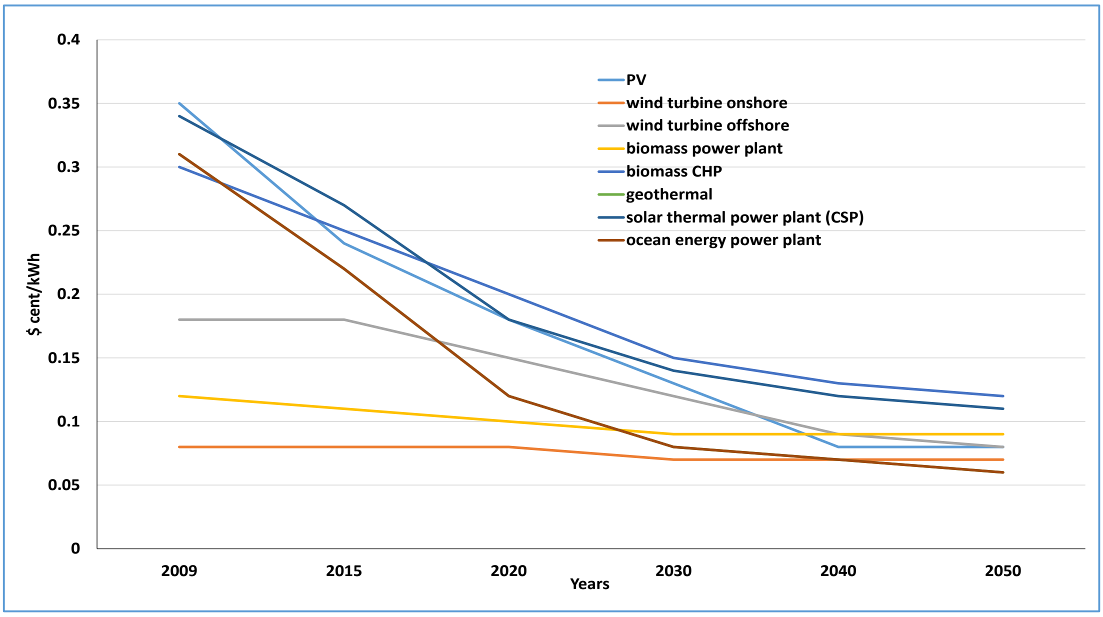


Figure 4-8: Expected development of electricity generation costs from fossil fuel and renewable options.

Source: (REN21, 2014).

4.5. The research framework

In order to explore the feasibility of investment in renewable energy resources in Libya, the research covers a number of themes, such as availability of energy sources in Libya, Libyan energy consumption and statutes of energy efficiency in Libya, see Figure 4-9. In fact, these three themes are the pillar of energy security in any given country.

As there is no national energy security definition, the meaning of energy security is extremely context dependent, for example on a level of economic development, a country's special circumstances, prevailing geopolitical matters, robustness of the energy system and perception of risks. However, some researchers focus on energy availability, infrastructure, prices, societal effects, environment, governance and energy efficiency as the main aspects of energy security (Ang et al., 2015). Therefore, the researcher has considered these aspects in the structure of the literature review in order to reduce the energy consumption, so to increase the opportunity of providing enough energy to consumer. In order to fulfil the requirements of this research and to meet its designed research objectives, studying the challenges and opportunities for the investment in renewable energy in Libya is the key in this study, as shown in Figure 4-9.

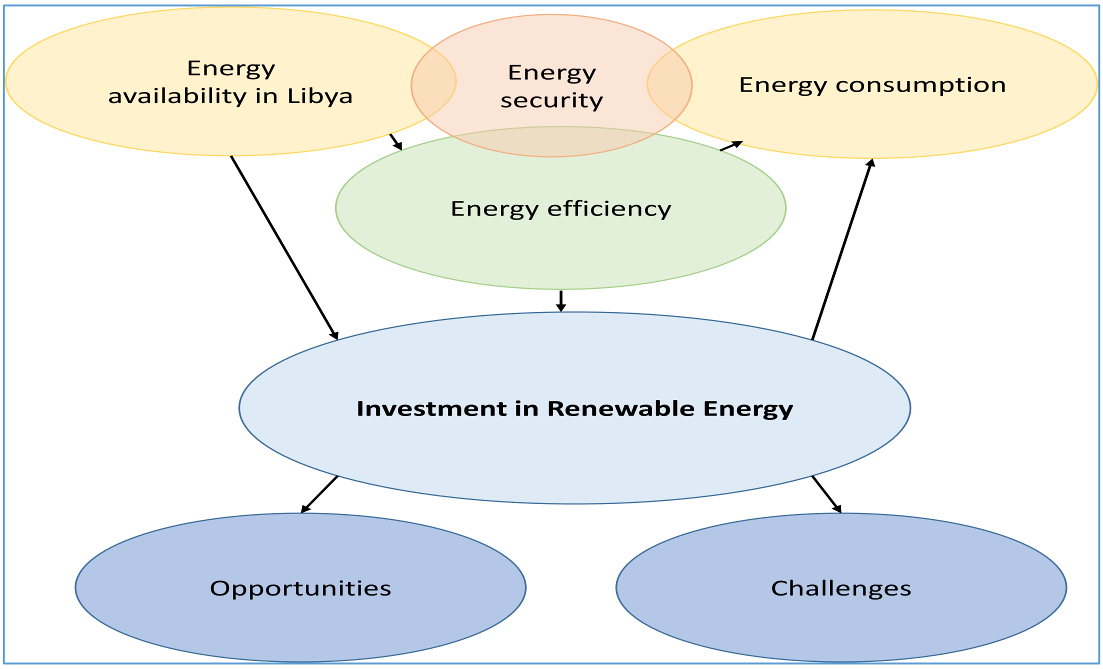


Figure 4-9: The research framework

Source: Author's own.

4.6. Summary

This chapter demonstrates the relevant literature to provide a background and understanding into the global renewable energy technologies of the current study. It has covered three issues. The first is the global market and industry overview literature, which includes global power generation sectors, global heating and cooling sectors, and global transportation sectors. The second issue is the global market state and industry trends for each technology: solar PV, concentrated solar power, solar thermal heating/cooling, and wind. The last issue explored is a summary of renewable energy cost development.

The international performance of renewable energy is continuously positive and it is grown rapidly in installed capacity of many renewable energy technologies. This is including solar (PV), solar water heating system, concentrating solar power (CSP) and wind.

The next chapter of this thesis describes and explains the key methodology and methods adopted in order to achieve the objective of this study and attempt to answer the research questions.

Chapter 5. The research methodology

5.1. Introduction

This chapter includes the methodological considerations, techniques and methods which are used to guide the data-collection process for this research. Additionally, the measurement and instrument development process is illustrated. As this research focuses on the feasibility of the utilisation of renewable energy resources, a significant investigation is conducted into the Libyan production and consumer sectors. This is in order to contribute to the debate between standardisation and adaptation. To achieve this, the data was collected using: (1) interviews with energy policy makers and people working in energy generation sectors in Libya and (2) questionnaires directed at energy consumers. The purpose of this chapter is to highlight the theoretical foundation and methodological and procedural issues needed to build the blocks of empirical studies designed to investigate associated relationships between the research structures. It examines the main matters concerning secondary and primary data collection, and importantly how to avoid replicating existing research.

The chapter specifically includes the introduction, which provides information about the suggested research methodology and data collection techniques and is organised as followed: firstly, the research design strategy of this research is previewed, including details of the justifications of the usage of specific research methods; secondly, the detailed data collection methods and design of research instruments are examined, followed by the research population of the study, including the research sample and the piloting of the research questionnaire. Data preparation and analysis are presented in the penultimate section, in order to pave the way for data analysis and the discussion of research results in the following chapters. Finally, as regards the initial stage and fieldwork, the reliability of the used measures are tested via expert judgment and a pilot study.

5.2. Research design

The research strategy or strategies, and the techniques or methods employed, must be appropriate for the questions that the researcher wants to answer (Robson, 1993). The research design is the plan, structure/framework, and methodology of investigation aimed at answering the research questions (Cooper and Schindler, 2003). Oppenheim

(1992) (Oppenheim, 1992) defined research design as a basic plan or strategy of research and the logic behind it, which will make it possible and valid to draw more general conclusions from it (Oppenheim, 1992). Kumar (1999) (Kumar, 1999) suggests that the term ‘research design’ refers to the procedural plan that is adopted by the researcher to answer a question objectively, economically and accurately (Kumar, 1999). The research design must follow on from research questions and provide data that enables them to be answered. It should define the main lines of the methodology, including sampling methods and the data-collection tools and procedures to be used to collect and analyse the empirical data, while taking into account the limits on the resources that are available (Gibril, 1995; Kerlinger, 1987). For the purpose of this study, the research design is constructed, step by step, to link the whole research together, as seen below in Figure 5-1:

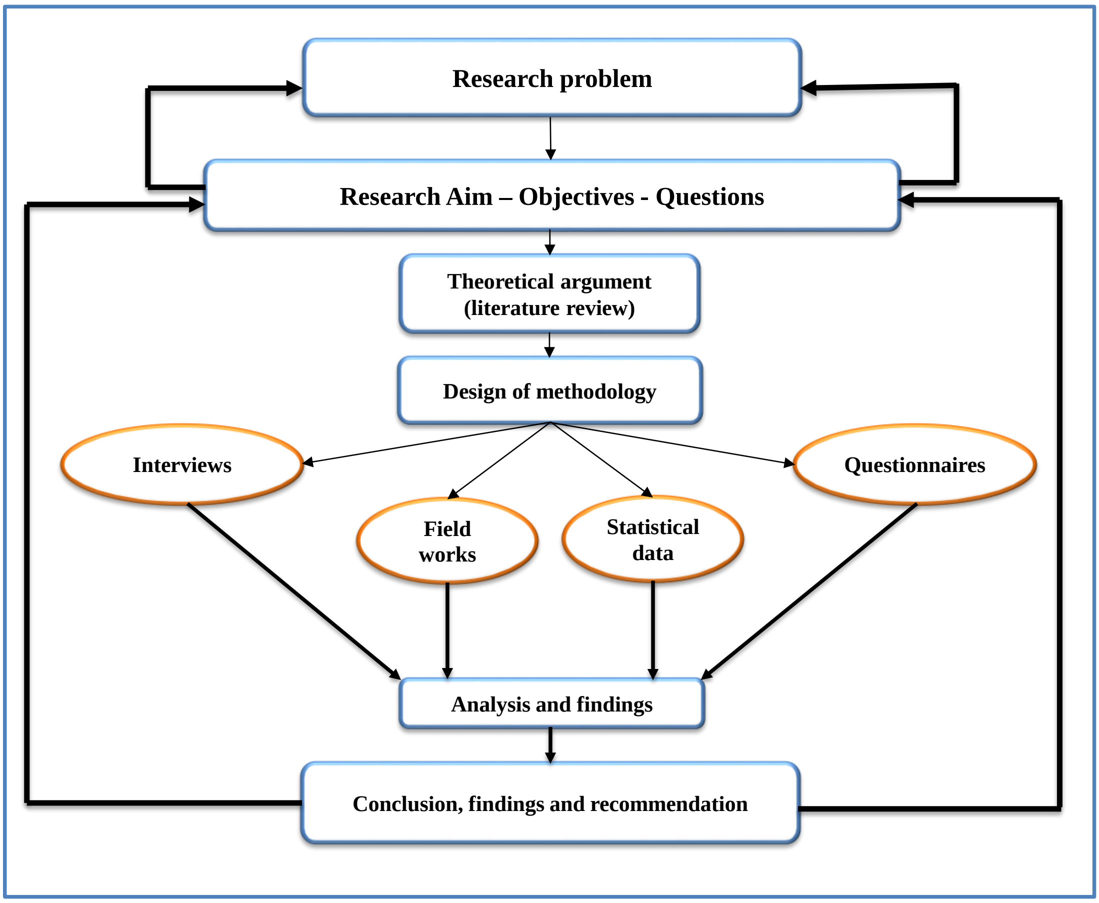


Figure 5-1: Research flow chart.

Source: Author’s own.

In terms of research design (strategy), the research contains a selection of procedures and methods for achieving the study goals and acquiring the information needed. The information requirement depends on how much is known about the research problem. Consequently, the choice of research strategy or design depends on the research questions, objectives and philosophy (PENN State, 2013). Concerning the main purpose of the current project, a research design may be defined as the specification of the way in which data and information are collected, analysed, interpreted, and constructed, to assist the researcher to draw reasonable explanatory and descriptive inferences.

The research strategy in this study was developed to promote a high-quality approach to the population and sample selection, instrument design and validation, data collection, and qualitative and quantitative (statistical) analysis used. This research has adopted mixed methodology (both quantitative and qualitative methods) as a research strategy. The next section justifies the appropriateness of the adopted research methodology and methods.

5.3. Research methodology

Research in the social sciences, which had originally adopted quantitative method as they emerged towards the end of the 19th century, has transferred towards qualitative method. This transfer from quantitative towards qualitative, or phenomenological method was also evident in business research, but in recent decades there has been a trend among researchers to develop approaches and methods named 'triangulation', which provide some bridging and a middle ground between the quantitative and qualitative method standpoints (Easterby-Smith, 1991; Yin, 1994). In accordance with Olsen (2004) (Olsen, 2004), the definition of triangulation in social science research is the mixing of methods or data so that diverse standpoints or viewpoints cast light upon a subject. The mixing of data types, known as data triangulation, is often believed to help in validating the claims that might arise from a primary pilot study. The mixing of methodologies, for example mixing the usage of two data-collection techniques (questionnaires and interviews), is a more profound form of triangulation (Olsen, 2004).The use of diverse research techniques, methods and approaches in one study is also triangulation, and such triangulation can overcome the potential bias and sterility of single-method approaches (Hussey and Hussey, 1997; Naseem, 2008). According to Bryman, triangulation can be understood as an idea of joining methods from different methodologies to overcome weaknesses in particular techniques (Bryman, 2004).

Mixed methods are usually associated with quantitative and qualitative (phenomenology) (Mangan, 2004). Qualitative data can assist the quantitative side of the study during design by assisting with instrumentation and conceptual expansion, whereas quantitative data can assist with the qualitative side of a study during design by finding a representative sample and locating deviant samples (Amaratunga et al., 2002; Naseem, 2008). Qualitative methods may aid in understanding the underlying important clarifications (Jones, 1997). According to Rossman and Wilson, the linkage between qualitative and quantitative data helps to start new lines of thinking through attention to paradoxes or surprises; to provide fresh insights, in their phrase "turning ideas around"; to develop or elaborate analysis, giving richer details; and to enable validation or corroboration of each other through triangulation (Lutzenhiser, 1993).

Generally triangulation suggests the use of a mixture of research techniques; the use of both quantitative and qualitative techniques in the same study may be very powerful in achieving insights and findings, and for helping in making inferences and in drawing conclusions, as shown in Figure 5-2 (Dilanthi et al., 2002; Naseem, 2008).

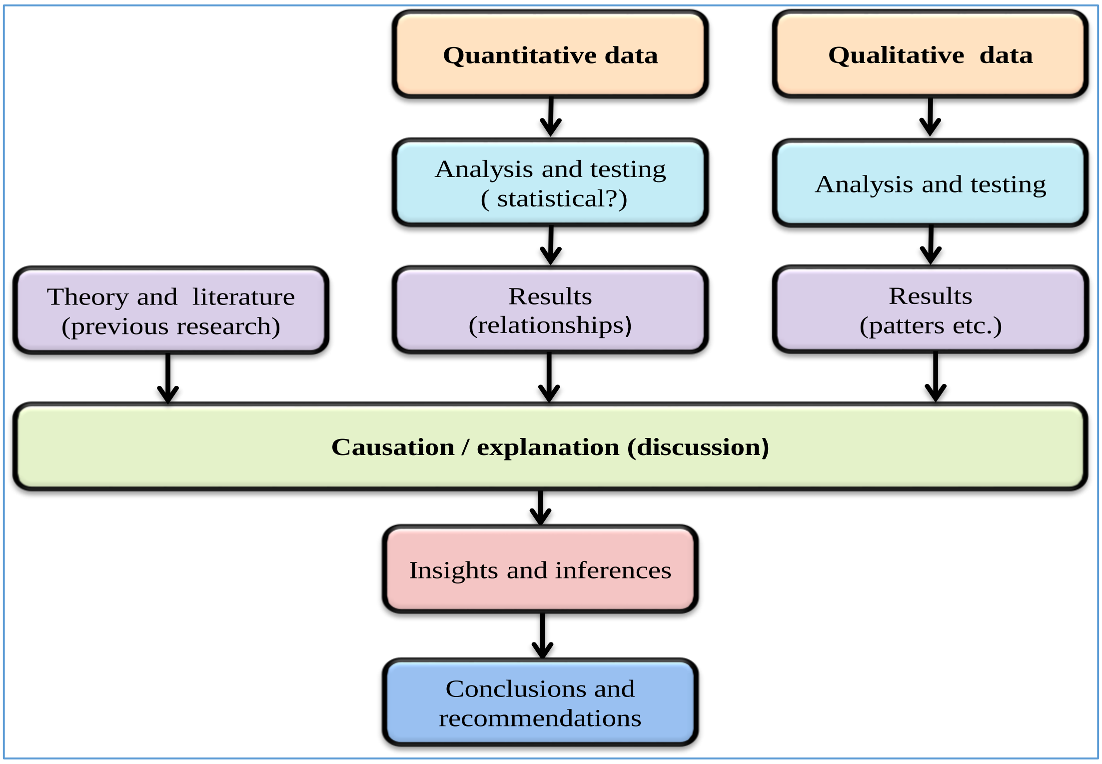


Figure 5-2: Triangulation of quantitative and qualitative.

Source: (Richard and Anita, 2008) p. 10.

Triangulation may be used for entire studies, for example by investigating a subject from several alternative research methodologies (Richard and Anita, 2008). Mixed-method triangulation is a research strategy whereby many techniques are employed to provide validation of data or the results of analysis. In this project triangulation is attained by the use of secondary methods – a literature review and the soliciting of expert opinions – and primary methods – questionnaires and semi-structured interviews. It can also be used to enhance the effectiveness of research methods.

The use of triangulation will be based on the researcher's theoretical position. It is not aimed only at confirmation but also at broadening and deepening one's understanding. It leans towards the support of interdisciplinary research, rather than being limited within the social sciences. Triangulation can, indeed, enhance reliability of scientific knowledge by improving both inner consistency and generalisability through joining both quantitative and qualitative techniques in the same study (Richard and Anita, 2008).

Creswell (2003) proposes three practical measures in selecting a research approach: 1) the nature of the research topic; 2) the available time the researcher has and 3) the extent to which the researcher is ready to indulge risk (Creswell, 2003). Taking these factors into account, the existing research’s investigation into the feasibility of the utilisation of renewable energy resources uses the empirical data that was collected from energy policy makers and user surveys. Thus, the researcher adopts both approaches, which are based on multiple methods of primary data collection.

The research design does not depend on the research philosophy only, since it also depends on the research type and strategy. As stated above, the current research is conducted in a single country (Libya), where there is a lack of the information about energy consumers and the energy sector (US & FCS, 2006).

Qualitative research aims to explore and describe problems that have already been identified, in this case finding the information necessary to help policy makers, and local and foreign investors to make informed decisions. In addition, it involves gathering, analysing and interpreting data that is difficult to quantify, and is based on meanings expressed through words. The tools often used for this research approach include interviews and observations (Government, 2011). It is based on the idea that the most important information is obtained from a relatively small group of people or individuals who are significantly involved in the topic in which the author is interested. This information offers an understanding of the problem being studied. On the other hand, the quantitative method includes an inquiry into an identified problem, with the purpose of generating data in the form of numbers. These data are then analysed using statistical methods (Sultan, 2005). Questionnaire-based surveys and experiments are generally used for quantitative research (Government, 2011).

5.4. Research methods

This section has described the research methods, procedures and techniques used to collect data for the current research. Both secondary and primary data have been collected in the data-collection process (sections 5.4.1 and 5.4.2 include more details about the types of data sources).

In this context, the research method could be categorised as qualitative, quantitative, and/or mixed. There is no rule in research that says that only one method must be used in an investigation, and using more than one method in an investigation can have considerable advantages. One important advantage of using multiple methods lies in the reduction of inappropriate certainty (Uche, 1995).

The researcher utilises in this study a combination of different research techniques, to study energy and the renewable energy sector through the power generation, policy maker and consumption sectors. The researcher also adopted the quantitative and qualitative methods which have been found to be more suitable for this type of study in order to achieve reliable and valid information. The qualitative method (by interviews) was adopted due to the researcher requiring information based on extrapolating. There are no references or complete scientific studies published on the utilisation of renewable energy resources in Libya which can give local and foreign investors reliable information and enable them to make decisions. In addition, the minister has been appointed, and most government authorities of renewable energy have been created, recently.

The most accurate information is available from certain people who are interested in this area due to personal motives (work, study or researcher). In order to answer the first research question and achieve the first two research goals, which require specific data about renewable energy and current energy resources, the researcher needs to conduct interviews with those people to discuss the energy currently used and relied upon as the main source of energy and revenues, and also to discuss environmental matters associated with the use of this energy. Likewise, the quantitative method (using questionnaires) is employed in this research, which studies a sample of energy consumers/users in Libya, to produce representative findings that can be applied to the Libyan energy situation and to other similar countries, like Nigeria.

In order to achieve the main aim of this study, as mentioned earlier in the first chapter, seven research objectives have been designed. Figure 5-3 demonstrates the connection between the research objectives, questions, and the methods used to answer each question.

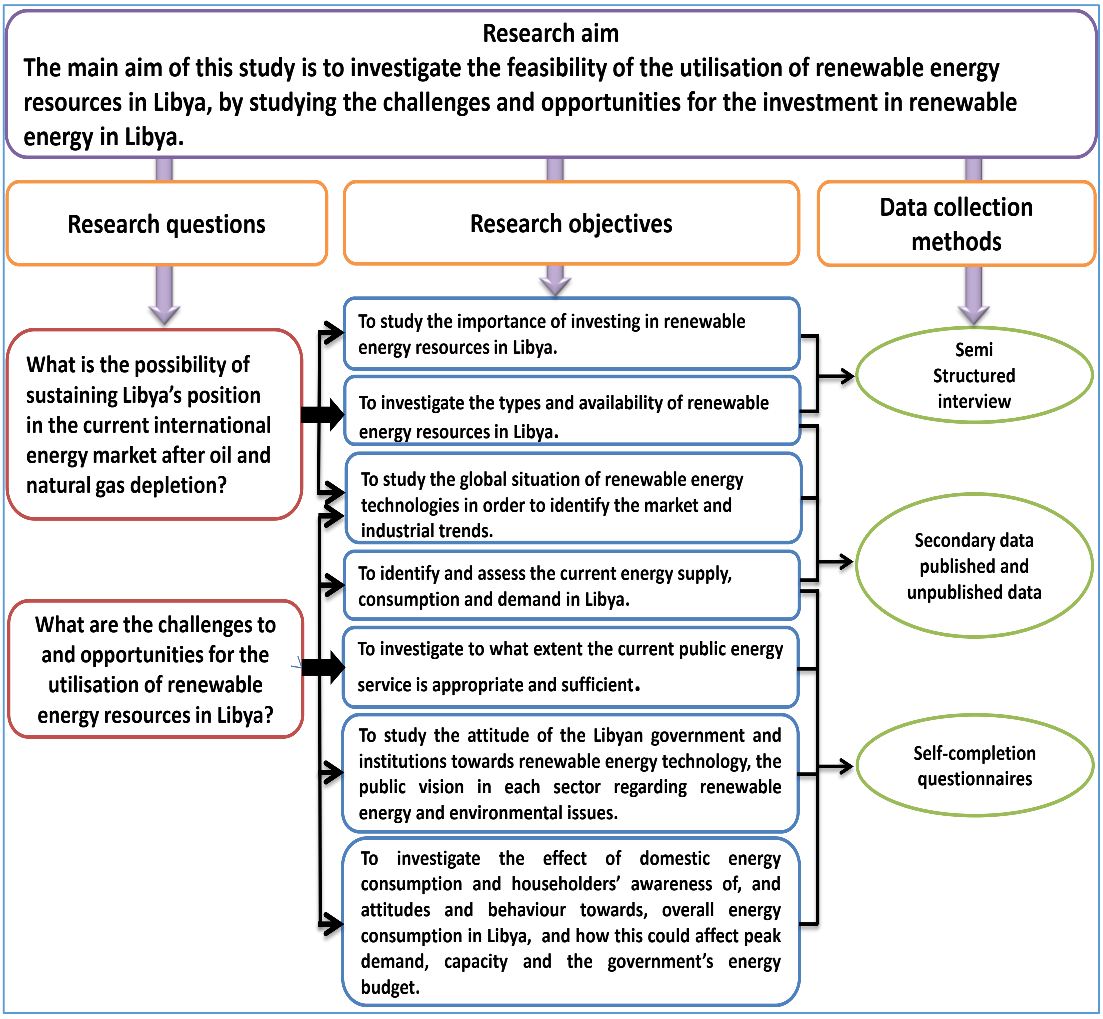


Figure 5-3: Research methodology.

Source: Author's own.

5.4.1. Secondary data

The analysis of documentary data is essential for an initial understanding of the current characteristics of the renewable energy sector. It has been also useful in defining the most appropriate institutions and managers at each level with whom to conduct the interviews for collecting further data and information. In addition, these documents can demonstrate current projects, current strategic plans, and future energy consumption in the renewable energy sector, the availability of renewable energy, and the perspective of policy makers, energy producers and consumers in relation to the energy sector in Libya. Secondary documentary data were collected from several government organisations and institutions in order to obtain the necessary information that is related to this subject, including policy statements, ministerial or departmental annual reports, legislation, energy sector letters and procedures. The researcher has also collected data from several companies, such as annual reports.

5.4.2. Primary data

Two types of primary methods were carried out in this research to collect data: interviews (face to face and over the telephone), and questionnaires.

5.5. Data collection

Data can be collected in several ways, from both secondary and primary sources. Secondary data are data that have already been collected and published in a formal format, for example textbooks, journals and annual reports, while primary data are obtained directly from individuals or groups (Khaled, 2007). In science or social research, data can be collected using several techniques, such as personal interviews, postal questionnaires, observational techniques, and the analysis of documents (unpublished data).

In order to answer the research question: ‘What is the possibility of sustaining Libya’s position in the current international energy market after oil and natural gas depletion?’ data was collected by means of interviews. The interview provides qualitative information describing perspectives on the importance of renewable energy to the country. It also provides information on the type and availability of energy and renewable energy resources, on the projects and the plans of the Libyan government concerning renewable energy technologies, and on the importance of investing in renewable energy technologies in Libya in the future.

This research needs a description and exploration of the opinions of the energy consumers, energy policy makers and energy generation sectors in Libya on currently used energy, and renewable energy implementation in the future. To this end, it requires both qualitative and quantitative data, and a questionnaire may provide the quantitative data measures of public understanding and opinion, as well as an examination of the role of the Libyan government and institutions in utilising renewable energy resources in the future, of current energy supply, consumption and demand, and of the efficiency and availability of the current public energy service. A questionnaire may also help explore the global situation of renewable energy technologies – aiming at identifying the market and industrial trends in order to clarify the investment opportunities – and furthermore the effect of domestic energy consumption and householders' awareness of, and attitudes and behaviour towards, the overall energy consumption in Libya and how this affects peak demand, capacity and government energy budget. As such, a questionnaire helps answer the research question: 'What are the challenges and opportunities to utilise renewable energy resources in Libya?'. Centred on this discussion, the motivation behind selecting a multi-method approach to research is now given.

5.6. The design of research instruments

The empirical study of the current research is mainly based on interviews with energy policy makers and customer surveys. Whereas quantitative questionnaires can provide evidence of patterns amongst large populations, qualitative interview data often gathers more in-depth insights on respondent and participant attitudes, thoughts, and actions (Harris et al., 2010). Semi-structured interviewing is more flexible than standardised techniques, for example a survey or a structured interview. While the researcher in this method will have some established general topics for investigation, these techniques allow the exploration of emergent themes and ideas rather than relying only on concepts and questions defined in advance of the interview (Harris et al., 2010). In this study, semi-structured interviews have been conducted with the managers, academics, policy makers, and experts and other senior people in power generation and the major consumer sectors in Libya. The semi-structured interview method served the purpose of the study perfectly, since it has an exploratory and explanatory nature. This is because this type of interviewing allows the researcher to find out new themes, thoughts and answers to questions that s/he did not think of, and in fact this was the case in this research.

The selection of the questionnaire is necessary for collecting information such as opinions, attitudes and facts from a large number of energy users, which reflect their responses and reactions towards the state of energy and renewable energy resources. Questionnaires consume less time than interviews and can be kept anonymous. However it can be hard to achieve an in-depth response from questionnaires, and they are not as flexible as interview methods.

The questionnaire is the most common tool used to collect primary related data in business studies (Robinson and Meah, 2013). According to Sekaran, a questionnaire can be defined as "*A reformulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives*" (Sekaran, 2003): p. 236. Furthermore, the questionnaire method will probably be the most appropriate form of gathering information from both managers and staff (Bryman, 2004). A questionnaire is a highly effective instrument of data collection, since it requires less time to manage and is therefore less expensive, and permits data collection from a larger sample of energy consumers in Libya. The development process of the interview questions list and questionnaire was carried out as follows.

5.6.1. The interview design

The interview was used as the first primary data-collection method to answer the first research question (for more information see Appendix A and Appendix B). It was designed to explore and describe the possibility of sustaining Libya's position in the current international energy market after oil and natural gas depletion. An interview is associated with both quantitative and qualitative method (Bryman, 2004). There are many advantages to the use of the interview as a data-collection method, for example the use of the interview increases the certainty, that is, the direct contact between the researcher and interviewee allows the interviewer to explain the objective of the study more freely, to clarify and to avoid doubt or any misunderstanding of the concepts or the questions (Bryman, 2004; Hussey and Hussey, 1997). Additionally, interviews, particularly semi-structured interviews, allow the interviewer to ask more complex questions and ask follow-up questions not possible in a questionnaire. Therefore, it may allow a higher degree of confidence in the replies than questionnaire responses (Oppenheim, 1992).

According to Saunders, semi-structured interviews are non-standardised and used in explanatory studies where the researcher has a list of themes and questions to be covered. Using this type of interview can help to explore and explain themes which have emerged from the literature review or the use of a questionnaire. Semi-structured interviews have the benefit of providing a chance to prompt the interviewees to explain, or build on, their responses. They might also lead the discussion into areas which have formerly not been considered, and may have a significant importance in answering the research questions (Hussey and Hussey, 1997).

Semi-structured interviews are used in this research. They allow the dialogue to be exploratory and unrestrictive. In addition, in order to obtain a more in-depth insight into the subject under study, the researcher did not record the interviews, because the recording procedures require formal acceptance from the Ministry of Public Security, which is too hard and complicated to achieve in Libya, and the researcher cannot control how long that will take. Moreover, recording is very sensitive in Libyan culture and it may bias the interviewees' answers. Therefore, the researcher adopted the method of note-taking during the interviews, this method is appropriate for such semi-structured interview. Any new questions which emerged during the interview time are coded and then added to the interviews questions list.

The main concern here is in formulating questions, for example to ensure that the required information is collected and miscommunication is avoided: it should be expected that some of the participants are not sufficiently familiar with some of the academic and renewable energy terminology. On the other hand, the interviews are administered by the researcher himself in order to ensure that the questions are correctly understood by the participants.

The interview questions fell into two categories: the first concerns general information regarding the interviewee's position, experience and qualifications; the second includes seventeen questions (started with seven questions) to survey the perceptions of Libyan experts of the energy and renewable energy sectors, and includes the interview (Arabic version), a participation form, an interview guide and a list of questions. For the interview questions designed to answer the first research question by covering the first two research objectives.

Participants in both the questionnaire (consumers/users) and interviews (energy generation, consumption and policy makers) are informed that their participation is voluntary, and that they are free to withdraw at any time without giving any reason, and without any implications for their legal rights. These statements are addressed on the front page of both the questionnaire and the interview script.

5.6.2. The questionnaire design

Questionnaires are used in this research as the second data-collection method. They study a sample of energy consumers/users in Libya, to produce representative findings that can be applied to the energy situation in Libya and other countries, and to answer the second research question (for more details see Appendix C and Appendix D). They are designed to explore and describe the challenges to and opportunities for utilising renewable energy resources in Libya, by achieving the last four research objective, which requires the opinion of people who are expected to use renewable energy in Libya, since their opinions towards renewable energy sources are important for policy makers and investors. At the same time, it is important to know their opinions and knowledge about the role of the government, current used energy and the level of efficiency and availability of this energy and its ability to meet their needs.

According to the discussion of the literature review in Section 3.5.2, the most important number in this study is domestic energy use, which in Libya accounts for about 36% of total energy consumption. Therefore, the researcher prepared two questionnaires, the first questionnaire to achieve research objectives 4, 5 and 6, and the second questionnaire to realise the last research objective.

In this research, self-completion questionnaires have been used to obtain data. This approach has several advantages, for example, all the finished responses can be collected in a short period of time and a good report can be recognised to encourage the participants, there is an opportunity to present the research topic and motivate the respondents to provide their answers honestly, any confusion about the questionnaire can be explained, it is less costly when distributed to group of participants, and it achieves a high response rate (Saunders et al., 2007; Yin, 1994). In the case of Libya, neither online nor postal questionnaires can be used due to the requirement that respondents have web sites or known emails, and because the Internet and postal system are not available everywhere.

According to Saunders et al., construction is a very significant matter for questionnaire design. In order to encourage the respondents to fill in and return the questionnaire, it must be designed in a way that makes it easy to read and complete, and must be attractive and not too long. The acceptable length of a self-completion questionnaire is between 4-8 pages of A4. Furthermore, the introduction must be clear and explain the research aims and provide a way to answer each part without difficulties (Saunders et al., 2003). Following the guidelines by Sekaran and Oppenheim, the following matters are given special attention in the questionnaire construction:

1. The question sequence is arranged from general to more specific questions. This makes the questionnaire as easy as possible for the respondents to read; and
2. Special attention is given to emphasise the confidentiality, that all responses will be treated with the utmost confidence and that results will be used for research purposes only (Oppenheim and Naftali, 2000; Sekaran, 2003).

Two questionnaires were designed for this study. The first one is to capture information from Libyan energy consumers in factories, housing, farms and public facilities. The second questionnaire is to achieve the last objective and capture information from only householders.

The first questionnaire consists of five main parts which were composed by the researcher after a comprehensive review of the relevant published literature. The first section concerns the details of participants. This section provides general descriptions of the farms, homes, factories and public facilities. The other sections of the questionnaire are similar, since the second concerns information related to the energy used by the participant. The third part of the questionnaire concerns the views of energy users on energy prices. The fourth part is designed to assess damages resulting from power or water outages. The final part looks at the availability of energy resources.

The second questionnaire consists of several parts. The first part is concerned with the characteristics and size of what is considered to be a reasonable representation of current dwelling types in Libya. The responses to this section provide a general description of the different types of household in this study. The second section of the questionnaire is about the frequency of use of cooling and heating systems in summer and winter, this section provides evidence of the relationship between Libya's electrical peak load and the increased heating and cooling needs during winter and summer. The third section of the questionnaire concerns the number and ages of appliances. The fourth section discusses what the Libyan households think about the rating of their appliances, and the factors that affect purchase of household appliances. The fifth section is designed to reveal energy consumption behaviour by Libyan household lighting types. The sixth section is about energy behaviour and energy awareness, which include general awareness of energy issues, views on energy-efficiency measures and associated investment, views on energy-saving issues, behaviour as regards renewable energy resources and CO_2 reduction schemes, prospective possible future investments in energy-saving measures, and views on the most suitable method of obtaining information on energy issues. The final part looks at the most important information about any energy-related adjustments in the respondent's behaviour.

Oppenheim and Naftali (2000) and Ghauri (1995) have stated that the choice of the kind of questionnaire can be influenced by several factors (Oppenheim and Naftali, 2000). Questionnaires are the most popular primary data-collection method used in business studies, of which the self-completed or self-administered questionnaire is less time-consuming than the interviewer-administered questionnaire, and can ensure a minimum of interviewer bias (Ghauri et al., 1995; Oppenheim and Naftali, 2000). The current research uses a self-completion questionnaire, written in English and plain Arabic (the national language in Libya) at the same time, in order to produce two versions. The Arabic version is the one that has been delivered by hand to each respondent for later collection.

As the participants targeted by the questionnaire are members of the general public (Libyan energy consumers in factories, homes, farms and public facilities), the questions should be written with clear language, style and structure (Malhotra, 2007). To realise this, the researcher discussed these matters concerning the Arabic version with Libyan experts and the supervision team (both the director and second supervisor are fluent in Arabic language). The questions have been expressed as simply as possible to reduce uncertainties during the data collection. Moreover, the questions have been worded following guidelines suggested by Oppenheim and Naftali (2000), Easterby-Smith et al. (2000), Malhotra and Birks (2003) and Sekaran (2003), who note that the following matters must be taken into account when writing the questions: familiar, direct and simple language should be used in wording the questions, and as such technical terms, abbreviations and nonsense terms should be avoided; each question should be kept as short as possible in a manner that would not affect the content and the proposed meaning of the question; and double-negative and double-barrelled questions should be avoided (Easterby-Smith et al., 2002; Malhotra and Birks, 2003; Oppenheim and Naftali, 2000; Sekaran, 2003).

The questionnaire of this research consists of different scales and categories depending on the research construct. The closed-questions type is adopted in most parts of the questionnaire, such as the demographic items, because of its relatively complete responses, specific answers, and the clarity of meanings and connotations. There are many types of questions that included in this research questionnaire. “Yes” or “No” answers, agree/disagree statements, and the multi-item Likert ordinal scales (degree of agreement and disagreement) are commonly used and recommended question formats for measuring latent consumer opinion constructs such as attitudes and values (Burns, 2008; DeVellis, 2003; Soares, 2004).

In the open-ended questions type, the respondents have the freedom to answer the questions (Khaled, 2007). Open-ended questions are often used by survey researchers to measure public opinion (Geer, 1988). Moreover, it is used when there are difficulties in determining the array of possible answers, and when it is essential to help the respondents feel valuable, as they can give the answer they prefer. Therefore, the researcher left space at the end of some questions, and also made use of some open-ended questions at the end of each part of the questionnaires to collect participant responses towards current energy and renewable energy sources in Libya.

Most questions that were designed to measure the energy consumers’ responses used the Likert 5-point scale: “(1) strongly disagree, (2) disagree, (3) not sure, (4) agree and (5) strongly agree” (reverse-coded where appropriate). This scale was selected in order to allow using the collected data in most statistical tests, as some only accept responses that are on at least a 5-point scale (Blunch, 2008; Busnaina, 2010). In addition, the Libyan experts advised that Libyan respondents are more familiar with “Yes” or “No” answers, agree/disagree statements, and Likert 3-point and 5-point scales (Likert 7-point is inappropriate). Regarding the sequence of questions, the researcher arranged them from general to more specific, in order to make the questionnaire as easy as possible for the respondents (Oppenheim and Naftali, 2000; Sekaran, 2003). The respondents are provided with supporting letters, one from the research director of study in English and the other one from the Libyan embassy in London, in Arabic.

The questionnaires were delivered to consumers in houses, farms, border gates, and remote areas by hand. Moreover, the research sample is relatively large (about 1522 for the general questionnaires and about 823 for the householders': more details about population and the sample are given in the analysis in chapters eight and nine).

5.7. Documentary sources

Document analysis is often used in combination with other research methods. It is a social research method and an important research tool in its own right and is an invaluable part of most schemes of triangulation. Document analysis is used in this research to support the previous two data-collection methods and to obtain further qualitative and quantitative data. These documents in fact provided rich governmental and strategic industrial data. Documentary sources were drawn from the energy sector sites visited by the author. They are in the form of policy and procedure documents relating to the overall energy and renewable energy programme. The renewable energy experts and other organisation managers allowed the author to take them as a reference, and the researcher was also given access to report profiles. These profile documents contain the solar radiation and wind speed information in different sites, reports about Libyan electricity demand and consumption, electricity readings (quantity and cost) for houses, supermarkets, farms, hospitals and others in Libya, and details of Libyan electrical steam and gas stations and the Libyan energy strategy (plan/goals).

5.8. Research population of the study area

This research mainly focused on the energy policy makers, energy consumers and energy producers across the four Libyan geographic regions (Northern, Eastern, Western and Southern). Figure 5-4 demonstrates the research population and the respective research techniques which were conducted by researcher on each research group:

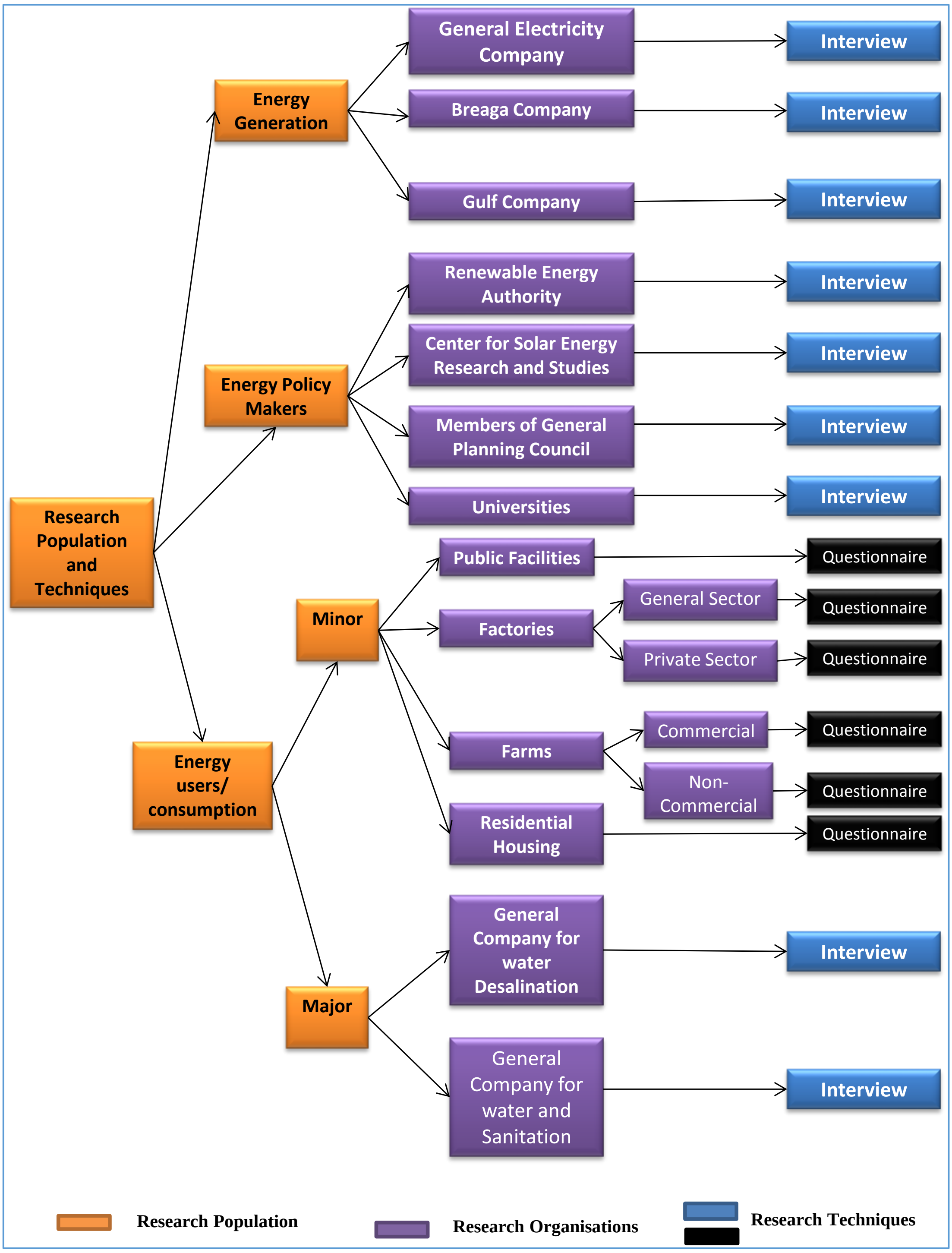


Figure 5-4: Research techniques and organisations.

Source: Author's own.

5.9. Research Samples

For the survey, the sample of this research consists of energy policy makers, energy generation sources and users, as illustrated in Figure 5-4. The research samples include interview participants and questionnaire respondents as follows:

5.9.1. Interview sample

The sample of interviews were selected based on four broad decision areas: identifying a suitable sampling frame, deciding on a suitable sample size, selecting the most appropriate sampling technique, and choosing the respondents within each organisations, institutions and company. The sample size can be determined by the research questions and/or objectives (Saunders et al., 2003) and the researcher's available budget and time (Lee and Palmer, 1999). Taking these determinants into account, nine organisations, institutions and companies are targeted for semi-structured interviews.

In order to gather evidence and information about the possibility of sustaining Libya's position in the current international energy market after oil and natural gas depletion, the researcher targeted a number of organisations and institutions in the Libyan energy sectors. Interviews are then conducted with key people who are responsible for policy making in these organisations and institutions. The researcher identified the persons in each organisation or institution who is most qualified to provide the required information, meeting the knowledgeability criterion for key information and willing to participate. Face-to-face interviews are then conducted with the experts, managers and academics who work in energy and renewable energy.

There are a total of 75 potential interviews subjects distributed among 10 sectors. 55 face-to-face interviews are conducted; details of these are shown in Table 5-1. Some of the interview participants include the Chairman of the Renewable Energy Authority, the Centre for Solar Energy Research and Studies, the General Company for Water and Sanitation, the General Company for Water Desalination, the General Electricity Company, and the faculty deans of Engineering of Tripoli University and Benghazi University. Top academics at these universities and others at various managerial levels were interviewed; the interviews were conducted by the researcher. This total of 55 interviews achieved 73% of the initial target sample. The coverage is comprehensive and the sample covered the key personal in the energy and renewable energy sectors in Libya. Unpublished data and information has been collected from different sectors and government organisations during the interviews. Table 5-1 summaries the interviews based on the sector and the organisation, with a unique code for each interviewee based on the location.

Table 5-1: Summary of face-to-face interviews.

Classification	Organisations of interviewees list	Code of interviewee	City	Number of Interviews
Energy Policy Makers E P M	Renewable Energy Authority (A)	A1,A2,……A5	Tripoli	5
	Centre for Solar Energy Research and Studies (B)	B1,B2,B3, B4	Tripoli	4
	Members of General Planning Council (C)	C1,C2,….C5	Tripoli	5
	Universities (D)	D1,D2,….D8	Tripoli/Benghaz i	8
Energy Generation Companies E G	General Electricity Company (E)	E1,E2,….E6	Tripoli/ Benghazi	6
	Breaga Company (F)	F1,F2,….F6	Tripoli	6
	Gulf Company (G)	G1,G2,….G5	Tripoli	5
Energy Costuming Companies E C	The General Company for Water Desalination (H)	H1,H2,……H10	Tripoli/ Benghazi	10
	The General Company for Water Sanitation (I)	I1, I2,I3	Tripoli/ Benghazi	3
	Utilities Sector (J)	J1,J2, J3	Tripoli/ Benghazi	3
Total				55

Moreover the researcher conducted eleven telephone interviews (telephone surveys) with some participants to certify their opinions after the last political change. Telephone interviews were conducted in 2013 with those participants after the Libyan political change on 17 March 2011, as shown in Table 5-3:

Table 5-2: Summary of Telephone interviews.

Institution	Participants	Previous position	New position
Renewable Energy Authority of Libya	EPM $_{A1-1}$	Manager of planning & studies department	The Chairman of R.E.A.O.L
Renewable Energy Authority of Libya	EPM $_{A5}$	Head of PV Section	Head of PV Section
Center for Solar Energy Research and Studies.	EPM $_{B3}$	Head of Thermal Energy Conversion Department	Head of Thermal Energy Conversion Department
Center for Solar Energy Research and Studies.	EPM $_{B2}$	Head of PV Conversion Department	Head of PV Conversion Department
Bank sector	EPM $_{C2}$	Director North Africa Bank & member in General Planning Council.	Director North Africa Bank & member in General Planning Council.
Bank sector	EPM $_{C3}$	Director Wahad Bank & member in General Planning Council.	Director of Wahad Bank and member in General Planning Council
Benghazi University	EPM $_{D2}$	Prof. Dept of Electrical & Electronics Engineering	Prof. Dept of Electrical & Electronics Engineering
Tripoli University	EPM $_{D5}$	Prof. Dept of Electrical & Electronics Engineering	Prof. Dept of Electrical & Electronics Engineering
General Company for Water Desalination.	EC $_{G1}$	Operation manager eastern region	Operation manager eastern region
General Company for Water and Sanitation	EC $_{I1}$	Director of Operation and Maintenance	Director of Operation and Maintenance

5.9.2. Questionnaire sample and response rate

In terms of questionnaires, the research population is relatively large, as is the sample size. As such, the administration of the questionnaires took a fairly long time, and was carried out from the start of 2011 to the end of 2013. Based on Krejcie and Morgan (2006), the sample size for a population of more than 250,000 with a confidence level of 95% and a margin of error (degree of accuracy) of 5% would be 384 (Lee and Palmer, 1999). Referring to the latest information from the commercial manager GECOL, in 2012 the total population of Libyan energy users was 1,223,727, distributed into four categories as shown in Table 5-3:

Table 5-3: Total population of Libyan energy users.

User type		Number of users	Sample size*
Residential housing [RES]		905,970	384
Farms	Commercial [FMC]	960	384
	Non-commercial [FMN]	116,199	
Factories	public sector [FTP]	33,454	384
	Private sector [FTV]	142,270	
Public facilities [PFL]		24,874	370
Total		1,223,727	1,522

*Sample size based on Krejcie and Morgan (2006) table.

This population of users is distributed across Libya in six geographical areas. The areas and figures, based on the GECOL 2012, are shown in Table 5-4 and Figure 5-5:

Table 5-4: The population size and sample for each area.

User type	Total	Regions					
		Tripoli	Benghazi	Western	Middle	Southern	Green Mountain
[RES]	905,970	317,347	147,569	187,017	135,475	53,669	64,893
[FMC]	116,199	33,473	8,992	40,640	15,754	16,044	1,296
[FMN]	960	73	417	172	193	86	19
[FTP]	33,454	9,637	3,103	8,003	8,390	2,438	1,883
[FTV]	142,270	48,905	30,489	20,328	22,137	6,588	13,823
[PFL]	24,874	6,395	3,931	5,677	3,954	2,026	2,891
Total accounts of users	1,223,727	415,830	194,501	261,837	185,903	80,851	84,805
*Sample Distribution	1,522	*421	*278	*337	*259	*120	*107

* Sample distribution: see Table 5-5 to Table 5-10.

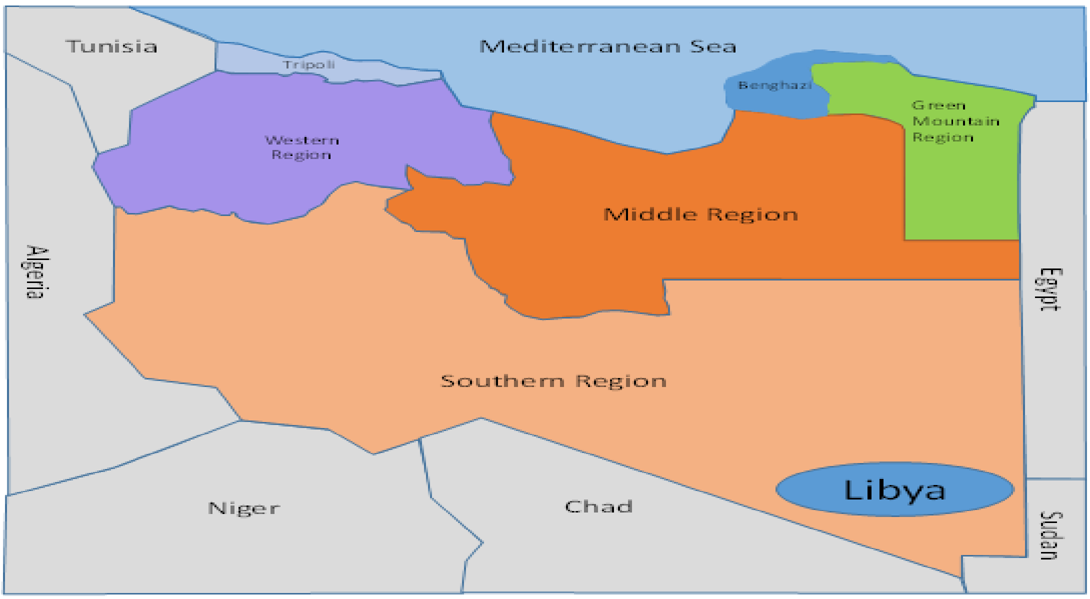


Figure 5-5: Map of Libya and the regions used in the survey of this study.

Source: Designed by Author.

Rather than test the whole population, these questionnaires are directed to only a sample. Statistical investigation such as this needs to consider the following methodology in probability sampling:

1. Identify a suitable sample frame based on your research questions or objective;
2. Decide on a suitable sample size;
3. Select the most appropriate sampling technique and select the sample; and
4. Check that the sample is representative of the population (Chua, 2006; Krejcie and Morgan, 2006).

In order to draw a representative sample from the population of study it is important to consider the above design. This research used a form of probability sampling named stratified random sampling, in which a proportional sample is selected. As pointed out before, Libya consists of six geographical areas. Additionally, the energy users/consumers in the study area do not have house numbers and/or post codes, so to decide which households, factories, public facilities or farms are used for the study sample, the current research's stratified random sampling was divided into non-overlapping groups, i.e. geographical areas across Libya. The first step is determining the number of questionnaires within the four categories for each of the six sample areas.

Sample size for each layer (Area) = $\frac{\text{size of layer (Area)}}{\text{size of whole sample}}$ size of layer (area) (Saunders et al., 2003).

The population size for each area is: Tripoli 415,830, Benghazi 194,501, Western 261,837, Middle 185,903, Southern 80,851 and Green mountain 84,805 (total = 1,223,727). To find the sample size for each area, we calculate as follows:

Table 5-5: The sample size of Tripoli.

Items	Size of area	Size of whole sample	Size of sample area	The sample
[RES]	317,569	905,970	384	135
[FMC]	33,473	116,199	192	55
[FMN]	73	960	192	15
[FTP]	9,637	33,454	192	55
[FTV]	48,905	142,270	192	66
[PFL]	6,395	24,874	370	95
Tripoli's sample size				421

Table 5-6: The sample size of Benghazi.

Items	Size of area	Size of whole sample	Size of sample area	The sample
[RES]	147,569	905,970	384	62
[FMC]	8,992	116,199	192	15
[FMN]	417	960	192	83
[FTP]	3,103	33,454	192	19
[FTV]	30,489	142,270	192	41
[PFL]	3,931	24,874	370	58
Benghazi's sample size				278

Table 5-7: The sample size of Western.

Items	Size of area	Size of whole sample	Size of sample area	The sample
[RES]	187,017	905,970	384	79
[FMC]	40,640	116,199	192	67
[FMN]	172	960	192	34
[FTP]	8,003	33,454	192	46
[FTV]	20,328	142,270	192	27
[PFL]	5,677	24,874	370	84
Western's sample size				337

Table 5-8: The sample size of Middle.

Items	Size of area	Size of whole sample	Size of sample area	The sample
[RES]	135,475	905,970	384	57
[FMC]	15,754	116,199	192	26
[FMN]	193	960	192	39
[FTP]	8,390	33,454	192	48
[FTV]	22,137	142,270	192	30
[PFL]	3,954	24,874	370	59
Middle's sample size				259

Table 5-9: The sample size of Southern.

Items	Size of area	Size of whole sample	Size of sample area	The sample
[RES]	53,669	905,970	384	23
[FMC]	16,044	116,199	192	27
[FMN]	86	960	192	17
[FTP]	2,438	33,454	192	14
[FTV]	6,588	142,270	192	9
[PFL]	2,026	24,874	370	30
Southern's sample size				120

Table 5-10: The sample size of Green Mountain.

Items	Size of area	Size of whole sample	Size of sample area	The sample
[RES]	64,893	905,970	384	28
[FMC]	1,296	116,199	192	2
[FMN]	19	960	192	4
[FTP]	1,883	33,454	192	11
[FTV]	13,823	142,270	192	19
[PFL]	2,891	24,874	370	43
Green Mountain's sample size				107

The researcher delivered the individual questionnaires by hand to a sample of energy users/consumers such as public facilities, factories (public sector and private), farms (commercial and non-commercial) and residential housing. From a total survey of 1,522 questionnaires distributed in the research area, 831 valid questionnaires were received : a 55% response rate (29 were rejected because they were incomplete).

The researcher personally distributed and collected the questionnaires with the help of four former university colleagues from different cities in Libya. Table 5-11 includes their allocated questionnaire numbers and the dates of their delivery and collection:

Table 5-11: Distribution of questionnaires collected by university colleagues from Libya.

Code	Colleague	The number of questionnaires	Date of distribution and collection
A. M 1	Ph.D student in NTU	150 (missing 23) Achieved 97	01/04/2013 to 01/07/2013
A. I 2	Ph.D student in NTU	160 (missing 55) Achieved 105	04/07/2013 to 17/08/2013
B. S 3	Ph.D student in NTU	110 (missing 15) Achieved 95	03/07/2013 to 07/08/2013
M. E 4	Ph.D student in NTU	140 (missing 42) Achieved 98	10/07/2013 to 02/09/2013
Achieved by others		395	
Achieved by researcher	Ph.D Student in NTU	436	01/01/2011 to 15/03/2011
Total of questionnaires		831	

An explanation was given to the participants as to how to complete the questionnaires, and they were also told of the importance of this work and its aims. A letter from the researcher including contact details was attached with the questionnaire, in case the participants needed support in completing it. At the end of the questionnaire there was a section where the participants could comment and provide feedback about the it. Most of the participants agreed that they were comprehensive. Libyan people were helpful and willing to participate in the research. Most of the participants demonstrated commitment in returning the questionnaire with careful answers. Table 5-12 summarises the questionnaires based on the sector and the organisation, with a unique code for each participant and the geographical location. The research sample's individuals are defined as adult (18 years old and above) Libyan energy consumers, who live in Libya and have reading and writing skills. The reason behind that is that the data-collection tool is a self-completion questionnaire.

Table 5-12: Summary of the questionnaires[5].

Classification	Sectors	Code of questionnaire	Distributed questionnaires	Received questionnaires
Minor Energy Customers M E C	[RES]	A1,A2,…A370	370	206
	[FMC]	B1,B2,…B192	192	113
	[FMN]	C1,C2,…C192	192	130
	[FTP]	D1,D2,…D192	192	106
	[FTV]	E1,E2,…E192	192	136
	[PFL]	F1,F2,.F384	384	140
	Total		1,522	831

In terms of sampling error, the sample of the current research presented an acceptable margin of errors (as 2.42% is less than 5%) with a confidence level of 95% and probability of 50%.

Additionally, as there was no effort in the sampling process to select certain sample elements over others, it could be considered that sampling bias errors did not occur. It is important here to say that "…. *the concept of error does not imply incorrectness but acknowledgement that there is a variation between the parameter and the static used to estimate it*…." (Burns, 2008): p. 184.

[5] Note: The maximum sampling error is calculated as follows: 0.95 ÷ √ 1,522 = ±2.42%.

5.10. Piloting the research questionnaire

Before proceeding to assess the research project using the above techniques, the researcher believes that it is essential to conduct a pilot study in which the method can be tested. As highlighted by Oppenheim (1992), "*questionnaires do not emerge fully fledged; they have to be created or adopted, fashioned and developed to maturity after many abortive test flights*" (Oppenheim, 1992):47. Apart from assessing the intelligibility and appropriateness of the interview technique, or a questionnaire, a pilot study assists the researcher in calculating the estimated time required for an interview and, on occasion, it proposes new concepts and questions to be involved in the interview. Questionnaire piloting is considered a significant matter in research. Malhotra and Birks (2003) suggest that a questionnaire should be pilot tested, prior to using it to collect data (Malhotra and Birks, 2003). Furthermore, Saunders et al., (2007) state that "…. *The purpose of the pilot test is to refine the questionnaire so that respondents will have no problems in answering the questions and there will be no problems in recording the data. In addition, it will enable you to obtain some assessment of the questions' validity and likely reliability of the data that will be collected"* (Saunders et al., 2007): p.386. In the current research the pilot study is conducted in two stages, these are explained next.

5.10.1. First stage: The other Libyan colleagues' review

In addition to the research's supervisor team comments, the first draft of the questionnaire is considered by eight colleagues who are doing PhD research in the School of Architecture, Design and Built Environment and the Business School in Nottingham Trent University. The colleagues provided the researcher with suggestions about design, question content and layout. Their recommendations were taken into account in the process of producing the second questionnaire draft.

5.10.2. Second stage: The experts' review

At the second stage the experts' review (also known as experts' judgment) has been used to ensure content validity (DeVellis, 2003; Theodosiou and Katsikeas, 2001).

This review reveals the extent to which the content of a measurement is captures within it the intended concepts that are to be investigated (Burns, 2008), and provides an important overview and understanding of the survey before distribution to guarantee that the questions mean exactly what is intended by the researcher and ensures that any misunderstanding is minimised. The researcher contacted three academic members of staffs as experts in the area, one in the University of Tripoli and two in the University of Benghazi in Libya, and also two professionals from the Centre for Solar Energy Research and Studies of Renewable Energy Authority of Libya. They were asked about the questions and wrote and provided the researcher with their notes and comments on the content and structure of the questionnaire. Their recommendations were also taken into account in the process of producing the second questionnaire draft.

5.11. Preparation for data analysis

As stated above, both quantitative and qualitative methods were used in this study. Semi-structured interviews were conducted with Libyan policy makers and energy users as a main data-collection method. The questionnaire is used as a second data-collection method with Libyan energy consumers in factories, housing, farms and public facilities, in order to collect information from a large number of users, and this reflects their understanding of, and responses and reactions towards, the state of energy and renewable energy resources. The following paragraphs present a brief discussion about the tests and the methods used in analysing the obtained data.

The nature of the data and the connection between the technique of data collection and the research objectives are considered as the basis for choosing the correct statistical analysis techniques. Consequently, the current study used what is related to the research questions and structure. Descriptive analysis of the data is the main statistical technique used to create a summary of the respondents' demographic characteristics, using means, frequencies and standard deviations of the responses. Descriptive or exploratory statistics comprise a conversion of the raw data into a form that will provide information to define a set of factors in a given situation. In this context, the researcher classified, coded and sorted the raw data collected into tables, in order to produce information that can be understood and interpreted. This process has been carried out through interview and questionnaire response checking, coding and transcribing**,** and this process, in fact, is credited by (Malhotra, 2007; Sekaran, 2003).

5.11.1. Interview data coding

Because of its nature, there is no standardised approach to the analysis of qualitative data. As such, there are numerous qualitative research traditions and approaches, with the result that there are also various strategies to deal with the data collected (Saunders et al., 2003). While different approaches that are not mutually limited can be combined, it can be debated that the thematic analysis approach is the most suitable one to be employed in this study. The interest of thematic analysis is on the content of the speech, that is, the researcher concentrates on what is said more than how it is said (Riessman, 2004).

In the current research, the data obtained from the face-to-face and phone interviews was processed and analysed using a number of steps, which started with all the interviews being coded. Each interview was given a letter and number related to each group. Using computer software, the codes were divided and classified into simpler codes to situate them for this study. The second step was carefully reading and rereading the data for each interview and then transcribing them, writing down each participant's response (both Arabic and English translations) on a separate sheet of page. In the third step, the researcher read the transcribed data closely in order to identify the topic area related to the study objectives. Each question's responses were placed together and rewritten on various sheets of paper so that all the responses to a specific question were together. Categories for the answers to each question were established and related data was placed under each category. The answers were sorted in terms of the topics or categories, and quotes were used to explain them.

5.11.2. Questionnaire data coding.

The first stage after the completion and collection of the questionnaires was coding, that is, giving a character and number to each questionnaire, in this case the character refers to the group and the number refers to the total of respondents in this group, so as to uniquely identify each questionnaire response. For example, the [RES] group (A1, A2, A3, A4, A5, A6, and A7 … A10), or the [FMC] and [FMN] groups (B, C) (B1, B2, B3, B4, B5 …B10) (C1, C2, C3, C4, C5 ...C10). This is followed by coding every question and answer in each questionnaire. For example, the answer "Yes" is given a value of one, and "No" is given a value of zero. In the case of multiple-choice questions, the answers are numbered sequentially, representing a rank order measured on a 5-point Likert-type scale (e.g., 1 = “Very dissatisfied”; 2 = “Dissatisfied”; 3= “Unsure”; 4 = “Satisfied”; 5 = “Very satisfied”). A database for each question is created and data entered using Microsoft Excel. The statistical analysis software Statistical Package for Social Sciences (SPSS) is used to analyse the data collected. Chapter eight explains the data-analysis procedure in greater detail.

5.12. The research’s initial stage and field work

The initial stage, fieldwork and data collection were conducted during the period 1 January 2011 to 15 March 2011. In order to study renewable energy in Libya it was necessary to explore the current situation of the energy sectors. Therefore, in order to pave the way towards conducting the major fieldwork of this research, the author went to Libya (in January, 2011) to take a provisional view of the population and information resources. The visit to Libya also helped to determine the availability of different renewable energy resources and the practical implementation of renewable energy technologies.

Based on the interviews during the initial stage and fieldwork within the Libyan energy sectors, the researcher gathered that there is a need to drive down carbon dioxide and other polluting emissions and to maintain conventional energy resources for future generations, and that these factors are driving the Libyan government to explore the usefulness of other renewable energy options. Overall, the researcher will investigate the status of current energy generation and consumption, and the challenges/opportunities for investment in and implementation of new renewable energy systems in Libya in the future.

5.13. Reliability and validity

Reliability and validity are critical and significant matters in the scale-evaluation process (Malhotra, 2007). Gorman and Clayton (1997) have defined constancy, or reliability, as *“the extent to which a measurement procedure yields the same answer however and wherever it is carried out”* (Gorman and Clayton, 1997):p.57. The concept of reliability signifies key questions that must be answered one way or another in any section of research, and so cannot be ignored. Indeed, it is certain that the level of reliability of a section of research has an impact on the credibility of the results and conclusions, and therefore must be considered throughout the research process (Shoab, 2012).

There are two kinds of validity in this context, known as internal validity and external validity. Internal validity refers to whether or not what is recognised as the ‘causes’ or ‘stimuli’ really produced what have been interpreted as the ‘effect’ or ‘responses’. External validity, on the other hand, commonly refers to the extent to which any research results can be generalised to a population from a research sample. There are many validity measures; the choice of the validity method used in a research project is directly related to the level of the study design. For example, for exploratory descriptive designs where there is little knowledge about the phenomena, self-evident measures might be adequate, whereas predictive research demands the highest degree of validity testing. The data-collection method can then be used with confidence to distinguish between people on the basis of predictable outcomes (Bryman, 2004). In the current research, the self-evident and external validity is examined via expert review and statistical tests. Furthermore, the use of different data-collection methods and different analytical techniques adds to the validity of this study at the level of data and analysis.

There are a number of ways to test reliability in scales and checks such as test-retest which is administering the same test a period of time after the first. In the current research Cronbach’s Alpha is used to measure reliability. Using the Reliability Statistics in the SPSS programme (Copy 22: 2014) to establish the reliability of the responses, the result on Cronbach’s Alpha scale for the entire questionnaire was 0.793. This score means that the collected responses and the findings have a relatively good level of consistency, as if the items show good internal consistency, Cronbach’s Alpha should exceed 0.70. This method, in fact, is credited by (Bowling, 1997; Bryman and Cramer, 1997). Reliability is also called ‘dependability’ in the literature, and it explains the level to which the technique is constant and consistent to permit repeating the same research using the same techniques, sample and data collection, so as to get the same findings (Sekaran, 2003), that is, it is concerned with the question of whether the findings of a study are repeatable (Bryman, 2004).

Semi-structured interview reliability is concerned with whether alternative interviewers would reveal similar information (Easterby-Smith, 1991; Easterby-Smith et al., 2002; Saunders et al., 2003). The researcher, however, provided the respondents with a list of the interview subjects before conducting the interview. The main reason behind this procedure is to encourage validity and reliability by enabling the respondents to consider the required information and allowing them the chance to collect supporting organisational documentation from their files. The empirical knowledge which emerged from the interviewees in each sector provided additional understanding into the answer received from various participants. The provided information in each interviewee was used to determine subsequent interviews.

Saunders et al. (2007) have stated that concern about reliability is associated with the issue of bias (Saunders et al., 2007). The researcher in the present study consciously avoided interviewer bias which can originate from comments, tone or non-verbal behaviour and create bias in the way that respondents respond to the questions being asked. The researcher tried to develop trust with the respondents by a good introduction of the study which emphasised the confidentially of their answers.

As discussed in the previous sections, this research is exploratory and descriptive, and uses consumer surveys. It aims to investigate the feasibility of the utilisation of renewable energy resources in Libya, by studying the challenges and opportunities for investment in renewable energy in Libya. The research also depends on collecting responses from a large sample of consumers (1,522 respondents) in order to produce generalisable results. Therefore, in the current research, the quantity and quality of the data collected for the sake of this study and the due care being taken in analysing these data confirm the reliability of this research at the level of methodological approach and results.

5.14. Ethical issues

Ethical issues are important for a researcher who deals with real people in real world situations (Bassey, 1999). Bell (1999) highlights that a researcher must be aware of, and be directed by, ethical procedures throughout the research process, and that common sense and courtesy are invaluable in forming good research practices (Judith, 1999). Because of the sensitivity of the research data and possibly the results, ethical standards are followed in order to protect the identity of participants. That is, the participants' identities are kept unknown and information participants provide is only used for the purpose of the research. Published material resulting from the research will not reflect the identities of participants (Oppenheim, 1992; Shoab, 2012).

The project was conducted using clear ethical procedures. Moreover the researcher considered during the research process, design, data collection and analysis, the following ethical issues which were addressed by the Nottingham Trent University Graduate School's guidance on ethical research and the regulations of the department of Higher Education in Libya, where the fieldwork was carried out. In this context, the ethical issues report was approved by Nottingham Trent University.

5.14.1. Permitting free choice

The contribution is voluntary, and the respondents' and participants' right to reject or withdraw from the study at any time without penalty was guaranteed.

5.14.2. Confidentiality and anonymity

All questionnaires remain confidential. The interview transcripts are also kept safe and there is no revelation of participants' identities. The identity of the interview subjects is kept anonymous by using serial numbers to distinguish the interviewees, such as $EPM_{A1,\ A2}$ and $_{A3}$.

Expected usage of the data, the identity of researcher, the participants' role in the research, the degree of anonymity and confidentiality, the techniques to be used and the expected length of questionnaires and interviews were clearly described. Also, all participants were guaranteed that after the meeting is finished they will duple check their answer for accurateness. If the participant required a copy of the results when the research is completed, the researcher guaranteed that he will send them a copy.

5.15. Summary

The current chapter has clarified the various options available for the carrying out of the field research and the logic for the selection of the specific approach, strategy and methods applied in this research project.

This research study investigates the usefulness of and opportunities for utilising renewable energy options in Libya. As it is of an exploratory and explanatory nature, the study uses both qualitative and quantitative aspects; therefore it uses a combination of data sampling, collection and analysis methods. The combination of these methods assures validity and reliability, and the justification behind this choice is provided within this chapter.

The following chapter will provide a discussion on the characteristics of the findings obtained from the interview and questionnaire analysis, as well as the research results derived from the data-analysis procedures through the qualitative and quantitative data-analysis phases, in order to achieve the objective of this study and attempt to answer the research questions.

Chapter 6. Interview data analysis and discussion.

6.1. Introduction

This chapter includes the data collected during the fieldwork, the situational analysis of renewable energy in Libya as indicated in the documents of renewable energy institutions which describe the renewable energy resources, current projects and future energy consumption in the renewable energy sectors, current strategic plans, and availability of renewable energy, and the perspective of policy makers, energy producers and consumers in relation to the energy sector in Libya. In addition, it gives support for a discussion of the results of this thesis. Specifically, the chapter contains an analysis of the first part of the interviews which were conducted with Libyan experts to investigate the types and availability of renewable energy resources in Libya. The data for this section has been collected by personal interviews conducted with Libyan renewable energy experts. The findings which emerged from the analysis of this data reflect renewable energy challenges and opportunities in Libya. This chapter is divided into two parts. The first part explores the initial section of the interviews, which was concerned with general information, while the second part tackles the remainder of the interview questions.

6.2. Potential of renewable energy sources in Libya

Many oil–rich countries in the MENA region, including Libya, are trying to diversify their economies and reduce their dependency on oil as a source of income and energy generation in order to develop more sustainable and knowledge-based economies. Securing alternative resources of energy and income is becoming critically important for these countries if they wish to maintain the same standard of living for future generations and reduce pollution and the carbon emissions caused by the use of fossil fuels.

The information currently available in the public domain regarding renewable energy in Libya indicates that Libya is rich in solar and wind energy resources. Libya has a huge area of 1,759,540 km² and a long coast, some 1,900 km along the Mediterranean Sea. 88% of its area is considered to be desert, where there is a high potentiality for solar and wind energy which can be used to generate electrical, thermal, photovoltaic and solar energy conversions. Moreover, it has been estimated that every year, each square kilometre (km²) of desert in the MENA region receives solar energy equivalent to 1.5 million barrels of crude oil (Franz, 2011).

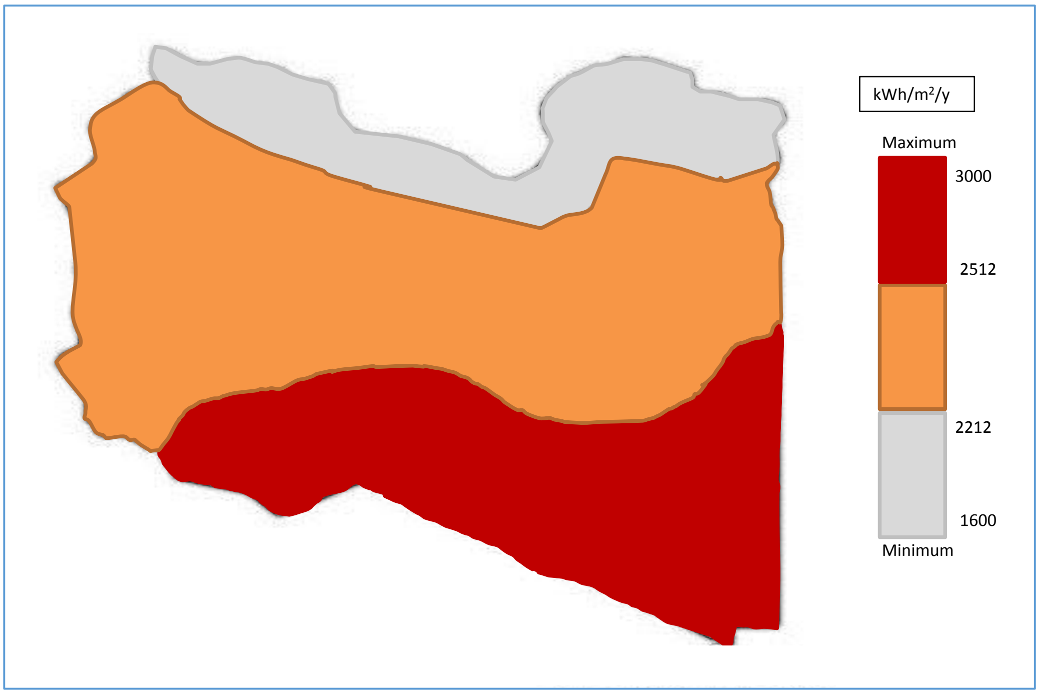


Figure 6-1: Estimated average solar energy in Libya in kWh/m² per annum.
Source: Author’s own.

Based on information extracted from data provided by the German Aerospace Centre (DLR) in 2007, Figure 6-1 indicates an average estimate of annual direct normal solar irradiance in Libya in kWh/m² per annum. The red colour represents areas of high potentiality of solar radiation with a range between 2,512 and 3,000 kWh/m^2/y, the orange colour indicates a range between 2,212 and 2,512 kWh/m^2/y and the grey colour represents the lowest potential, with a range between 1,600 and 2,212 kWh/m^2/y.

6.2.1. Description of interviews and interviewees

Collecting accurate data and information about energy research or projects, takes a long time and requires many personal contacts in the case of the government, as some of the information is considered to be state secrets, so even the few who have the data cannot freely go through them. As mentioned earlier in the methodology chapter, interviews were first conducted from the 1st of January to March 2011, and additional phone interviews were conducted in 2012 and 2013. This second group of interviews were taken with eleven participants after the most recent political change. Each interview included sets of questions. All fifty-five participants in this research provided some information during the interviews and also gave valuable and interesting insight for this research project.

A series of the interview questions are used to gather data concerning the research questions related to each participant at each organisation or company within the research study. Specific data has been collected about daily and monthly total radiation (kWh/m^2/m) and wind speed (m/s) readings by the Libyan Centre for Solar Energy Research and Studies (CSERS) and the Renewable Energy Authority in Libya (REAOL) for many regions across Libya, to aid the study of the types and availability of renewable energy resources in Libya. More details in Table 5-1.

6.2.2. The research interview

Data and information have been collected from the interviews and analysed in qualitative and quantitative ways, which is not merely for the purposes of counting and providing numeric summaries, but also to discover variations and examine complexities (Graisa and Al-Habaibeh, 2011). In this respect a semi-structured interview approach was used which allowed the dialogue to be exploratory and unrestrictive. In addition, in order to obtain a more in-depth insight into the subject under study, and used new questions which emerged during the interviews. Both closed questions and open questions were utilised in the interviews, closed questions being chosen as suitable for questions with structured answers for simplified coding and analysis.

6.3. Part one: Information from the interviews institutions

This part includes analysis and findings arising from secondary documentary data, such as organisational and institutional documents which were collected during the interviews. This analysis includes important points that were raised during the dialogue, referring to and supporting these secondary documents.

6.3.1. Libyan renewable energy targets

The efforts to introduce a complete or partial alternative to the traditional sources (oil and natural gas) of electrical power have been continuing since 1976, at which time the use of photovoltaic (PV) systems was started, specifically to supply electricity for a cathodic protection station for the oil pipeline connecting the Dahra oil field with Sedra Port. In addition, four experimental stations were installed in the telecommunication field in 1979. In 1983 projects in the field of water pumping were started, where water was pumped for irrigation at El-Agailat by a PV pumping system. The latest project was the construction of the Al-Fattaih wind farm at the end of 2010 with a production of 60 MW, the first stage of renewable energy development with a project cost of about 184 million Libyan dinars.

One of the main drawbacks of renewable energy is the intermittent nature of these resources. However, many significant achievements have been made in the past few years which make it more feasible to use renewable energy in conjunction with traditional energy resources. The role of renewable energy in any country mainly depends on the availability of the resources such as solar radiation, wind, biomass and geothermal. The most suitable way to determine the best utilisation of renewable energy is through assessment of load variation patterns. Accordingly, it is important to find the extent to which local loads and the renewable energy generation schedule match. In this regard, most months in Libya are hot in general, with a mean temperature of more than 35ºC, and this is associated with a high rate of electricity consumption in Libya. Most of the monthly load consists of water pumps, electric fans and air conditioning. According to the data obtained from the Planning and Studies Department of the Renewable Energy Authority in Libya in February 2011, there is a plan for the share of renewable energy against traditional energy to reach 30% by the year 2030, mainly through wind energy, concentrating solar power (CSP), solar photovoltaic (PV) and solar water heating (SWH), as shown in Figure 6-2.

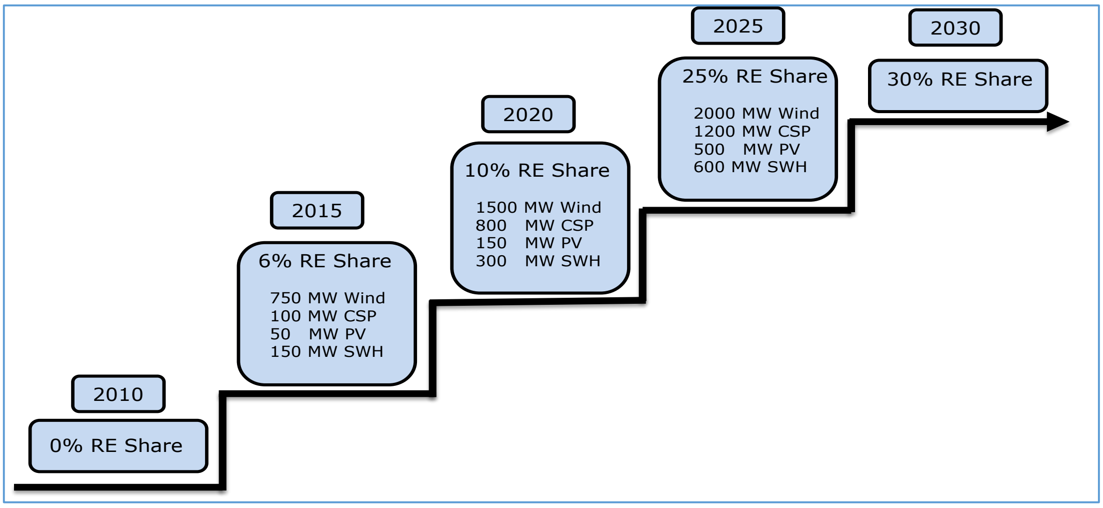


Figure 6-2: Renewable energy sharing plan, data extracted from the Planning and Studies Department of REAOL.

6.3.2. Libyan wind energy

With regards to wind energy, Libya has a long coast of some 1,900 km. The potential of the wind is reasonable in several regions, with an average speed of about 5 m/s in most cases: a speed which can be harnessed economically. However, there are a number of factors that dominate the amount of electricity which can be produced from wind including wind speed, height and turbine model as stated by Ahwide (2013) in the earlier discussion (see chapter 4 Section 4.3.4.2). Moreover, turbines at a site where the wind speed averages 8 m/s produce about 75-100% electricity more than those where the average wind speed is 6 m/s as mentioned by AENews (2016) in chapter 4 and Section 4.3.4.2. In relation to wind energy resources, the data extracted from the Wind Atlas of Libya (version 1.0 March 2008) indicates, as shown in Table 6-1, the estimated average wind speed in different Libyan cities.

Table 6-1: The estimated average wind speed in different Libyan cities.

Location	Average of the wind speed m/s
Chat	5.0 – 5.5 m/s
Sabah	6.0 – 6.5 m/s
Tarakin	6.5 – 7.0 m/s
Tubruq	7.0 – 7.5 m/s
Al maqrun	7.0 – 7.5 m/s
Tukra	7.0 – 7.5 m/s
Jbalzaltan	7.5 – 8.0 m/s
Al-Fattaih- Darnah	8.0 – 8.5 m/s

Wind energy could play an important role in the future by contributing partially to energy needs and to the total electric energy demand. During the visit to the Renewable Energy Central Authority of Libya as part of the fieldwork in March 2011, new wind energy data were acquired for a period of three months for four out of the sixteen meteorological stations which have been in operation since 2010. These are shown in Table 6-2.

Table 6-2: Average wind speed in four cities.

Location	Average of the wind speed m/s
Sebha	**6.634**
Tarakn	**6.105**
Al Rqabh	**5.909**
Chat	**4.171**

	A	B	C	D	E	F	G	H
1	date & time	Uv	TT	RH	GR	GRT	WD	WS
2	UNIT	W/m²	°C	%	W/m²	W/m²	°N	m/s
3	04/01/2011 00:00	0	12.9	99.2	0	0	270	2.7
4	04/01/2011 00:10	0	13.2	99.2	0	0	280	2.2
5	04/01/2011 00:20	0	13.2	99.2	0	0	279	2
6	04/01/2011 00:30	0	13.1	99.2	0	0	285	2.1
7	04/01/2011 00:40	0	13.1	99.2	0	0	275	1.7
8	04/01/2011 00:50	0	13.2	99.2	0	0	274	1.9
9	04/01/2011 01:00	0	13.2	99.2	0	0	278	1.8
10	04/01/2011 01:10	0	13.2	99.2	0	0	286	2.4
11	04/01/2011 01:20	0	13.3	99.2	0	0	287	2.4
12	04/01/2011 01:30	0	13.4	99.1	0	0	293	2.8
13	04/01/2011 01:40	0	13.4	98.9	0	0	290	3
14	04/01/2011 01:50	0	13.6	98.8	0	0	288	2.9
15	04/01/2011 02:00	0	13.6	98.7	0	0	289	2.8
16	04/01/2011 02:10	0	13.6	98.6	0	0	290	2.4
17	04/01/2011 02:20	0	13.7	98.6	0	0	293	3.2
18	04/01/2011 02:30	0	13.6	98.6	0	0	296	3.3
19	04/01/2011 02:40	0	13.6	98.5	0	0	293	3.7
20	04/01/2011 02:50	0	13.7	98.3	0	0	286	2.8
21	04/01/2011 03:00	0	13.7	98.3	0	0	279	2.6
22	04/01/2011 03:10	0	13.7	98.3	0	0	279	2.5
23	04/01/2011 03:20	0	13.8	98.3	0	0	284	3.3
24	04/01/2011 03:30	0	13.5	98.3	0	0	278	3.6
25	04/01/2011 03:40	0	13.2	98.3	0	0	272	3.2
26	04/01/2011 03:50	0	13.3	98.3	0	0	275	2.7
27	04/01/2011 04:00	0	13.3	98.4	0	0	278	3.6
28	04/01/2011 04:10	0	12.5	98.8	0	0	265	3.3
29	04/01/2011 04:20	0	12.4	98.7	0	0	264	2.7
30	04/01/2011 04:30	0	12.8	98.7	0	0	271	2.1
31	04/01/2011 04:40	0	12.9	98.7	0	0	283	3.9
32	04/01/2011 04:50	0	13.1	98.7	0	0	285	3.6
33	04/01/2011 05:00	0	13.3	98.7	0	0	293	3.6
34	04/01/2011 05:10	0	13.5	98.7	0	0	295	4.9
35	04/01/2011 05:20	0	13.5	98.8	0	0	294	4.5

Jan 2011 | Feb 2011 | Mar 2011 | **Apr 2011** | May 2011 | Jun 2011 | Jul 2011

Figure 6-3: The readings from the wind station in Chat.

Table 6-2 shown the average wind speed in four cities during the period between 30th November 2010 and 20th January 2011 recorded by stations distributed in these four regions, which take readings every 10 minutes (see Figure 6-3). The researcher calculated and recast the data to be easily comprehensible and comparable. Thus, the summary of monthly wind speed averages for each area has been calculated. The tables' data have been collected during the fieldwork, this information was extracted from several wind stations in various regions by the Libyan Centre for Solar Energy Research and Studies (CSERS).

Furthermore the researcher collected another dataset which is produced by stations distributed in areas across Libya, where readings were taken every 3 hours between 1985 to 1995 (see Figure 6-4 and Table 6-3). A senior member of CSERS stated in interview that:

'These unpublished data are used in locating economically viable wind projects that may be implemented in the future.' (EPM$_{B3}$)

Q	P	O	N	M
WIND DIRECTION(degrees)&SPEED(knots)				benina station
DATA	TIME	DIRECTION	SPEED(Kts)	SPEED(m/s)
01/01/1994	00:00	0	0	0.0
01/01/1994	03:00	0	0	0.0
01/01/1994	06:00	0	0	0.0
01/01/1994	09:00	0	0	0.0
01/01/1994	12:00	280	6	3.1
01/01/1994	15:00	270	10	5.1
01/01/1994	18:00	280	13	6.7
01/01/1994	21:00	260	10	5.1
02/01/1994	00:00	250	10	5.1
02/01/1994	03:00	220	10	5.1
02/01/1994	06:00	240	10	5.1
02/01/1994	09:00	280	15	7.7
02/01/1994	12:00	270	15	7.7
02/01/1994	15:00	270	25	12.9
02/01/1994	18:00	250	18	9.3
02/01/1994	21:00	320	10	5.1
03/01/1994	00:00	330	15	7.7
03/01/1994	03:00	300	9	4.6
03/01/1994	06:00	330	10	5.1
03/01/1994	09:00	320	10	5.1
03/01/1994	12:00	280	15	7.7

... SPT | AGT | JUL | JUN | MAY | APR | MAR | FEB | JAN

Figure 6-4: Wind data.

Table 6-3: Monthly average of wind speed (m/s) from 1985 to 1995.

Cities	Monthly average of wind speed (M/S) for some regions.												SUM	AVG
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		
Benina	4.3	4.8	5.7	6.2	5.9	6.0	5.8	5.3	5.1	5.0	4.8	4.4	63	5.3
Ejdabia	2.2	2.8	3.9	3.6	3.6	3.4	3.5	3.0	2.7	2.3	2.0	2.0	35	2.9
Sorman	3.4	2.8	3.0	3.4	3.3	3.2	3.0	2.7	2.8	2.7	2.6	2.8	36	3.0
Zuara	4.5	4.5	5.2	5.4	5.3	5.0	4.4	4.5	4.8	4.4	4.0	4.2	56	4.7
Sirt	5.1	5.3	5.5	5.6	5.3	4.9	4.3	4.3	4.7	4.7	4.6	4.9	59	4.9
Mesrata	5.2	5.3	6.1	5.7	5.4	5.0	4.2	4.1	4.6	4.5	4.8	5.3	60	5.0

The researcher collected another set of data which was produced by station readings in the capital city of Tripoli during 2011, as seen in Table 6-4.

Table 6-4: Monthly average of wind speed (m/s) in 2011.

Cities	Monthly average of wind speed (M/S) for some regions												SUM	AVG
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC		
Tripoli	2.9	3.9	3.1	3.4	3.5	3.2	3.4	2.8	3	2.9	2.9	3.2	38.2	3.2

Table 6-3 and Table 6-4 show that the average wind speed ranges between 2.9 and 5.3 metres per second from data taken every 3 hours in a number of Libyan areas. One of the main advantages of the wind in Libya is that there is a correlation between the wind speed pattern and the pattern of the demand for electrical power in most places (El-Osta, 1995; Faraj, 2009). Furthermore, Libya is exposed to dry and hot winds which blow several times during the year (Mohammed and Milad, 2010). In addition, the countries neighbouring Libya have started to utilise the wind as an energy resource with installations ranging from demonstration projects to commercial-size wind farms (Yosaf, 1998), which is a clear indication of its feasibility in the region.

Renewable energy is not a well-investigated subject in Libya due to the availability of oil, as Libya is one of the world's leading oil exporters. Despite the fact that renewable energy, such as wind power as discussed above, is widely available in Libya, it is still difficult to break the dependency on oil and natural gas, not only for energy supply but also for revenues to finance the development of the society and the infrastructure.

6.3.3. Libyan Solar Energy

It could be argued that solar energy is the most important renewable energy resource. Based on data acquired from the Centre for Solar Energy Research and Studies, the average annual solar radiation in some areas in Libya is summarised in Figure 6-5. Solar energy could be considered to be one of the main resources available to Libya due to its location. The daily average solar radiation on a horizontal plane is about 7.1 kWh/m^2/day on the coastal region in the north and 8.1 kWh/m^2/day in the South region, and the average annual duration of sunlight is more than 3,500 hours.

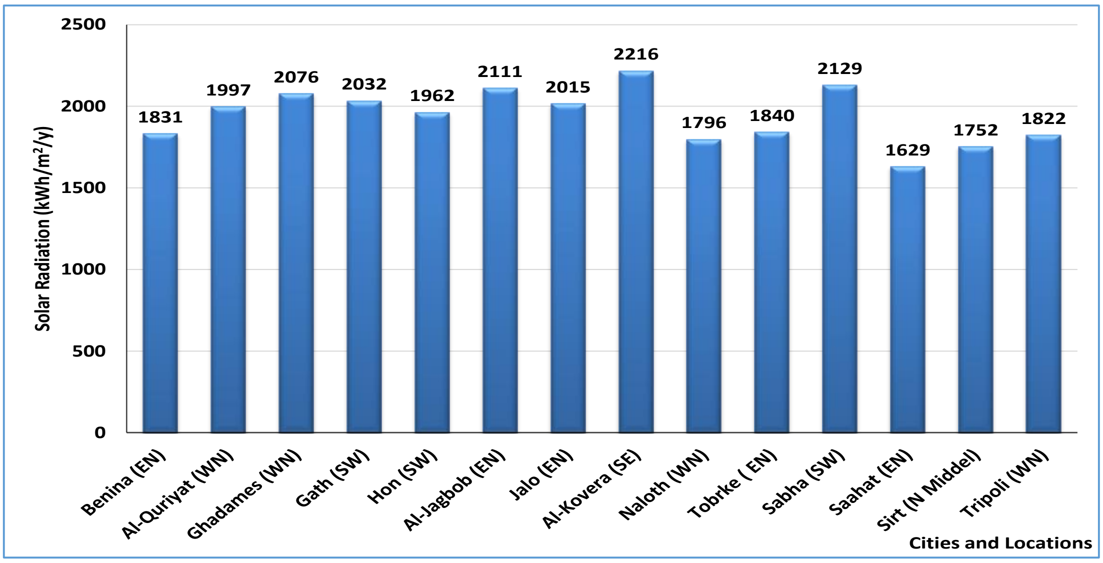


Figure 6-5: Average annual solar radiation in some areas in Libya.

In terms of power technology, the most significant measure is the energy cost per kWh provided. With solar energy, this cost essentially depends on two factors: the capital cost per watt of capacity and the PV power-conversion efficiency as pointed out by REN21 (2013) in Section 4.3.1.2. Table 6-5 shows the sample of these technologies:

Table 6-5: Power Generation (Characteristics and Costs)

Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE- U.S. cents/kWh)
Solar PV: Rooftop	Peak capacity: 3-5 kW (residential); 100 kW (commercial); 500 kW (industrial) Capacity factor:10-25% (fixed tilt)	2,275 (Germany; average residential) 4,300-5,00 (USA) 3,700-4,300 (Japan) 1,500-2,600 (Industrial)	20-46 (OECD) 28-55 (non- OECD) 16-38 (Europe)
Solar PV: Ground-mounted Utility-scale	Peak capacity: 2.5-250 MW Capacity factor:10-25% (fixed tilt) Conversion efficiency: 10-30% (high end is CPV)	1,300 – 1,950 (Typical global) Averages: 2,270 (USA); 2,760 (Japan); 2,200 (China); 1,700 (India)	12-38 (OECD) 9-40 (non- OECD) 14-34 (Europe)
Concentrating solar thermal power (CSP)	Types: parabolic trough, Fresnel, tower, dish Plant size: 50-250 MW (Fresnel) Capacity factor:20-40% (no storage); 35-75% (with storage)	Trough, no storage: 4,000-7,300 (OECD); 3,100-4,050 (non-OECD) Trough, 6 hours storage: 7,100-9,800 Tower, 6-15 hour storage: 6,300-10,500	Trough and Fresnel: 19-38 (no storage); 17-37 (6h. storage) Tower: 20-29 (6-7h. storage); 12-15 (12-15h. storage)
Solar thermal: Domestic hot water systems	Collector type: flat-plate, evacuated tube (thermosiphon and pumped system) Plant size: 2.1-4.2 kW_{th} (single family); 35 kW_{th} (multi-family) Efficiency: 100%	Single- family: 1,100-2,140 (OECD, new build); 1,300-2,200 (OECD, retrofit) 150-635 (China) Multi-family: 950-1,850 (OECD, new build); 1,140-2,050 (OECD, retrofit)	1.5-28 (China)
Solar thermal: Domestic heat and hot water systems (combi)	Collector type: same as water only Plant size: 7-10 kW_{th} (single family); 70-130 kW_{th} (multi-family) 70-3,500 kW_{th} (district heating); >3,500 kW_{th} (district heat with seasonal storage) Efficiency: 100%	Single- family: same as water only Multi-family: same as water only district heat (Europe): 460-780; with storage: 470-1,060	5-50 (Domestic hot water) district heat: 4 and up (Denmark)
Solar thermal: Industrial process heat	Collector type: flat-plate, evacuated tube, parabolic trough, liner Fresnel Plant size: 100 kW_{th}-20 MW_{th} Temperature range: 50-400 ºC	470-1,000 (without storage)	4-16
Solar thermal: Cooling	Capacity: 10.5-500 kW_{th} (absorption chillers); 8-370 kW_{th} (absorption chillers) Efficiency: 50-70%	1,600-5,850	n/a

For more information see Appendix E and Appendix F.

Furthermore, the researcher collected data during the fieldwork which is extracted from daily and monthly averages of radiation and duration of sunshine readings from the stations of different regions by the Libyan Centre for Solar Energy Research and Studies (CSERS). The summary of monthly averages has been calculated as shown in Table 6-6:

Table 6-6: Monthly average of total radiation ($kWh/m^2/m$) during 1982-1988.

Cities	Monthly average of Total Radiation ($kWh/m^2/m$) some Libyan regions												SUM	AVG
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC		
Tripoli	2.95	3.87	5	5.97	6.45	7.09	7.05	6.47	5.48	4	3.15	1.83	59	4.94
Gath	4	4.8	4.7	6.3	6.3	6.6	6.8	6.3	5.8	5.1	4.1	3.5	64	5.36
Jalo	3.66	4.54	5.37	6.56	6.74	7.16	7.17	6.74	5.74	4.83	3.86	3.44	66	5.48
Sabha	4.18	4.88	5.81	6.68	6.65	7.35	7.26	6.96	6.51	5.56	4.75	3.97	71	5.88
Shahat	2.3	2.72	3.93	5.45	6.05	6.73	6.72	6.14	4.67	3.59	2.69	1.97	53	4.41
Hon	3.54	4.22	5.1	6.19	6.61	7.06	7.09	6.69	5.91	4.72	3.8	3.19	64	5.34
Al-Kovra	4.43	5.38	6.04	6.86	7.24	7.43	7.25	7.19	6.45	5.67	4.7	3.99	73	6.05
Al-Quryat	3.55	4.63	5.65	6.61	6.75	7.12	7.39	7.02	5.45	4.32	3.47	3.2	65	5.43
Al-Jagbob	3.8	4.7	5.59	6.71	7.1	7.67	7.66	7.1	6.22	5.13	4	3.51	69	5.77

The renewable energy authority of Libya has stated that the average number of hours of solar brightness is about 3,200 hours per year and the average solar radiation is 6 kWh/m^2 per day. This equates to $10^6 \times 1.5 / 365 \approx 4{,}110$ barrels of oil per square metre per day. Therefore, if we use only 0.1% of Libya's area, that is $(0.001 \times 1.7 \times 10^6)\ m^2$, this would lead to an equivalent of $(1.7 \times 10^6\ m^2 \times 0.001) \times 4110 = 6.986$ million barrels of oil per day of energy. This number is six times more than the current Libyan production of oil. An interviewed senior member from the energy policy maker interview group has stated that:

'Libya has important wind and solar energy source potential. Feasibility studies have shown that the Mediterranean coastline is a good location for onshore and offshore wind parks. A wind atlas based on satellite and meteorological station data has been completed.' (EPM_{A3})

Another interviewee said:

'Renewable energy is the hope of the world in providing clean and safe energy, to be able to bridge the gaps which will result from the depletion of oil and natural gas.' (EG_{G3})

Therefore, wind and solar energy could provide a good complement to meet peak loads, and this in turn can be a good reason for the encouragement of investment in wind and solar energy projects in Libya.

6.3.4. Current projects in renewable energy

The distribution network of electricity in Libya is expensive due to its vast area (Salah, 2006). Distributed generation is a new important trend in energy systems, which should be considered as an alternative to traditional energy production. This concept is significant in the prevention of power failure, which can be avoided if an area does not depend on a single energy resource. Utilisation of renewable energy resources makes distributed systems more feasible due to the fact that energy can be produced closer to the demand points, decreasing the need for long transmission lines and reducing power loss across those lines. The use of renewable energy resources, in its simplest form of direct use for heating water solar ovens, geothermal heat pumps and mechanical wind turbines, or in its more complicated form of indirect use in creating other energy sources to produce electricity by means of photovoltaic cells and generation through wind turbines, could save the public budget significant funds, and provide a good service to people, particularly those in remote areas.

An interviewed manager from the energy policy makers interview group stated that,

'there are a number of installed PV systems in Libyan companies and applications,' *(EPM_{B3})* and provided these tables:

Table 6-7: Total installed PV systems in communication systems.

Company	Station	kW p
GPTC	80	850
Almadar	172	1500
Libyan	57	330
Oil Comp	30	120
Total	393	2800

Table 6-8: Total installed PV systems in Libya.

Application	kW p
Communication	950
Mobile	1850
Cathodic Protection	800
Rural Electrification	725
Water Pumping	120
Grid Connected	30
Total	4475

The Al-Fattaih wind farm project was started at the end of 2010 with the aim of producing 60 MW as the first stage of renewable energy development. The total project cost was about 184 million Libyan dinars. The objectives of this project are as follows: power generation and the diversification of power sources, localization of wind energy technology in Libya, acquisition of scientific expertise and knowledge transfer to Libya, breaking the dependence on oil, and a contribution to the preservation of the environment. In this context, an interviewed senior from REAOL has stated about this project that:

'Site selection was based on field studies which confirmed that the wind speed was up to 8.5 m/s and the location is close to the public network for electricity. The project consists of 37 turbines with a capacity of 1.65 MW/turbine, the total capacity of the project is about 60 MW and the expected annual energy output is about 235,000 MWh or 235,000,000 kWh (This energy is enough to supply about 25,000 homes).' (EPM$_{A2}$)

In the same line of support, another interviewee said:

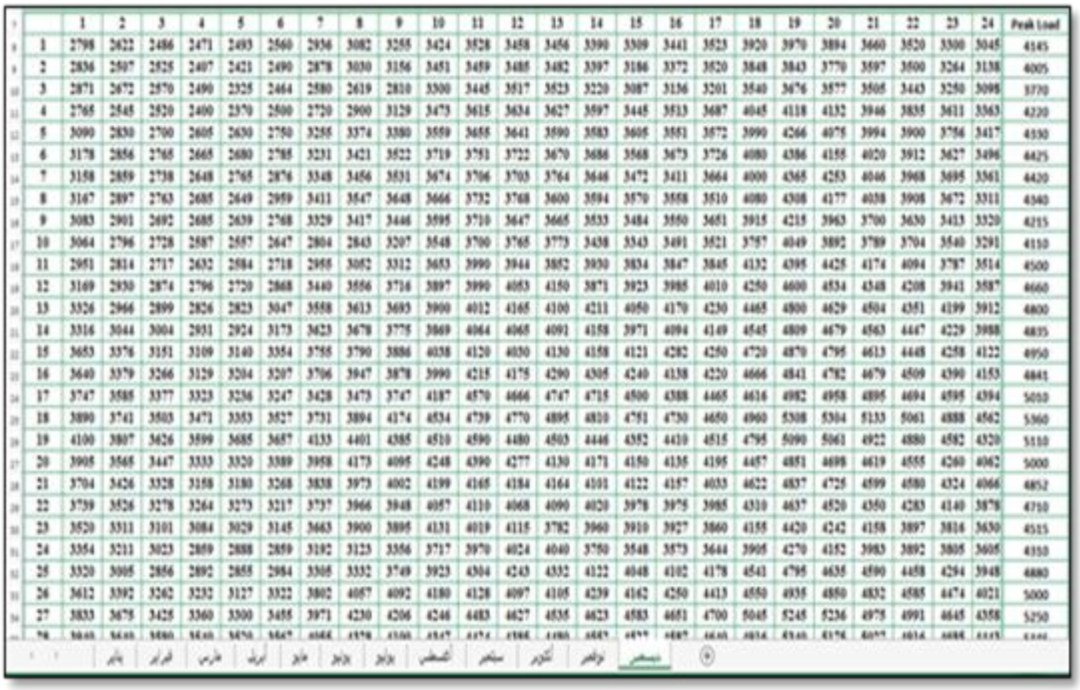
'In addition, according to the feasibility study, this project will achieve the following: saving in fossil fuels equivalent to 475,000 barrels of crude oil yearly, this is equivalent to about 25 million Libyan dinars, reducing carbon dioxide emissions by about 120,000 tons annually, and generating about 2 million Libyan dinars from the sale of carbon certificates.' (EPM$_{A3}$)

The investment costs per kW for an operational life of about 25 years for this project can be calculated as 184,000,000 LD / 235,000,000 kWh / 25 years = 0.031 LD per kWh. It is important to compare the cost per kWh with the current electricity projects which use oil and natural gas.

6.3.5. Current electric energy projects

During the first part of the interview at GECOL, the researcher was provided with some information and documents about the company in order to support the discussion:

'Currently Libya has an electric production capacity of about 6,766 gigawatts (GW), with peak load of around 5,981 GW in 2012, which is included in GECOL's statement.' (see *Figure 6-6*) *'In fact, due to the condition of the plants (age and conditions) they are not able to produce their capacity. Therefore, the Libyan government has to build new plants in order to face this gap and solve this problem.' (EG$_{E2}$)*



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Peak Load
1	2798	2622	2486	2471	2493	2560	2936	3082	3255	3424	3528	3458	3456	3390	3309	3441	3523	3920	3970	3894	3660	3520	3300	3045	4145
2	2836	2597	2525	2407	2421	2490	2878	3030	3156	3451	3459	3485	3482	3397	3186	3372	3520	3848	3843	3770	3597	3500	3264	3138	4005
3	2871	2672	2570	2490	2325	2464	2580	2619	2810	3300	3445	3517	3523	3220	3087	3136	3201	3540	3676	3577	3505	3443	3250	3098	3770
4	2765	2545	2520	2400	2370	2500	2720	2900	3129	3473	3615	3634	3627	3597	3445	3513	3687	4045	4118	4132	3946	3835	3611	3363	4220
5	3090	2830	2700	2605	2630	2750	3255	3374	3380	3559	3655	3641	3590	3583	3605	3551	3672	3990	4266	4075	3994	3900	3756	3417	4330
6	3178	2856	2765	2665	2680	2785	3231	3421	3522	3719	3751	3722	3670	3686	3568	3673	3726	4080	4386	4155	4020	3912	3627	3496	4425
7	3158	2859	2738	2648	2765	2876	3348	3456	3531	3674	3706	3703	3764	3646	3472	3411	3664	4000	4365	4253	4046	3968	3695	3361	4420
8	3167	2897	2763	2685	2649	2959	3411	3547	3648	3666	3732	3768	3600	3594	3570	3558	3510	4080	4308	4177	4038	3908	3672	3311	4340
9	3083	2901	2692	2685	2639	2768	3329	3417	3446	3595	3710	3647	3665	3533	3484	3550	3651	3915	4215	3963	3700	3630	3413	3320	4215
10	3064	2796	2728	2587	2557	2647	2804	2843	3207	3548	3700	3765	3773	3438	3343	3491	3521	3757	4049	3892	3789	3704	3540	3291	4150
11	2951	2814	2717	2632	2584	2718	2955	3052	3312	3653	3990	3944	3852	3930	3834	3847	3845	4132	4395	4425	4174	4094	3787	3514	4500
12	3169	2930	2874	2796	2720	2868	3440	3556	3716	3897	3990	4053	4150	3871	3923	3985	4010	4250	4600	4534	4348	4208	3941	3587	4660
13	3326	2966	2899	2826	2823	3047	3558	3613	3693	3900	4012	4165	4100	4211	4050	4170	4230	4465	4900	4629	4504	4351	4199	3912	4800
14	3316	3044	3004	2931	2924	3173	3623	3678	3775	3869	4064	4065	4091	4158	3971	4094	4149	4545	4809	4679	4563	4447	4229	3988	4835
15	3653	3376	3151	3109	3140	3354	3755	3790	3886	4038	4120	4030	4130	4158	4121	4282	4250	4720	4870	4795	4613	4448	4258	4122	4950
16	3640	3379	3266	3129	3204	3207	3706	3947	3878	3990	4215	4175	4290	4305	4240	4138	4220	4666	4841	4782	4679	4509	4390	4153	4841
17	3747	3585	3377	3323	3236	3247	3428	3473	3747	4187	4570	4666	4747	4715	4500	4388	4465	4616	4982	4958	4895	4694	4595	4394	5050
18	3890	3741	3503	3471	3353	3527	3731	3894	4174	4534	4739	4770	4895	4810	4751	4730	4650	4960	5308	5304	5133	5061	4888	4562	5360
19	4100	3807	3626	3599	3685	3657	4133	4401	4385	4510	4590	4480	4503	4446	4352	4410	4515	4795	5090	5061	4922	4880	4582	4320	5110
20	3905	3565	3447	3333	3320	3389	3958	4173	4095	4248	4390	4277	4130	4171	4150	4135	4195	4457	4851	4698	4619	4555	4260	4062	5000
21	3704	3426	3328	3158	3180	3268	3838	3973	4002	4199	4165	4184	4164	4101	4122	4157	4033	4622	4837	4725	4599	4580	4324	4066	4852
22	3739	3526	3278	3264	3273	3217	3737	3966	3948	4057	4110	4068	4090	4020	3978	3975	3985	4310	4637	4520	4350	4283	4140	3878	4710
23	3520	3311	3101	3084	3029	3145	3663	3900	3895	4131	4019	4115	3782	3960	3910	3927	3860	4155	4420	4242	4158	3897	3816	3630	4515
24	3354	3211	3023	2859	2888	2859	3192	3123	3356	3717	3970	4024	4040	3750	3548	3573	3644	3905	4270	4152	3983	3892	3805	3605	4350
25	3320	3005	2856	2892	2855	2984	3305	3332	3749	3923	4304	4243	4332	4122	4048	4102	4178	4541	4795	4635	4590	4458	4294	3948	4880
26	3612	3392	3262	3232	3127	3322	3802	4057	4092	4180	4128	4097	4105	4239	4162	4250	4413	4550	4935	4850	4832	4585	4474	4021	5000
27	3833	3675	3425	3360	3300	3455	3971	4230	4206	4246	4483	4627	4535	4623	4583	4651	4700	5045	5245	5236	4975	4991	4645	4358	5250

Figure 6-6: Libya's network peak load, 2012.

Another interviewee said:

'Most of Libya's existing power stations are oil-fired; some of these have been converted to natural gas.' (EG$_{E4}$)

The interviewee provided additional information as shown in Table 6-9, including plant types, full names, start years and life assumptions, fuel types and actual capacities.

Table 6-9: Libyan power generation units.

Plant type	Full name	Start year	Retirement assumption	Fuel type	Plants numbers	Actual capacity (MW)
Steam-based turbines	Khoms	1982	2012	LFO/NG	4	480
	Tripoli West	1980	2011	HFO	6	500
	Derna	1985	2015	HFO	2	130
	Tobrik			HFO	2	130
Gas-based turbines	Abo- Kmash	1982		LFO	3	45
	Khoms	1995	2025	LFO/NG	4	600
	Tripoli South	1994	2024	LFO	5	500
	Zwitena	1994	2024	LFO/NG	4	200
	Al-Kofera	1982		LFO	2	50
	West mountain	2005	2035	LFO/NG	4	624
Combined cycle units	Zawiya Gas	1999-2005	2037	LFO	6	990
	Zawiya steam	2007		Non-fuel	3	450
	Benghazi North Gas	1995-2002		LFO/NG	4	615
	Benghazi North Steam	2007		Non-fuel	2	300
Others		1990		HFO/NG		582
Total						6766

LFO: Light fuel oil. HFO: Heavy fuel oil. NG: Natural gas.

Table 6-9 demonstrates that many plants are long past their retirement assumptions, therefore they need significant maintenance, as is clear from an interviewed manager from the energy generation sector who provides the table below and stated that:

‘a sample of the cost of establishing some stations in Libya and their production capacities and types of fuel. In fact, these stations use large quantities of fuel and require periodic maintenance and ongoing operating expenses.’ (EGE2)

Table 6-10: Plants by type, capacity and total cost.

Plant name	Type	Capacity	Total cost (LD)
Benghazi North	Combined cycle power	750	475,838,213
Misrata	Combined cycle power	750	547,052,119
Zoitina	Combined cycle power	250	532,835,894
Elsarir	Gas	855	643,214,051
Obary	Gas	640	652,835,101
Golf	Steam	1400	1,852,148,543
Tripoli South	Steam	1400	1,663,686,041

The total electricity generation by GECOL in 2012 from fourteen main power stations, was approximately 33,980 GWh and consumed 6,003,262,899 m^3 of NG, 2,388,932 m^3 of LFO and 805,472 m^3 of HFO. As Libya's power demands are growing rapidly, these amounts are expected to grow by 250% by 2020. The quantity of fuel consumed to produce 1 MW h in 2012 is shown in Table 6-11.

During the summers of 2011-2014, Libya was hit by widespread blackouts as power plants could not keep up with demand. To prevent such outages in the future and to meet surging power consumption, Libya's state-owned GECOL has plans to spend $3.5 billion building eight new combined cycle and steam cycle power units. There are currently difficulties with complying with the government's policy, as confirmed by an interviewed manager from the energy policy maker and energy generation sectors, who stated that:

'Indeed, GECOL has serious financing issues due in part to low electricity prices (around 0.02 LD/kWh) and also to the fact that only 40% of Libyans pay their power bills.' (EPM$_{A2}$)(EPM$_{B3}$)(EG$_{E2}$)

Chapter seven's questionnaire analysis and the discussion about subsidized electricity prices in chapter three further confirm these issues.

Table 6-11: The quantity of fuel consumed to produce 1 MWh in 2012.

Plant type	Power production MW			Consumed fuel m^3			Fuel consumption rate m^3/MW		
	LFO	HFO	NG	LFO	HFO	NG	LFO	HFO	NG
Steam-based turbines	410481	95002	2915254	805472	30617	129464800	1.962	0.322	44.409
Gas-based turbines	3740093	0	15504390	1277788	0	4499392011	0.342	0	290.201
Combined cycle units	3266174	0	4981905	1079190	0	1374406088	0.330	0	275.880
Others	4145			1337			0.323	0	0
Total							2.957	0.322	610.49

The quantity of the fuel which is used in steam-based turbine plants to produce one MW is equal to 1.962 m^3 when using LFO (1,960 L), 0.323 m^3 when using HFO (323 L), and 44.409 m^3 when using NG (44,409 L). The power stations of various kinds consume a large quantity of fuel for electricity production, including great quantities of oil burned internally rather than sold or retained. An interviewed senior manager from the energy generation sector (EG_{E5}) provided the fuel consumption statistics for 2012 in the North Benghazi plants, as shown in Table 6-12.

Table 6-12: North Benghazi plants' fuel consumption rate in 2012.

Rate	Power production MW h		Consumed fuel m^3	
	LFO	NG	LFO	NG
Year	1533563	1057740	543812	291789392
Day	4201.542	2897.37	1489.896	799422.992
Hour	175.064	120.724	62.079	33309.291

Table 6-12 demonstrates that during 2012 the North Benghazi station consumed 62.079 m^3 (62,079 L) of LFO per hour for the production of 175.064 MWh, and 33,309.291 m^3 of NG per hour for the production of 120.724 MWh. The quantity of the fuel consumed in the production process is too large, especially when compared to plants using sunlight or wind farms. There are great opportunities to create wind farms in many areas in Libya. Neighbouring countries are undertaking activities in the renewable energy sector, such as Egypt where a 150 MW station to generate electricity from solar energy has been built in south Cairo at a cost of $125 million. Solar energy is currently used in solar water heating for household or industrial use as well as electricity generation via photovoltaic cells, as mentioned in the CSP market section in chapter four.

6.3.6. Evaluated existing plants

An interviewee from GECOL (EG_{E2}) introduced some documents as support for his discussion, such as the final project report of the KWS/VGB team on "Increasing the Performance of the Power Generation and Desalination Plants" by evaluating power generation, requirements of maintenance and cost estimation. This is aimed at increasing net electrical output and availability, increasing operational efficiency and reducing costs at eight power plants (Khoms, Tripoli West, Tripoli South, Zawia, Western Mountains Benghazi North, Derna and Tobruk). The results of this project are as follows:

6.3.6.1. Steam turbines (24 Units)

With the maintenance of the HP heaters, leakages, insulation and the reduction of unburned combustibles, condensate and water losses, the following short-term improvements of the steam units are possible.

- 196 MW higher electrical outputs
- 7.2 million LD fuel cost reduction
- 3 million MWh yearly fuel reduction
- 4.2% higher efficiency

The investment for these measures is 44-50 million LD including new auxiliary boilers. These measures must follow the immediate and long-term measures to increase reliability.

6.3.6.2. Gas turbines (23 Units)

With measures like filter cleaning and compressor washing (1,000 h-1,500 h) you get higher efficiency, reach higher electrical production and reduce costs.

- 84 MW higher electrical outputs
- 7 million LD fuel cost reduction
- 1 million MWh yearly fuel reduction
- 1% higher efficiency

6.3.6.3. Total power plants (8 plants)

The investment for all measures is relatively high but necessary to reduce unforeseen shutdowns and to otherwise increase reliability.

- The estimated total cost for all measures is 822 million LD.
- The resultant increase in power output would be 332.2 MW.

This investment makes normal operation possible for the next 10-15 years with high reliability. The estimated costs are likely to deviate from actual market costs.

Another interviewee from GECOL said:

'However, despite the reduced consumed quantity of fuel and increase of the supposed life by 10 to 15 years, these stations continue to consume large quantities of fuel with the concomitant environmental detriments, in other respects, an inability to meet Libyan electricity demand.' (EGE5)

6.4. Part two: The general interviews questions

This part includes the analysis and findings of the rest of the interview questions. In order to achieve a more in-depth understanding of the subject under study, the second part of the interview includes new questions which emerged during the interview period. The result of the interviews have been summarised based on the classifications in Table 6-13.

Table 6-13: Renewable energy is available for commercial utilisation in Libya.

Q 1: Do you think renewable energy is available in Libya for commercial utilisation?			
Sectors	Responses		
	Yes	No	Don't know
Energy policy makers (EPM)	100%	0	0
Energy generation (EG)	71%	0	29%
Energy customers (EC)	56%	0	44%
Total %	78%	0	22%

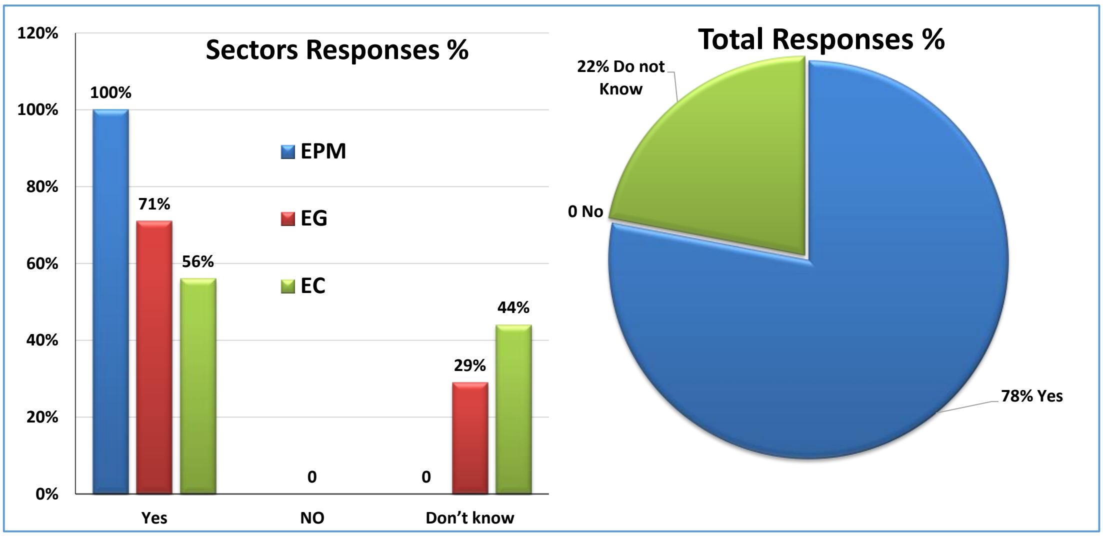


Figure 6-7: Renewable energy is available for commercial utilisation in Libya.

As shown in Table 6-13 and Figure 6-7, 100% of the energy policy makers (EPM) think that renewable energy is available in Libya for commercial utilisation. The majority of the energy generation (EG) group 71% and about 56% of energy customers

(EC) believe that renewable energy is available. None of the interviewees expressed certain knowledge of a lack of commercially available renewable energy, with 22% of the respondents simply being unaware due to a lack of information or knowledge. It is evident that the energy policy makers have more experience and information than the other two groups.

Policy makers (EPM) are well aware of the potential of renewable energy in Libya, following by the energy generation (EG) bias and worried about their interest of keeping same old technologies not interested in others, while energy customers (EC) not all well informed, same with energy generation.

Members of the EG group thought that renewable energy resources will have a huge effect on their functions, and that many users will lose their businesses. The results of question one agree with the previous literature review of this research, such as Franz Trieb (Salah, 2006) and the Atlas of Libya's measurements (Franz, 2011). It is clear from the interviews that there is some resistance from the energy generation group to renewable energy, as stated by one of the interviewees:

'Many functions in the General Electricity Company will be redundant if discovery and utilisation of renewable energy is carried out.' (EG_{E1})

Lack of confidence from the consumer market is also reflected in the comment of one of the interviewees:

'Any new projects will increase taxes, and therefore Libya does not need any other projects at this time. The GMMR resulted in a tax of 20 dirhams per litre on petrol, 25 dirhams on domestic gas cylinders, about half a dinar per litre of engine oil, airline tickets, tariffs on currency exchange, etc.' (EC_{I1})

On a similar line of inquiry to that of question one, participants were asked a question regarding the importance of renewable energy in Libya. Their responses are shown in Table 6-14.

Table 6-14: The importance of renewable energy to the development of Libya.

Q 2: Do you think renewable energy is important to the development of Libya?			
Sectors	Responses		
	Yes	No	Don't Know
Energy policy makers (EPM)	91%	9%	0
Energy generation (EG)	82%	12%	6%
Energy customers (EC)	88%	13%	0
Total %	87%	11%	2%

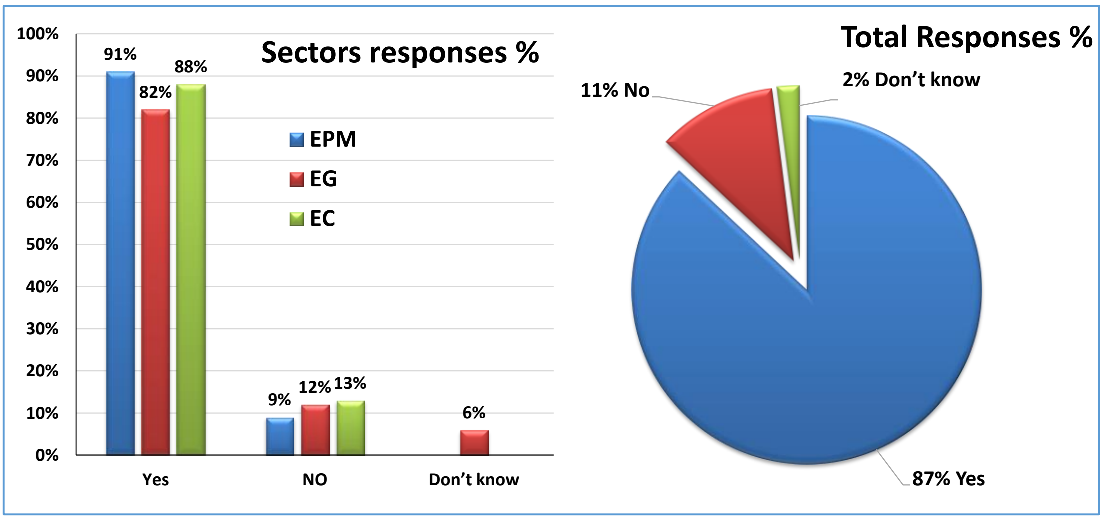


Figure 6-8: The importance of renewable energy to the development of Libya.

As shown in Table 6-14 and Figure 6-8, 87% of respondents believe that renewable energy will play an important role in the Libyan economy and environment in the future, although 9% of the EPM, 12% of the EG and 13% of the EC groups do not believe that, and 6% of EG indicated that they do not know. This result confirms what has been mentioned in the theoretical section, namely the importance of renewable energy to the development of the economy, and this was clear from several interviewees:

'Libyans should admit that it's important to support the economy with renewable resources ... to maintain the standard of living and face the country's growing demands for energy ... not only for energy supply but also for financial revenues, sustaining the public budget and providing good service to the people in scattered villages and countryside areas.' (EPM$_{A1}$)

Another interviewee from the General Planning Council said:

'There are no scientific studies, academic research or feasibility studies by economic decision makers to indicate that there are any obstacles to the utilisation of renewable energy.' (EPM$_{C1}$)

As one of the interviewees from the CSERS said:

'Libya has a huge area and a long coast, and solar and wind energy have the potential to be harnessed economically, but currently there are no suitable businesses or projects available in order to utilise these resources.' (EG$_{F3}$)

Table 6-15: Renewable energy will satisfy energy demand following the expiration of oil.

Q 3: Do you think renewable energy will satisfy energy demand following the expiration of oil?			
Sectors	Responses		
	Yes	No	Don't know
Energy policy makers (EPM)	82%	0	18%
Energy generation (EG)	59%	12%	29%
Energy customers (EC)	56%	6%	38%
Total %	67%	5%	27%

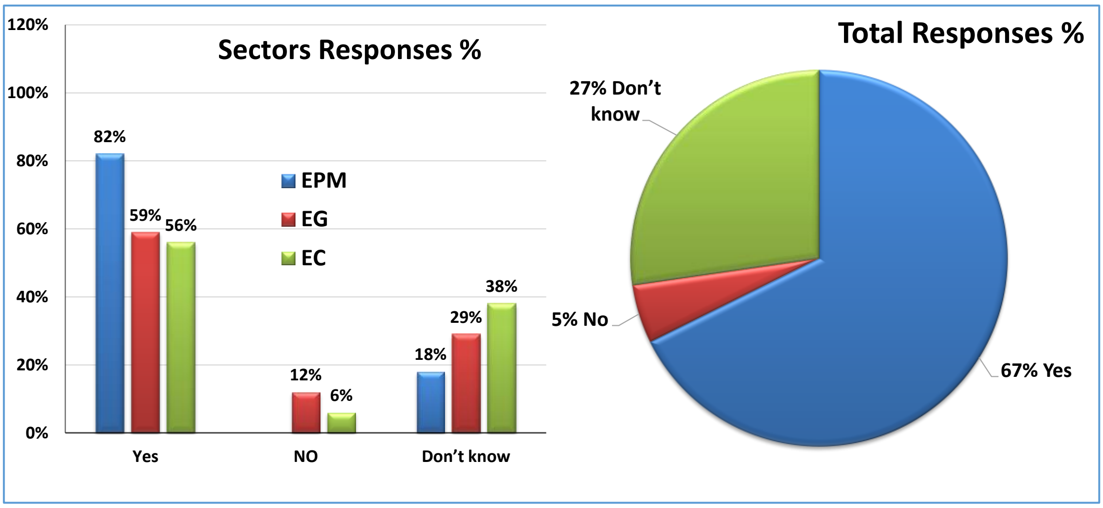


Figure 6-9: Renewable energy will satisfy energy demand following the expiration of oil.

As indicated in Table 6-15 and Figure 6-9, 67% of the interviewees believed that renewable energy will satisfy energy demands after the expiration of oil, 5% think not and 27% lack the necessary knowledge and information with regards to the ability and capacity of renewable energy. It was felt that consumers and producers of energy have limited confidence or knowledge regarding the capability of renewable energy. This was clear from an interviewed manager from the EG sector who stated that:

'We have no data about the costs of renewable energy in the future, it's not an important matter at this time due to the availability of oil... As regards the environmental issue and energy demand after oil ... renewable energy is the best source of energy environmentally and economically, but its utilisation in Libya is still in the early days.' (EG_{E3})

Table 6-16: Type of renewable energy with the highest feasibility.

Q 4: Which type of renewable energy do you think has the most potential and could become the most economically feasible for large-scale use?					
Sectors	Responses				
	Biomass	Geothermal	Wind	Wave and tidal	Solar
Energy policy makers (EPM)	0	0	32%	23%	45%
Energy generation (EG)	0	0	35%	18%	47%
Energy customers (EC)	0	0	38%	13%	50%
Total %	0	0	35%	18%	47%

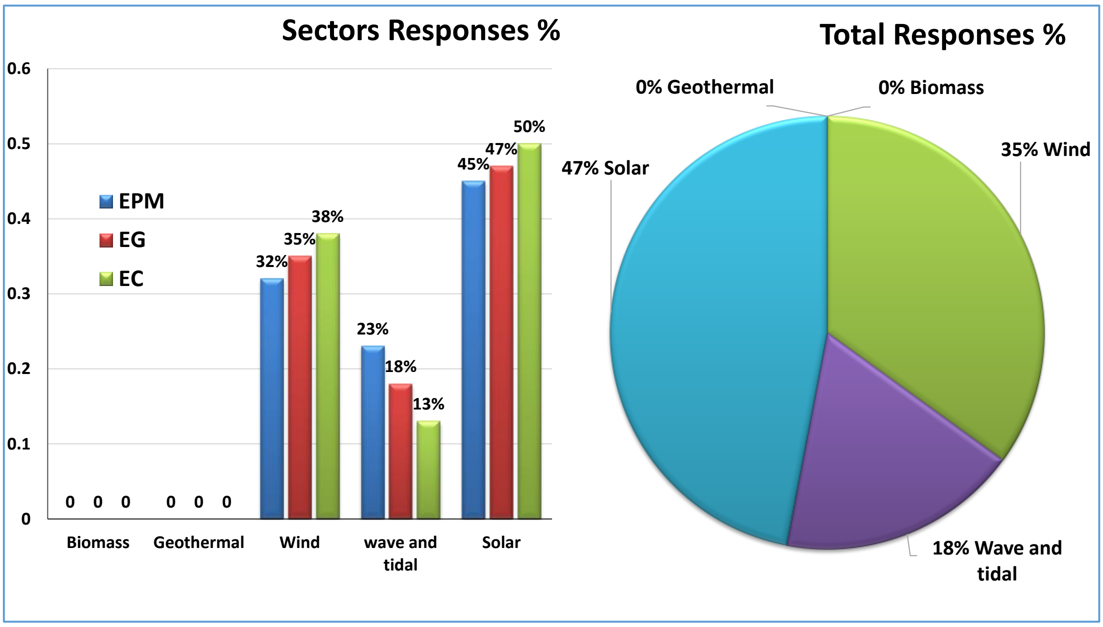


Figure 6-10: Type of renewable energy with the highest feasibility.

Table 6-16 and Figure 6-10 indicate that 47% believe solar is the dominant technology for the future, followed by wind energy (35%) and wave and tidal (18%). This is consistent with the location of Libya and its huge desert with exposure to solar radiation throughout the year.

Biomass and geothermal are still seen as unusual, and this is also consistent with the nature of the Libyan Desert, with its shortage of arable land and animals, and its small population. This was clear from an interview with a manager from the EPM group who stated that:

'I believe that solar energy will be the main source of energy in its small and/or large-scale form in scattered villages which are far away from the grid ... I confirm that it is the best solution.' (EPM$_{D2}$)

Another interviewee said:

'The use of renewable energy in Libya in its different ways and forms is important not just for supplying Libya... but also for helping other countries, such as European and African countries.' (EPM$_{B1}$)

Another respondent said:

'The utilisation of renewable energy in Libya on a large scale could result in a diversification of the sources of energy and the creation of new employment opportunities.' (EG$_{E3}$)

Table 6-17: Energy sector that has the best investment opportunities.

Q 5: What energy sector do you think could have the best investment opportunities?		
Sectors	Responses	
	Oil and Natural Gas	Renewable Energy
Energy policy makers (EPM)	45%	55%
Energy generation (EG)	41%	59%
Energy customers (EC)	75%	25%
Total %	53%	47%

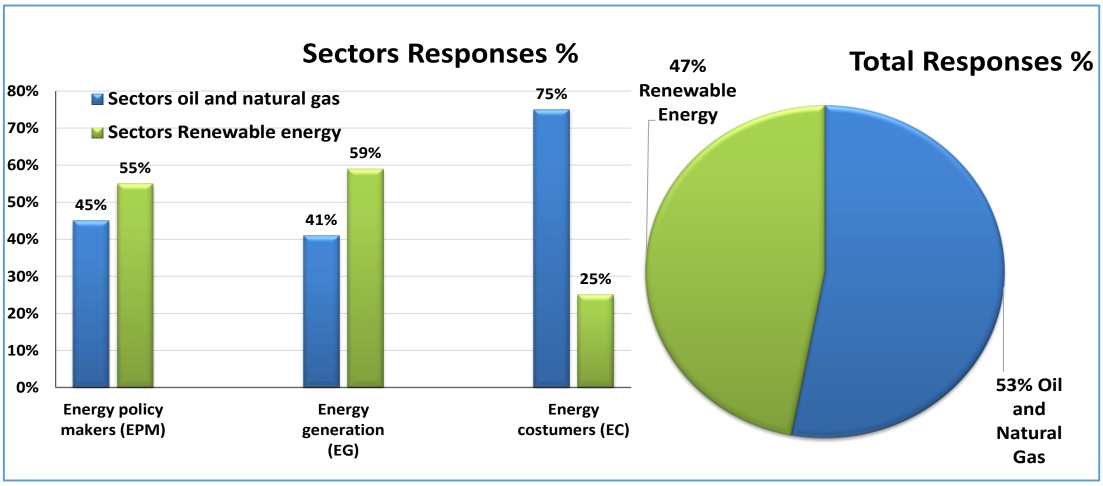


Figure 6-11: Energy sector that has the best investment opportunities.

As presented in Table 6-17 and Figure 6-11, about 47% of interviewees believe that renewable energy will be the best field for investment. On the other hand 53% of interviewees think that investment should be in fossil fuels such as oil and natural gas. The latter group seems to have a lack of knowledge and information about the details of investment; an interviewee from the energy customer group stated that:

'I think it is still too early to compare these resources due to cost, risk and safety ... We use a traditional source with a high level of confidence and reliability, and which is still cheaper than other sources.' (EC_{H1})

Another interviewee said:

'Indeed, it might not need a second thought to invest in oil and natural gas companies ... On the other hand, it would take more time to consider other investments.' (EC_{H3})

As one manager at the CSERS put it:

'We should utilise every source of energy and support the entrance of local and foreign investors into Libya's market ... Additionally, we still need improvements to the infrastructure of the country, such as the road network, and investment laws to attract investors.' (EPM_{B3})

The GECOL has already begun contact with international agencies and investors to use the Clean Development Mechanism (CDM) of the Kyoto Protocol for renewable energy growth. In addition, the Libyan government has already issued a law to encourage foreign investors in all sectors.

Table 6-18: The reasons behind the inability of electricity production to meet demand.

Q 6: What are the reasons behind the insufficient electricity production to meet demand?				
Sectors	Responses			
	Productive capacity of stations	Increasing energy demand	Grid size	Other technical problems
Energy policy makers (EPM)	18%	41%	14%	27%
Energy generation (EG)	18%	47%	18%	18%
Energy customers (EC)	31%	38%	31%	0
Total %	22%	42%	20%	16%

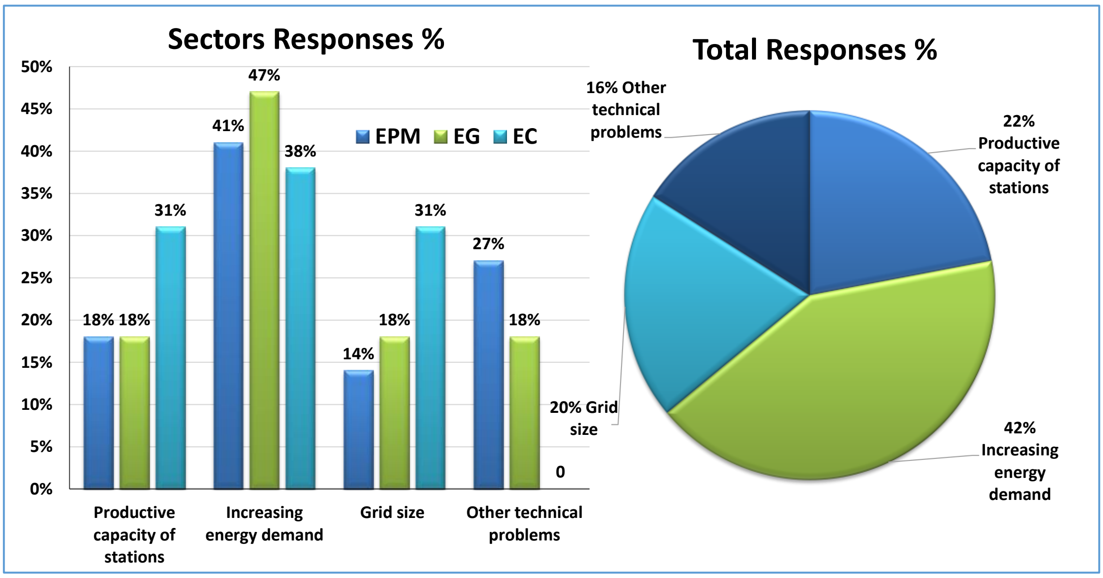


Figure 6-12: The reasons behind the inability of electricity production to meet demand.

Table 6-18 and Figure 6-12, indicate that the interviewees believe that the inability of electricity production to meet demand is caused by an increase in energy demand with limited production capacity from power stations (64%), other maintenance and technical problems (16%) and the effect of the size of the grid (20%). It was evident that demand has been growing quickly beyond the production capacity in place. One of the interviewees from the energy generation sector stated that:

'Currently, Libya's energy network consists of approximately 13,000 miles of 66 kV and 30 kV lines and 8,000 miles of 220 kV lines, and does not cover all of the Libyan scattered villages ... Long distance lines would require periodic maintenance.' (EG$_{E6}$)

Another interviewee stated that:

'I expect that electrical consumption will double in the coming years.' (EPM $_{C2}$)

Another interviewee stated:

'I believe that it's impossible to increase the production capacity of the power stations due to several reasons. For example, most energy plants require urgent maintenance and upgrades.' (EG$_{E3}$)

Another interviewee suggested that:

'Libya's energy sector requires crucial investment. The General Electricity Company has suggested that it may allow private investment in Libya's generation and distribution sectors to be able to meet the demand.' (EG$_{E1}$)

Table 6-19: Adequate effort was put into promoting renewable energy by the Libyan government.

Q7: Do you think that adequate effort was done to promote renewable energy by the Libyan government?			
Sectors	Responses		
	Yes	No	Yes, but more is needed
Energy policy makers (EPM)	23%	14%	64%
Energy generation (EG)	47%	29%	24%
Energy customers (EC)	13%	50%	38%
Total %	27%	29%	44%

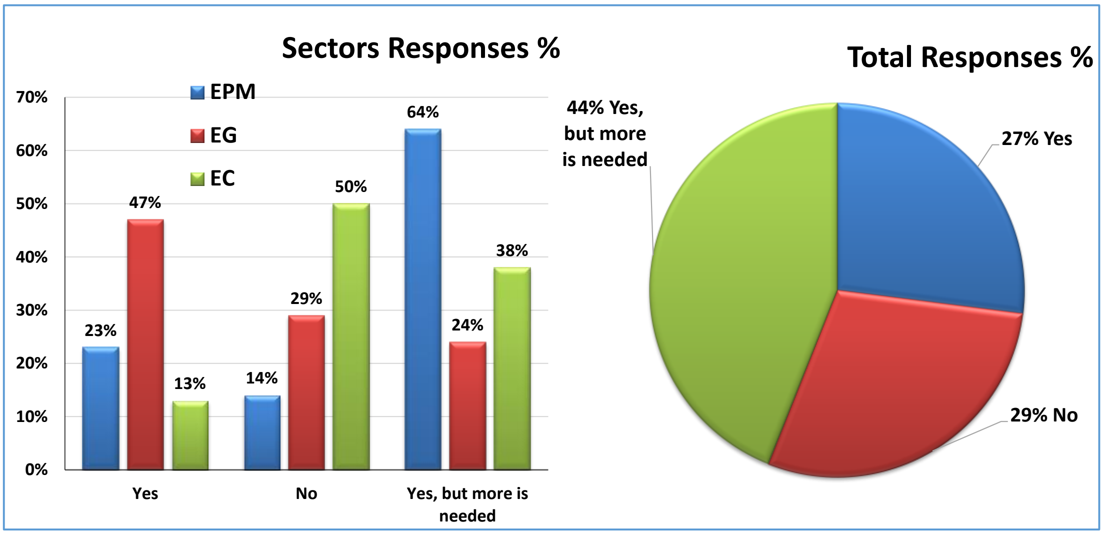


Figure 6-13: Adequate effort was put into promoting renewable energy by the Libyan government.

In response to government efforts in relation to renewable energy, Table 6-19 and Figure 6-13 show that 27% of interviewees believed that the government has made sufficient efforts to promote renewable energy, and a further 44%agreed that the Libyan government has promoted renewable energy, but that more work is still needed. The remaining 29% of them said that the Libyan government has not done enough to promote renewable energy. One of the interviewees who believed that the government has done enough stated that:

'The Libyan government has created the Renewable Energy Authority and Centre for Solar Energy Research and Studies which are supposed to be responsible for renewable energy development and establishment.' (EPM_{C1})

Table 6-20: The expectation that renewable energy will be used in Libya.

Q 8: When do you expect renewable energy will be used in Libya?			
Sectors	Responses		
	Short term (0-10 years)	Medium term (10-50y)	Long term (50y+)
Energy policy makers (EPM)	62%	31%	7%
Energy generation (EG)	23%	36%	41%
Energy customers (EC)	17%	31%	52%
Total %	91%	77%	65%

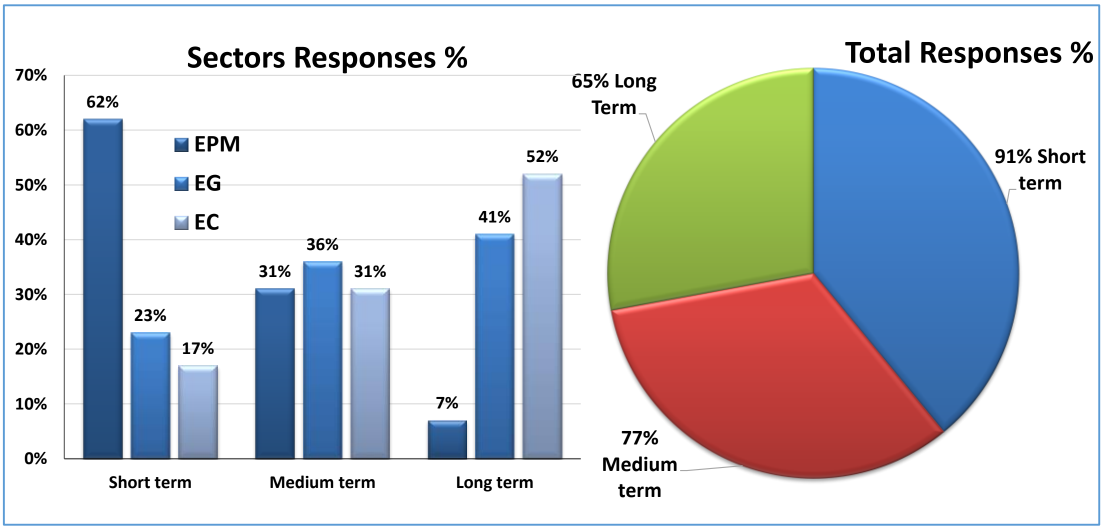


Figure 6-14: The expectation that renewable energy will be used in Libya.

It can be seen from Table 6-20 and Figure 6-14 that the majority of respondents from the EPM group, 62%, thought that in Libya renewable energy will be in use in the short term, 31% of them expected that it will be used in the medium term, and 7% believe that it will be used only in the long term. However, the EG and EC groups are less optimistic with only 23%, and 17%, 36%, and 31%, and 41%, and 52% believing that renewable energy will be used in the short, medium, and long term respectively. This result confirms that there are ambitions in the EPM group in Libya, while there are no practical measures on the ground to implement these ambitions: if there were, the results of the EG and EC groups would reflect it. This situation is clear from several interviewees:

'The REAOL has a plan which was organized in coordination with the Libyan government … There are practical measures which have been taken on the ground, but the conditions experienced by the country have caused a delay in the execution of contracts and projects associated with the implementation of this plan.' (EPM_{A3})

Another interviewee noted that:

'The energy prices in Libya are subsidised heavily, which has made an impact on the consumer choice of energy ... Energy subsidies should be decreased or cut to create a competitive market.' (EPM_{C5})

Another interviewee from the General Company for Water Sanitation believed that the government has not made an appropriate commitment to the use of renewable energy in the near future and stated that:

'There are no efforts being made on the ground, for example there is no process to educate people as to the importance and use of renewable energy in Libya in the near future.' (EC_{I2})

Another interviewee from the General Company for Water Desalination said:

'I expect the use of wind and solar power will happen very soon in Libya because of Libya's geographical location, it is located between many countries which are currently working on the use of renewable energy and this will make Libya pay attention towards this subject, which directly affects the lives of its citizens.' (EC_{H2})

Another interviewee from the Gulf Company has stated that:

'Globalization will push Libya to diversify its sources of energy and revenue.' (EG_{G5})

Table 6-21: The public opinion with respect to renewable energy in Libya.

Q 9: What is the public opinion with respect to renewable energy in Libya?		
Sectors	Responses	
	Acceptance	Rejection
Energy policy makers (EPM)	74%	26%
Energy generation (EG)	43%	57%
Energy customers (EC)	22%	78%
Total %	46%	54%

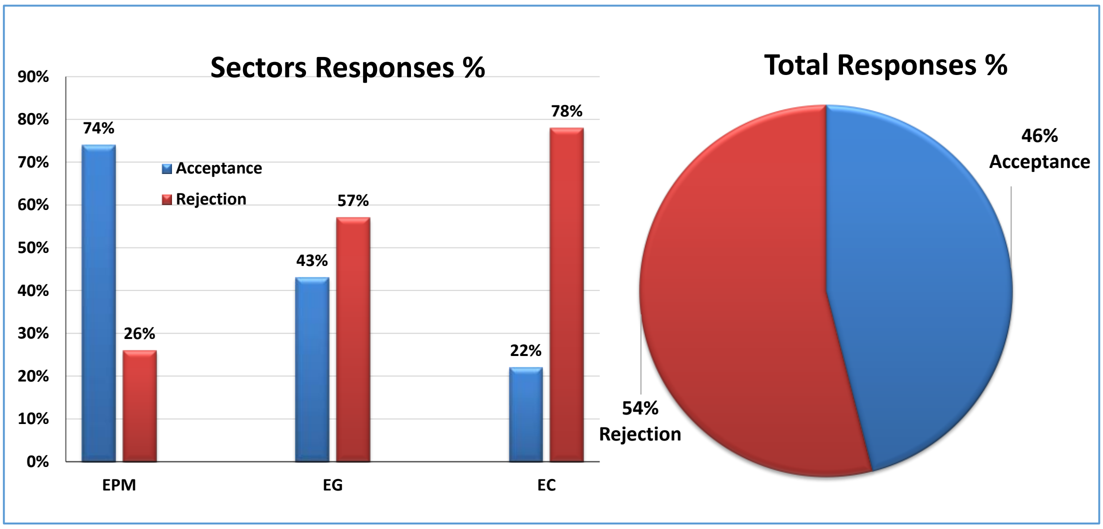


Figure 6-15: Public opinion with respect to renewable energy in Libya.

The researcher conducted interviews with EPM, EG and EC groups to understand their knowledge and awareness about the public opinion. From Table 6-21 and Figure 6-15 it can be noted that 74%, 43% and 22% respectively of the EPM, EG and EC groups believe that there is acceptance in the public for renewable energy resources and technologies. whilst 26%, 57% and 78% of the EPM, EG and EC groups do not believe that. This marks a difference between the groups of the study, and this is clear from some of the interviewee comments:

'The evidence suggests that people's opinions about renewable energy depend to a large extent upon what they understand about the aesthetic, environmental and economic impacts of those renewable energy resources, especially as concerns their local community.' (EPM$_{D2}$)

Another interviewee from the CSERS in Libya said:

'When renewable energy technologies are available and produce competitive energy prices to current energy prices, there would be a change in opinion about current use of energy, regardless of environmental factors.' (EPM$_{B4}$)

Table 6-22: The expectation that the production of energy from renewable sources will provide affordable energy and reduce the energy expenses burden in Libya.

Q 10: Do you expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	65%	31%	4%
Energy generation (EG)	33%	41%	26%
Energy customers (EC)	19%	38%	43%
Total %	39%	37%	24%

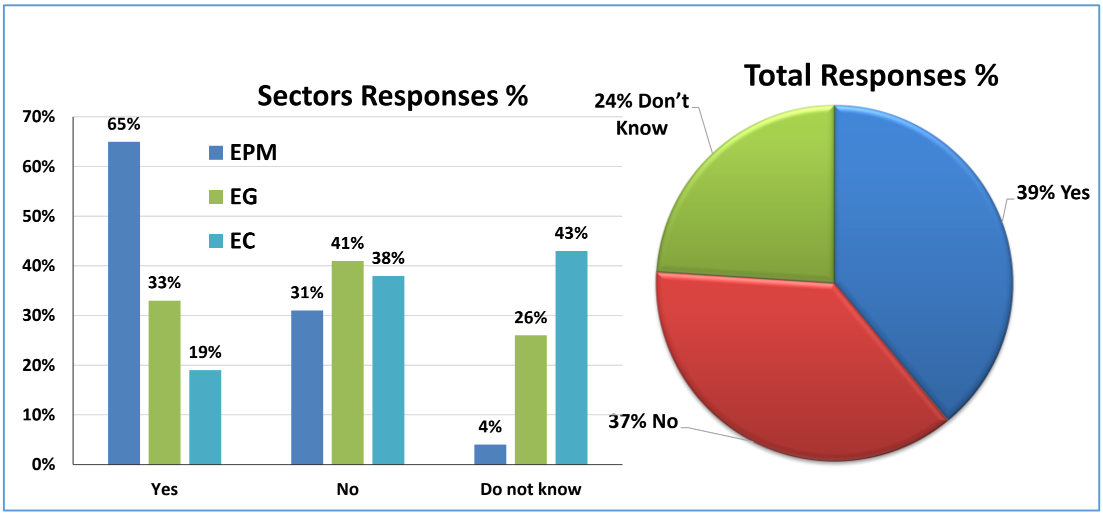


Figure 6-16: The expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden in Libya.

As shown in Table 6-22 and Figure 6-16, an average of 39% of the respondents from across the EPM, EG and EC groups believe that the production of energy from renewable sources will provide affordable energy and reduce the energy expenses burden in Libya. 37% of them, however, do not believe that, while 24% are not sure. The result indicates that there are conflicting expectations and justifications, and this can be seen from several interviewees:

'Prices linked to the cost of production of renewable energy are still relatively high compared to the cost of producing energy from traditional sources, therefore I expect the prices of energy produced by renewable technology to be unable to compete with the price of energy produced by traditional sources of energy.' (EPM$_{A4}$)

Another interviewee said:

'The Libyan government needs to study the energy usage behaviour of consumers, in order to be able to regulate energy consumption and also use their tools to control and guide the consumer to use energy efficiently.' (EPM$_{B1}$)

As referred to by one of the CSERS interviewees:

'We work for the purpose of implementing the use of renewable energy in Libya as soon as possible ... as all the conditions are encouraging the implementation of projects in this regard, but the laws still restrict the work of investors in this area due to the control of the electricity government's. The budget for scientific research on renewable energy is a major obstacle for the work of the relevant authorities.' (EPM$_{B1}$)

Another interviewee from GECOL said:

'GECOL suffers from many problems such as technical and consumed plants, leading to repeat interruptions and the irregular generation of electricity for households. The state should search for other sources of energy.' (EG$_{E5}$)

Another interviewee said:

'There are many villages in Libya which are far away from the network. Extending the grid to cover these areas is considered uneconomic and difficult.' (EG$_{E4}$)

Another interviewee reported:

'long hours of power outages, up to more than twelve hours a day in some areas. In agricultural areas it may continue over consecutive days ... There are different reasons for the interruptions, such as low-voltage transformers, shutdown of the 30 kilovolt station.' (EG$_{E6}$)

Table 6-23: The climate change resulting from environmental pollution should force a reconsideration of the continuing use of conventional energy.

Q 11: Libya is one of the countries affected by climate change as a result of environmental pollution is that can be a calling for reconsideration to continue using conventional energy?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	65%	35%	0%
Energy generation (EG)	52%	36%	12%
Energy customers (EC)	65%	26%	9%
Total %	61%	32%	7%

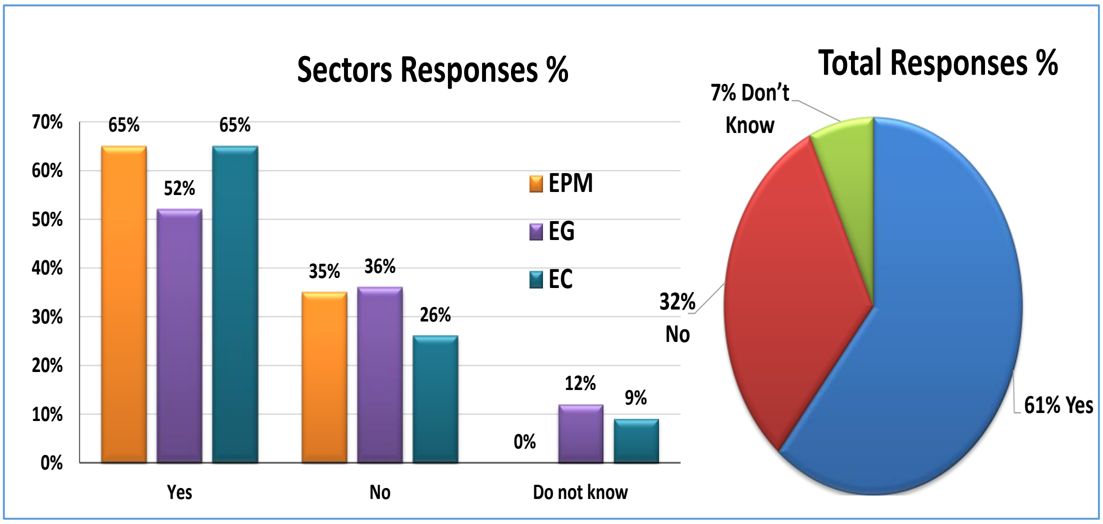


Figure 6-17: The climate change resulting from environmental pollution should force a reconsideration of the continuing use of conventional energy.

As presented in Table 6-23 and Figure 6-17, an average of 61% of the interview groups consider that the government should work to prevent environment pollution and reconsider using conventional energy. This result confirms what has been mentioned in the theoretical part in section 2.4. On the other hand, 32% of the interviewees do not think that, attributing it to the lack of alternative sources of energy. The remaining 7% of them say that they do not know, and that they do not have enough information about the reason behind environment pollution. On this topic, the interviewees have said:

'In addition to local fuel consumption, the fossil fuel refineries have caused several types of environmental pollution … The areas which are adjacent to the refineries are difficult to exploit or optimally use due to polluted air, the smell of gas, manufacturing materials and burnt fuel. There is chronic disease in residential areas surrounding the refineries.' (EG$_{G4}$)

An interviewee from the EPM group said that:

'In order to limit greenhouse gases (carbon dioxide emissions), the government should put a levy on industrial companies … That could realise significant results… I think major conservation procedures should begin immediately.' (EPM$_{B3}$)

Another interviewee from the policy maker group said:

'There are several studies about the relationship between environmental pollution and economic growth … In my opinion the lack of technological progress and/or changes

in the composition of output and economic growth will either assist in the improvement of the quality of the environmental or will lead to greater levels of pollution ... as well as do more damage to the region, the country and the global environment.' (EPM$_{C5}$)

With respect to argument in chapter two section 2.4 about the Libyan government signing and ratifying the Kyoto Protocol, another interviewee from the EPM group said:

'Although Libya signed and ratified the Kyoto Protocol in 2006, unfortunately neither the government nor industrial companies have gained any benefits from the protocol yet.' (EPM$_{A1}$)

Table 6-24: The belief that the costs of energy production by renewable energy sources are more expensive than the current sources.

Q 12/ Do you expect that the cost of energy production by renewable energy sources are more expensive than the current source?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	43%	46%	11%
Energy generation (EG)	63%	25%	12%
Energy customers (EC)	59%	9%	32%
Total %	55%	27%	18%

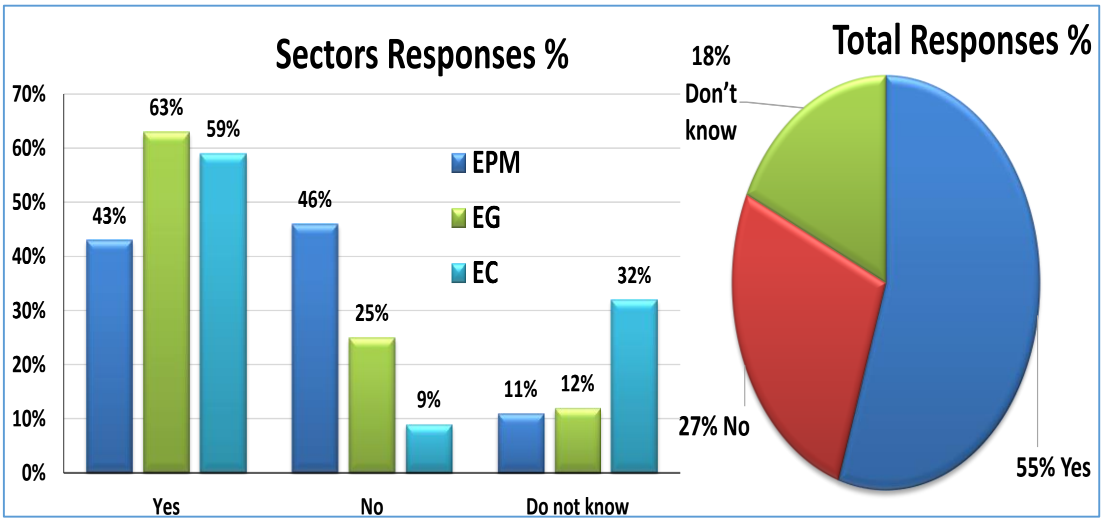


Figure 6-18: The belief that the costs of energy production by renewable energy sources are more expensive than the current sources.

As demonstrated in Table 6-24 and Figure 6-18, 55% of the EPM, EG and EC interviewees believe that the cost of energy production by renewable energy sources is more expensive than the current sources, while 27% do not think that. Most of them said that the cost of operating stations and periodic maintenance expenses have a negative impact on the public state budget. 18% of respondents did not know, as they lacked enough information about the cost of energy production from renewable energy sources. The results are supported by the comments of several interviewees:

'A reorientation to using the sun and wind as the principal sources of energy is the only way to achieve energy self-sufficiency after oil ... Maintaining the oil reserves is an important issue regarding the security of Libya's national energy ... the use of oil and gas as a local fuel is a waste of its economic value when it can be used in many areas such as the petrochemical and plastics industries.' (EG_{F3})

Another interviewee from REAOL believed that the cost of energy production from solar energy sources is more expensive than from wind power, and at the same time that both are more expensive than the current sources:

'I expect that the use of wind power will currently be less expensive than the use of solar power because the technology used in solar power generation is still expensive.' (EPM_{A4})

Another interviewee from the utilities sector stated that:

'As a consumer of energy in the first place I'd buy cheaper energy where I do not know about the energy technology which will produce the lowest energy price' (EC_{J3})

Table 6-25: The expectation/knowledge that the Libyan government has planned to reduce carbon emissions from the use of traditional fuel in electricity and water production stations.

Q 13: Do you expect/know that Libyan government has planned to reduce carbon emission from using traditional fuel in electricity and water production stations?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	62%	31%	7%
Energy generation (EG)	23%	58%	19%
Energy customers (EC)	13%	57%	30%
Total %	33%	48%	19%

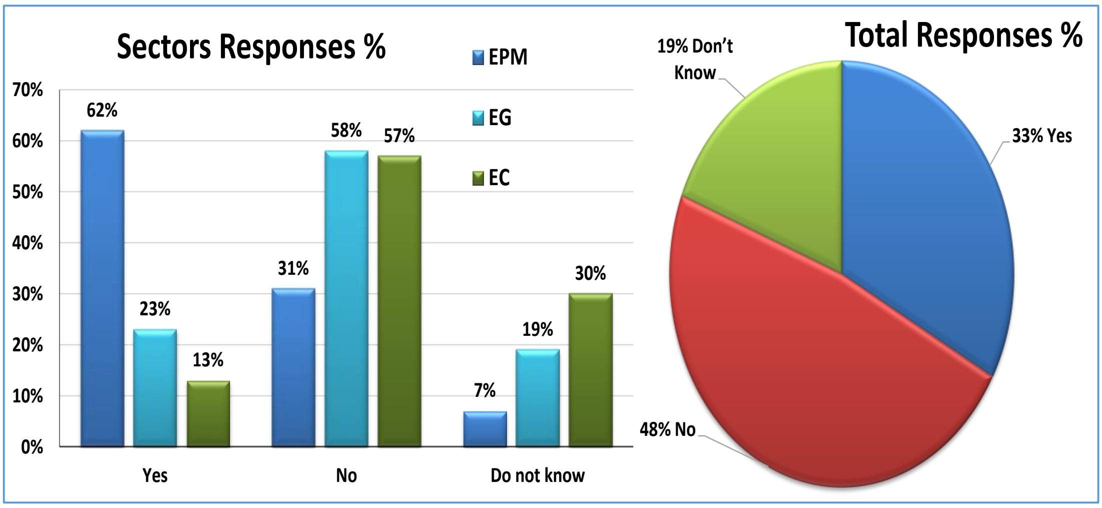


Figure 6-19: The expectation/knowledge that the Libyan government has planned to reduce carbon emissions from the use of traditional fuel in electricity and water production stations.

As revealed in Table 6-25 and Figure 6-19, 33% of the interviewees from the EPM, EG and EC groups suppose that the Libyan government has planned to reduce carbon emissions from the use of traditional fuel in electricity and water production stations. This result confirms what was mentioned in the first part of this chapter. On the other hand, 48% of the respondents do not think that, while the last 19% of them said they have no idea. The comments from several interviewees illustrate these results:

'The state has transferred many of the electricity and water stations to integrate gas in order to produce electricity and at the same time reduce carbon emissions.' (EG_{E5})

Another interviewee from the CSERS stated that:

'Electricity generated from fossil fuel is still more feasible both physically and commercially than electricity generated by renewable energy technologies ... It provides greater energy security, although it generates higher carbon emissions than renewables-based electricity.' (EPM_{B3})

Another interviewee from the CSERS stated that:

'The government should be supporting the production of electricity from renewable energy resources, since this measure may contribute in the longer term to both electricity security and the reduction of carbon emissions.' (EPM_{A4})

Table 6-26: The Libyan government has a clear policy for renewable energy.

Q 14: Do you think that, the Libyan government has clear policy for renewable energy?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	12%	79%	9%
Energy generation (EG)	7%	68%	25%
Energy customers (EC)	2%	64%	34%
Total %	7%	70%	23%

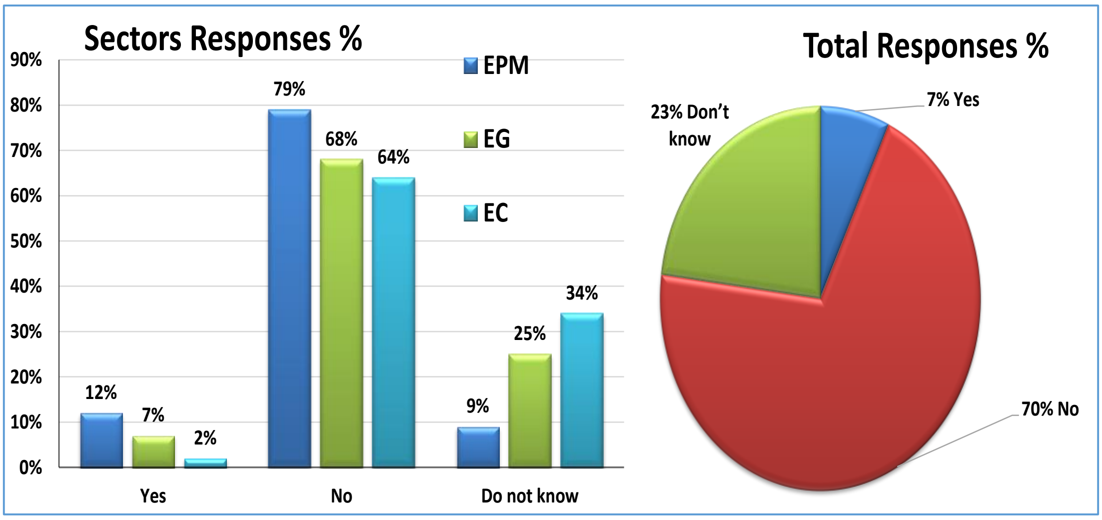


Figure 6-20: The Libyan government has a clear policy for renewable energy.

As demonstrated in Table 6-26 and Figure 6-20, only 7% of the interviewees believed that the Libyan government has a clear policy for renewable energy, with 70% saying there is no clear policy, and 23% not being sure. These results are reflected in the comments of a couple of the interviewees:

'Although the plan of using renewable energy for the production of electricity is a collaboration between GECOL, the renewable energy authority and the Libyan government ... there are no clear policies that support the implementation of projects within Libya, such as providing adequate safeguards for investors to allow private companies both domestic and foreign to participate in the implementation of this plan.' (EPM$_{A2}$)

An interviewee from the CSERS stated that:

'New governments after the political change of 2011 did not take any concrete steps to start renewable projects in order to utilise renewable energy resources in Libya ...

However, there has been an expansion in the establishment of academic conferences, scientific symposia and international posts.' (EPM$_{D4}$)

Table 6-27: The requirement of technical, commercial and environmental study phases for the implementation of renewable energy projects in Libya.

Q 15: Do you think that, there are any technical, commercial and environment studies phases required for the implementation of renewable energy projects in Libya?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	7%	82%	11%
Energy generation (EG)	14%	50%	36%
Energy customers (EC)	16%	51%	33%
Total %	12%	61%	27%

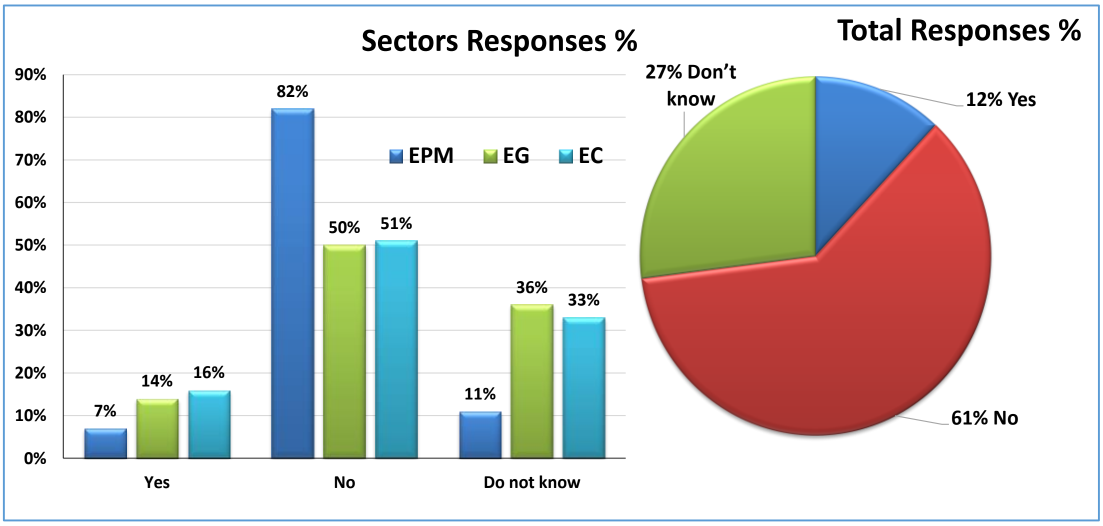


Figure 6-21: The requirement of technical, commercial and environmental study phases for the implementation of renewable energy projects in Libya.

As demonstrated in Table 6-27 and Figure 6-21, 12% of the respondents from the energy policy maker, generation, and consumer groups supposed that technical, commercial and environmental feasibility studies are required by the Libyan government for the implementation of renewable energy projects, with 61% disagreeing and 27% saying that they were not sure. As one interviewee commented:

'The Libyan government does not have a clear policy regarding renewable energy projects.' (EPM$_{D8}$)

Another interviewee believed that there are in fact requirements for technical, commercial and environmental studies before the implementation of a renewable energy project in Libya. In particular, the researcher asked the interviewee to explain which one of the studies they meant; a description of proposed development, consideration of alternatives, noise, shadow flicker, ecology, soils and geology, hydrology and water quality, landscape impact assessment, cultural heritage, forestry, cumulative impact, scope of field surveys and telecommunications systems. The interviewee then stated that:

'I do not mean such studies. I speak only of the economic feasibility study (financial) and the technical assessment of the wind speed active in the sites.' (EPM$_{D7}$)

On a similar line of inquiry, contributors are asked a question regarding the availability of information or scientific studies about the use of any type of renewable energy in Libya, as shown in Table 6-28.

Table 6-28: Access to information or scientific studies about the use of any type of renewable energy Libya.

Q 16: Do you have any information or scientific studies about the use many types of renewable energy in Libya?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	43%	53%	4%
Energy generation (EG)	26%	62%	12%
Energy customers (EC)	21%	43%	36%
Total %	30%	53%	17%

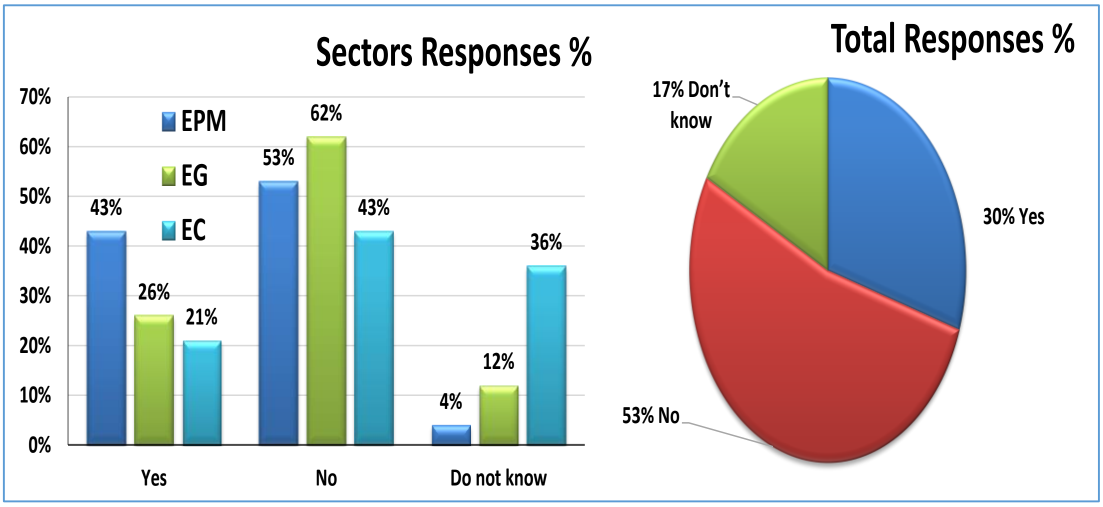


Figure 6-22: Access to information or scientific studies about the use of any type of renewable energy Libya.

As revealed in Table 6-28 and Figure 6-22, 43% of the respondents from the EPM group believed that there is information and scientific studies concerning the use of renewable energy in Libya, 53% believed that there is not enough, and 4% have no idea about it. The majority of the EG group (62%) and about 43% of the EC interviewees agree that information and scientific studies on the use of renewable energy technologies in Libya are not available, with 12% of the interviewees in EG disagreeing with that view, and a significant percentage (36%), simply not knowing. It is evident that the energy policy makers have more experience and access to information than the other two sectors. It is equally clear from the interviewees that there is some resistance to renewable energy in Libya, as stated by one of the interviewees:

'In Libya there are no real scientific studies of the energy and investment aspects.' (EC_{J3})

A lack of information and scientific studies for use of renewable energy for power generation further reflected upon by one of the interviewees:

'We have undertaken studies regarding the use of renewable energy in desalination and sanitation plants, but unfortunately we did not get any encouragement from the state, or other instantiations which have relevant authority.' (EC_{H9})

The director of the Centre for Solar Energy Research and Studies said on this subject that:

'There are no detailed studies of the possibility of using renewable energy, even the readings that can be provided to you by our department for your study ... lack information for some days because of the interruption of the Internet at the metering station or other technical problems ... The government is currently working on a request for the help of international experts in conducting studies on the infrastructure of establishing renewable energy project in Libya.' (EPM_{A1})

With regard to the discussion in the previous section in this chapter about the plan for renewable energy sharing with traditional energy, which mainly includes wind energy, concentrating solar power (CSP), solar photovoltaic (PV) and solar water heating (SWH), participants were asked a question as shown in Table 6-29.

Table 6-29: Renewable Energy plan has led to any significant accomplishments.

Q 17: Do you believe the Renewable Energy plan has led to any significant accomplishments?			
Sectors	Responses		
	Yes	No	Do not know
Energy policy makers (EPM)	9%	56%	35%
Energy generation (EG)	15%	44%	41%
Energy customers (EC)	13%	34%	53%
Total %	12%	45%	43%

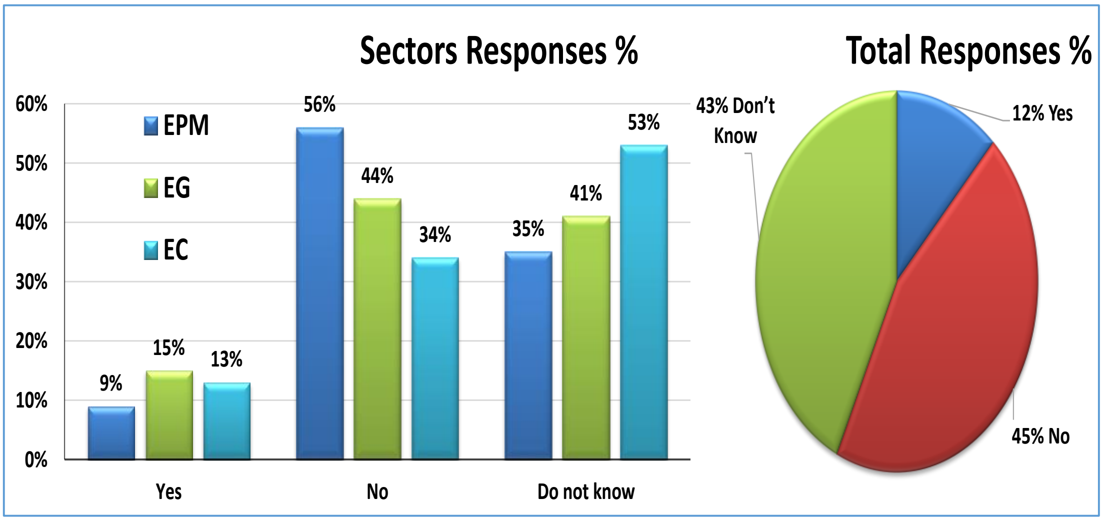


Figure 6-23: Renewable Energy plan has led to any significant accomplishments.

As presented in Table 6-29 and Figure 6-23, 56% of the interviewed energy policy makers believed that they have not achieved any significant accomplishments from the Renewable Energy Authority plan so far. 44% of the EG and about 34% of EC interview groups agree that the plan of sharing renewable energy in Libya is not being successfully implemented. However, 43% on average of participants across the groups have no idea or not enough information about it. With the assumption that the energy policy makers have more experience and information than the other two groups, the result reflects that all groups believe that the plan has not led to any significant accomplishments. In addition, the EPM interviewees thought that the main reason behind the failure in implementing or continuing to implement the plan was the interim Libyan government, which by its very nature would only exist for a short time after the Arab spring. Therefore, the results of question 17 agree with the previous literature review, since all the projects discussed there are old and there has been nothing new in this respect. It is clear from the interviews that there is some disregard from the new interim Libyan government towards the renewable energy plan. For example, one of the interviewees stated:

'Included in the 2013 public budget of the state which was approved by parliament were 12 million LD for the implementation of projects related to renewable energy, but no projects were accomplished in this regard and the results of the implementation of the plan remain zero at present.' (EPM$_{D7}$)

This was also reflected by another of the interviewees:

'Although the existing power stations are unable to cover the basic needs of the citizens, the new Libyan government has not carried out any recent projects ... The political problems are reflected on the normal life of citizens and have disrupted most of the government projects, especially energy projects.' (EPM$_{C5}$)

Finally, the director of the Renewable Energy Authority said that:

'It is important to report that there is no progress in our plan at present ... The Authority needs foreign investment consultants to implement this plan, and for that we need to develop a good infrastructure and improve security.' (EPM$_{A4}$)

6.5. Summary

This chapter demonstrates the outcomes of analysed data from the secondary and primary (interview) sources. The organisation of this chapter is guided by the research question and the objectives of this study. Semi-structured interviews with 55 participants from the three main sectors concerned with renewable energy provided further details and documents to inform the overall picture. From utilising the secondary approach in the first part of this chapter, it is clear that it is important to understand the current situation of energy and the potentiality of other energy resources. Most of these countries, including Libya, are trying to diversify their economy and reduce dependency on oil as a source of income and energy generation. Securing alternative resources of energy and income is becoming critically important for these countries if they wish to maintain the same standard of living for future generations and reduce pollution and carbon emissions.

It is clear, despite the recent political changes in Libya, that renewable energy is still strategically of high importance. Solar and wind energy are considered the main sources of renewable energy, followed by wave and tidal energy. There is a need to attract investors in renewable technologies by enhancing the infrastructure and the existing laws. Renewable energy technology is still within its infancy in Libya. A clear strategy and timetable is still needed to take this sector forward, particularly in relation to developing the skills and knowledge needed for the installation and maintenance of renewable energy systems.

Chapter 7. Analysis of the general energy consumers' questionnaire.

7.1. Introduction

In this chapter the researcher presents the analysis of the energy consumer questionnaires in order to achieve the research objectives and answer the second research question. The primary purpose of conducting the questionnaire survey was to produce data that will answer the research question, 'What are the challenges to and opportunities for the utilisation of renewable energy resources in Libya?'

The process of data analysis requires the choosing of the appropriate analysis to use for each item of the questionnaire (e.g. frequencies, averages, or content analysis). This questionnaire survey is conducted to elicit the opinions of Libyan energy consumers/users, which are in turn used to achieve the research objectives that require the opinion of the public who are expected to invest in and/or use renewable energy.

7.2. Characteristics and Features of the questionnaire Sample

The questionnaire was designed to capture data from Libyan energy consumers in four sectors, namely factories (FTP and FTV), housing (RES), farms (FMC and FMN) and public facilities (PFL) in Libya as shown in the methodology chapter Figure 5-4. It was completed by 832 respondents (55% response rate) across the six regional capitals (see Table 7-1 and Figure 7-1). Participating consumers in this research are members of the general public. The questionnaire provides a general description of the farms, homes, factories and public facilities. It consists of five main parts which were determined by the researcher. The first section is different from one questionnaire to another depending on the nature of the participants and represents different details of each sector, for example area, garden area, ownership, location and other characteristics as detailed in the following tables.

The following sections of the questionnaire are similar, since the second concerns information related to the energy which is used by every participant. The third part of the questionnaire concerns the views of energy users towards energy prices. The fourth part is designed to assess the problems behind power or water outages. The final part looks at the most important information about energy sources and environmental issues.

Table 7-1: Respondents' categories.

Consumers sectors		Valid frequencies
Residential Housing [RES]		206
Farms	Commercial [FMC]	113
	Non-Commercial [FMN]	130
Factory	Public Factory [FTP]	106
	Private Factory [FTV]	136
Public Facilities [PFL]		140
Total		831

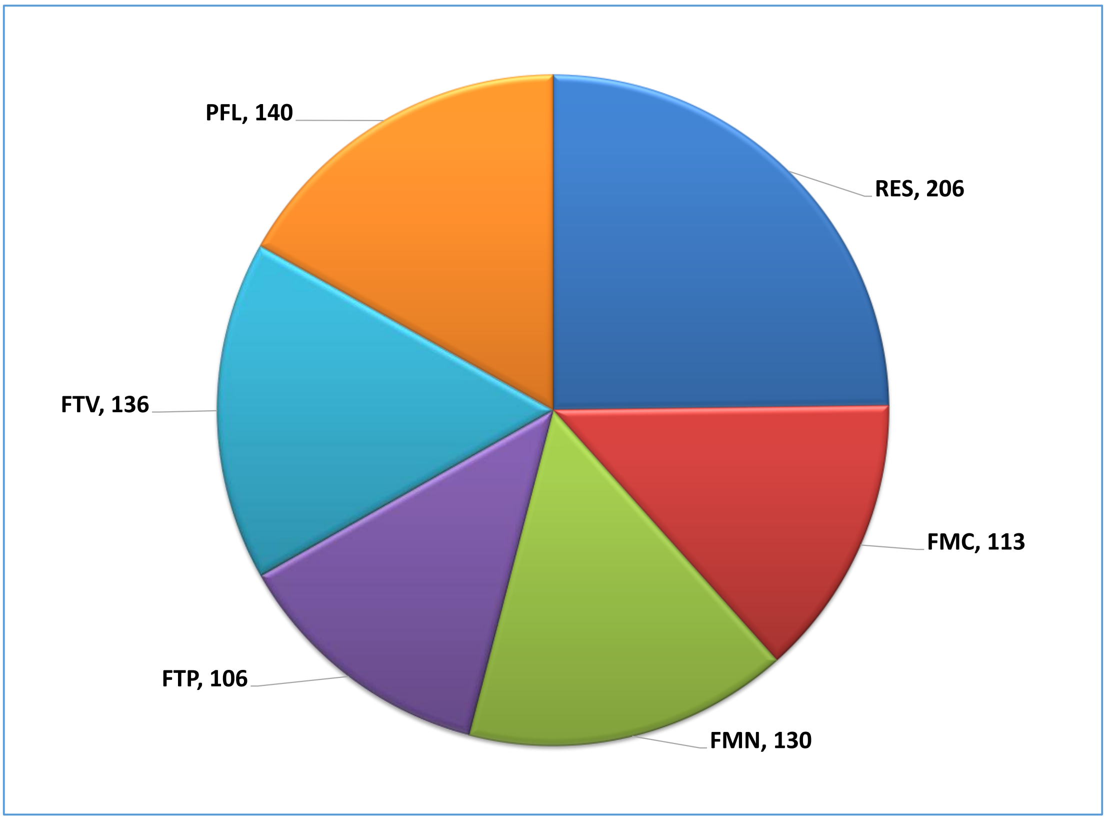


Figure 7-1: Respondents' categories.

Table 7-1 and Figure 7-1 show the participating consumers in the four sectors of this research, based on the number of participants in each segment. The researcher built his questionnaire in order to achieve the research objectives through analysis of the questionnaire findings:

7.3. The fourth objective

This part of the research aims to use the findings which emerged from applying the quantitative and qualitative analysis by SPSS to answer the second research question. In order to achieve the fourth research objective, the researcher has divided this analysis into two sections: The first section includes the definition of the Libyan energy consumption sectors, and the second section gives an assessment of current energy supply, consumption, and demand in Libya.

7.3.1. Energy consumption sector definition

The researcher has designed the first part of the research questionnaire in order to achieve the fourth objective. A summary of the sector responses which demonstrate the detailed characteristics of the four sectors sampled is as follows:

The questionnaire sample has included all types of houses across Libya in different regions according to the statistical distribution of the research sample. In Libya there are different types and areas of housing, Table 7-2 includes the research sample which includes different home types: 16.5% are private houses, 6.8% apartment buildings, 16% private villas, 14.1% government houses, 18.9% flats and 27.7% have more than one type. Additionally, it includes homes of different areas; 10.2% are small (defined as less than 120 m^2), 34.5% are medium (120-150 m^2), 18.9% are large (150-300 m^2) and 3.4% are very large (more than 300 m^2). The results demonstrates that the most common housing adopted by the Libyan government are either middle or large, which together represent 53.4%, and that most of the common housing (61.1%) has no garden, as seen in the table above. 71.8% of the housing is privately owned with the responsibility of paying bills, about 25.3% of public housing is rented to people who are responsible for the payment of bills, and the remaining 2.9% of housing are public ownership, with the residents having no responsibility for paying their bills. The state properties are often used for government employees.

Table 7-2: Detailed characteristics of the RES sector sample.

Items	Response	Freq	%
Home description	Private house	34	16.5
	Apartment building	14	6.8
	Private villa	33	16.0
	Government house	29	14.1
	Flat	39	18.9
	More than one	57	27.7
Home area	Small (Less than 120m^2)	21	10.2
	Middle (120m^2-150m^2)	71	34.5
	Large (150m^2-300m^2)	39	18.9
	Very large (More than 300m^2)	75	36.4
Home garden	No garden	126	61.1
	Annex small garden	23	11.2
	Housing Annex two gardens	41	19.9
	Annex large garden	16	7.8
Garden area	No garden	126	61.2
	Small (Less than 120 m^2)	23	11.1
	Middle (120m^2-150m^2)	17	8.3
	Large (150m^2-300m^2)	7	3.4
	Very large (More than 300m^2)	33	16.0
Home ownership	Private ownership with the responsibility of paying bills	148	71.8
	Public ownership with the responsibility of paying bills	52	25.3
	public ownership with no responsibility for the payment of invoices	6	2.9
Home location	Tripoli	84	40.8
	Benghazi	42	20.4
	Western	35	17.0
	Middle	24	11.7
	Southern	9	4.4
	Green Mountain	12	5.7

Table 7-3 examines the research sample of 243 farms, of which 113 are commercial (FMC), and the remaining 130 are non-commercial (FMN) . The sample includes the most important types of Libyan farms distributed in the different regions, according to the statistical distribution of the research sample. 28.3% and 25.5% FMC and FMN respectively are agricultural, 27.4% and 13.8% are animal-related farms, and 23.9% and 33.8% are poultry farms. There are no fish farms. The research sample includes farms that are involved in more than one type of agricultural activity: 20.4% and 26.9%

of FMC and FMN respectively. This result represents the nature of the farm that is popular in Libya.

The results showed that of agricultural farms, 23.9% and 9.2% of FMC and FMN respectively are rain fed; usually these types of farms cultivate wheat, barley and other types of grass which are used to feed animals and birds. Most of them are far away from the water and electricity networks, and the electricity delivery costs are too expensive. The other 76.1% and 90.8% of FMC and FMN respectively are irrigated farms. The source of water in these cases can be the public water network, local wells, tanks, and rainwater storage, and the farms usually produce fruits and olives.

There are a number of farms which have residential houses for the farmers: about 15% and 6.2% of FMC and FMN respectively, while some have housing for workers: about 5.3% and 10% of FMC and FMN respectively. 17.7% and 19.2% have facilities for milk productions, 2.7% of FMC (and 0% of FMN) include a swimming pool, 23.9% and 23.1% of FMC and FMN respectively have meat-selling shops and 35.4% and 41.5% of FMC and FMN respectively have more than one of these facilities. The questionnaire results show that 52.2% and 60% of FMC and FMN are private and 47.8% and 40% of FMC and FMN are in public ownership and are responsible for the payment of bills.

Table 7-3: Detailed characteristics of the FMC and FMN samples.

Items	Responses	Frequencies		%	
		FMC	FMN	FMC	FMN
Farm description	Agricultural Farm	32	33	28.3	25.5
	Animal Farm	31	18	27.4	13.8
	Birds Farm	27	44	23.9	33.8
	Fish Farm	-	-	-	-
	More than one	23	35	20.4	26.9
Business type	Non-Commercial	130	130	100	100
	Commercial	113	113	100	100
Agricultural type	Rain fed Farm	27	12	23.9	9.2
	Irrigated Farm	86	118	76.1	90.8
Farm area	Small (Less than 10000 m^2)	-	8	-	6.2
	Middle (10000 m^2 - 50000 m^2)	3	18	2.7	13.8
	Large (50000 m^2 – 10000 m^2)	64	58	56.6	44.6
	Very large (More than 100000 m^2)	46	46	40.7	35.4
Farm's facilities	Residential house	17	8	15.0	6.2
	Home of workers	6	13	5.3	10
	Milk productions	20	25	17.7	19.2
	Outdoor swimming pool	3	-	2.7	-
	Meat selling Shops	27	30	23.9	23.1
	More than one	40	54	35.4	41.5
Farm ownership	Private ownership with the responsibility of paying bills	59	78	52.2	60
	Public ownership with the responsibility of paying bills	54	52	47.8	40
	public ownership with no responsibility for the payment of invoices	-	-		-
Farm location	Tripoli	10	35	8.8	26.9
	Benghazi	43	15	38.1	11.5
	Western	22	51	19.5	39.2
	Middle	21	15	18.5	11.7
	Southern	14	12	12.4	9.2
	Green Mountain	3	2	2.7	1.5

Table 7-4 includes the two categories of Libyan factories, private (FTV) and public (FTP). Factories have been divided into three levels, small, medium and large, and the survey included factories in different regions according to the statistical distribution of the research sample. 0% and 10.3% of FTP and FTV respectively are small, 29.2% and 89.7% are of medium size, and 70.8% and 0% are large. The research sample size is 242, and has been distributed among 106 FTP and 136 FTV.

Several types of industries are included in the research sample. 2.8% and 11% of FTP and FTV respectively manufacture leather clothing, 10.4% and 30.9% produce foodstuffs, 12.3% and 40.5% building material, 0% and 11% industrial carpentry, 22.6% and 6.6% furniture fittings, 37.7% and 0% are petroleum industrial, and 14.2% and 0% are other industries.

In terms of factory facilities, the results show that 18.9% and 11% of FTP and FTV respectively have worker buildings, 50.9% and 56.6% have administrative buildings and 30.2 and 32.4% include more than one, such as a worker building, an outdoor swimming pool, shops, farms and/or administrative buildings. Additionally, the results show that 29.2% and 100% of FTP and FTV respectively are privately owned with the responsibility of paying bills, and 70.8% and 0% of FTP and FTV respectively are under public ownership with the same responsibility.

Table 7-4: Detailed characteristics of the FTP and FTV samples.

Items	Responses	Frequencies		%	
		FTP	FTV	FTP	FTV
Factory description	Small project	-	14	-	10.3
	Middle factory	31	122	29.2	89.7
	Large factory	75	-	70.8	-
Business type	Public ownership	106	-	100	-
	Private ownership	-	136	-	100
Production type	Leather clothing	3	15	2.8	11
	Foodstuffs	11	42	10.4	30.9
	Building materials	13	55	12.3	40.5
	Industrial carpentry	-	15	-	11
	furniture fittings	24	9	22.6	6.6
	Petroleum industrial	40	-	37.7	-
	others	15	-	14.2	-
Factory Facilities	Worker building	20	15	18.9	11
	Outdoor swimming pool	-	-	-	-
	Shops	-	-	-	-
	Farm	-	-	-	-
	Administrative buildings	54	77	50.9	56.6
	More than one	32	44	30.2	32.4
Farm ownership	Private ownership with the responsibility of paying bills.	31	136	29.2	100
	Public ownership with the responsibility of paying bills	75	-	70.8	-
Farm location	Tripoli	27	43	25.5	31.6
	Benghazi	17	38	16	27.9
	Western	26	17	24.5	12.5
	Middle	23	24	21.7	17.6
	Southern	6	7	5.7	5.3
	Green Mountain	7	7	6.6	5.1

Table 7-5 breaks down the PFL sample of about 140 contributors, which includes several types of public facilities in different regions and locations, with some of them located in the desert, along the coast, or near roads, borders or residential areas. These facilities include police stations 5.7%, apartment buildings 12.1%, schools 12.1%, hospitals 8.6%, parks 3.6%, checkpoints 6.4%, banks 9.3%, social care homes 5.7%, customs borders airports and harbours, 7.1%, monitoring points 5%, mobile containers 3.6%, clinics 10%, courts 5.7%, and 5.1% serve more than one purpose. The results also show that the areas of 69.3% of the facilities are more than 300 m^2, 25% are between 120 m^2 and 300 m^2 and 5.7% are less than 120 m^2. Only 27.2% of the participants stated that there are no other facilities within the main site, 15% have only an annex garden, 7.1% of them have shops and 50.7% of public facilities have more than one facility, such as an annex garden, a swimming pool, a restaurant or cafe and/or shops. The results have shown that 27.2% of public facilities have no garden, while the rest have gardens of varying sizes: 11.4%, 15%, 25% and 21.4% are respectively small, medium, large and very large.

Table 7-5: Detailed characteristics of the PFL sample.

Items	Responses	Freq	%
Facility description	Police station	8	5.7
	Apartment building	17	12.1
	School	17	12.1
	Hospital	12	8.6
	Park	5	3.6
	Checkpoint	9	6.4
	Bank	13	9.3
	House social care	8	5.7
	Custom border (Airport & Harbour)	10	7.1
	Mentoring point	7	5.0
	Mobile containers	5	3.6
	Clinical	14	10.0
	Court	8	5.7
	More than one	7	5.1
Site's area	Small (Less than 120 m^2)	8	5.7
	Middle (120 m^2 – 150 m^2)	12	8.6
	Large (150 m^2 - 300 m^2)	23	16.4
	Very large (More than 300 m^2)	97	69.3
Site's facilities	No facilities	38	27.2
	Annex garden	21	15.0
	Swimming pool	0	0
	Restaurant / Cafe	0	0
	Shops	10	7.1
	More than one	71	50.7
Garden area	No garden	38	27.2
	Small (Less than 120 m^2)	16	11.4
	Middle (120 m^2 – 150 m^2)	21	15.0
	Large (150 m^2 – 300 m^2)	35	25.0
	Very large (More than 300 m^2)	30	21.4
Site's location	Tripoli	35	25.0
	Benghazi	28	20.0
	Western	34	24.3
	Middle	21	15.0
	Southern	12	8.6
	Green Mountain	10	7.1

7.3.2. Assessment of current energy supply, consumption and demand

This section of the research questionnaire analysis has been written with the purpose of addressing the fourth research objective and answering the second research question. In order to do this, the researcher has analysed this part of the questionnaire data. A per-sector summary of the responses about the assessment of current energy supply, consumption and demand is in the following tables.

Table 7-6: Energy types which are used as energy sources in each sector.

Q2-1: Energy Type.				
Sector	N	Response %		
		Electricity	Fossil fuel	Both
RES	206	13.1	-	86.9
FMC	113	-	-	100
FMN	130	-	9.2	90.8
FTP	106	-	-	100
FTV	136	-	-	100
PFL	140	-	-	100

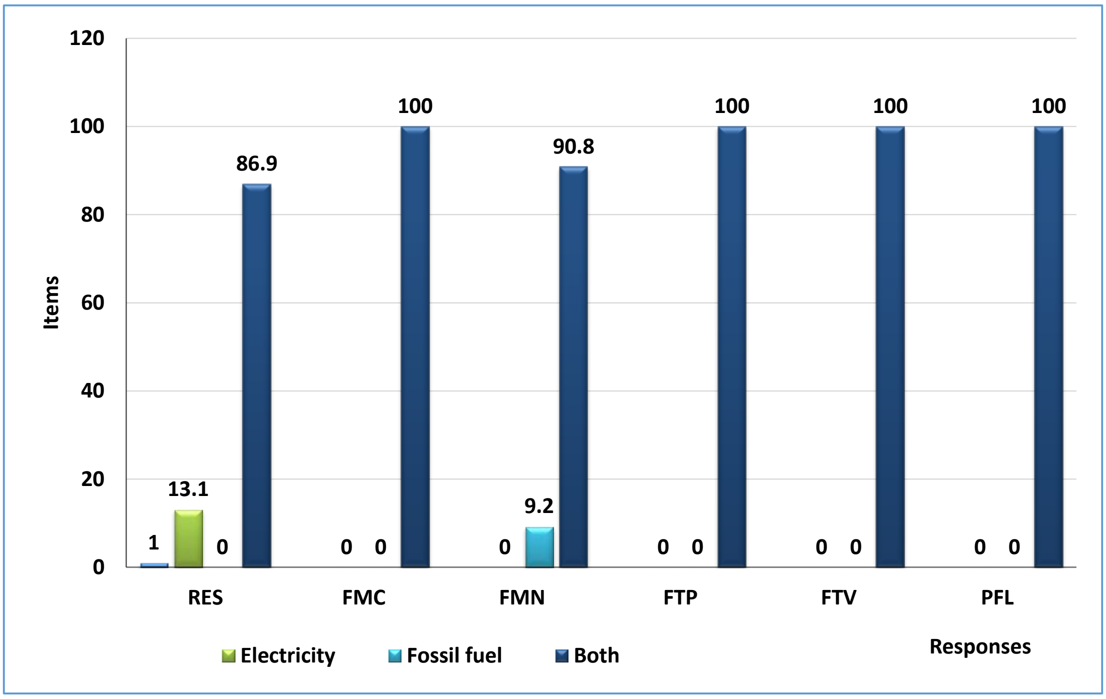


Figure 7-2: Responses of energy type which used as energy source in each sectors.

The answers to question 2-1, as displayed in Table 7-6 and Figure 7-2, indicate that the majority of the sector samples surveyed depend on both electricity and fossil fuels for energy, with no distinction being made between the sources of this energy (network, generators and others), and fossil fuels being defined as any combustible organic material, such as coal, oil or natural gas. The energy is used for cooling, space and water heating, lighting, appliances and machines. 13.1% of those in the residential sector use only electricity, with the use of electric appliances tying in to living in tall apartments. On the other hand, 9.2% of FMN have used only fossil fuels as an energy source, which is due to the location of their sites, where there is no electricity or water network. The rest of the sectors, FMC, FTP, FTV and PFL, use both electricity and fossil fuels as sources of energy.

The responses to question 2-2, as presented in Table 7-7, indicate that the majority of the sectors surveyed are using electricity from the public grid. Only 4.3%, 9.2%, 3.7% and 12.8% of RES, FMN, FTV and PFL respectively are dependent on generators for electricity alone, typically either because of a lack of confidence in the use of the public network due to sudden outages or irregular electricity, or because their locations are far away from the sources of electricity and are situated far enough outside of cities that there is no water and electricity network. The main reason behind the large percentage that uses both public network electricity and generators is the lack of confidence in the grid. This is in-line with GECOL suggestions to allow other investors in Libya's generation and distribution sectors to be able to meet the demand as motion in the earlier discussion by Rose (2004) Section 2.3.1.1. page 15.

Table 7-7: The source of the electricity being used in each sector.

Q2-2: Electricity source.					Total
Sector	N	Response %			
		Network	Generators	Both	
RES	206	37.9	4.3	57.8	100%
FMC	113	76.1	-	23.9	100%
FMN	130	67.7	9.2	23.1	100%
FTP	106	76.4	-	23.6	100%
FTV	136	52.2	3.7	44.1	100%
PFL	140	42.9	12.8	44.3	100%

Table 7-8, demonstrates current energy usage in the surveyed sectors. Question 3-1 covers the used electricity. It has been found that 100% of all the sectors are using the electricity for some or all of the following: hot water, lighting, cooling, heating and powering their appliances. Even the people who do not use the electricity grid at all and are living far away from the cities are using electricity for multiple purposes.

Question 3-2 demonstrates the second type of energy used, namely gas cylinders. Despite the RES sector's use of electricity for many purposes, it also uses gas cylinders as follows: for water heating in the kitchen and bathroom 10.2%, for lighting as an alternative to electricity during the period of outages 5.3%, for heating 33.5%, and 51% are using gas for more than one of these purposes. The FMC sector is using gas cylinders for many purposes, such as using portable containers in temporary sites, for instance water heating 12.4%, lighting 4.4%, heating 32.7% and 50.5% for more than one task. In addition, about 5.4% of FMN use it for water heating, 8.5% for lighting, 44.6% heating, 9.2% and 32.3% for multiple purposes. 7.5% and 7.4% of the FTP and FTV sectors respectively are using it for water heating. Only 9.4% of FTP is using it for heating. 12.3% and 11.8% of FTP and FTV respectively are using it for their machines and appliances, and 70.8% and 80.8% are using it for more than one task. Only 5% of PEL is using it for lighting, 22.1% for heating, 24.3% for machines/appliances and 48.6% are using it for more than one purpose.

Table 7-8: The types of energy used (electricity and fossil fuel).

Sector	N	Response %						
			water heating	lighting	cooling	heating	Machine / appliances	More than one
		Q3-1: Electricity.						
RES	206		-	-	-	-	-	100
FMC	113		-	-	-	-	-	100
FMN	130		-	-	-	-	-	100
FTP	106		-	-	-	-	-	100
FTV	136		-	-	-	-	-	100
PFL	140		-	-	-	-	-	100
		Q3-2: Gas.						
RES	206		10.2	5.3	-	33.5	-	51
FMC	113		12.4	4.4	-	32.7	-	50.5
FMN	130		5.4	8.5	-	44.6	9.2	32.3
FTP	106		7.5	-	-	9.4	12.3	70.8
FTV	136		7.4	-	-	-	11.8	80.8
PFL	140		-	5	-	22.1	24.3	48.6
		Q3-3: Kerosene.						
RES	206		-	-	-	28.6	9.7	61.7
FMC	113		-	-	-	13.3	26.5	60.2
FMN	130		-		-	37.7	15.1	47.2
FTP	106		-	-	-	37.7	15.1	47.2
FTV	136					36	14	50
PFL	140				-	21.4	20.7	57.9
		Q3-4: Diesel.						
RES	206			31.1		27.2		41.7
FMC	113					15.9	52.2	31.9
FMN	130			6.2			46.2	47.6
FTP	106		-	-	-	17	32.1	50.9
FTV	136			-	-	19.9	10.3	69.9
PFL	140			7.9	-	11.4	37.9	42.8

Question 3-3 illustrates the third type of energy used in these sectors, kerosene. 28.6%, 13.3%, 37.7%, 37.7% and 21.4% of the RES, FMC, FMN, FTP and PFL sectors respectively are using kerosene for heating. Furthermore, 9.7%, 26.5%, 15.1%, 15.1%, 14% and 20.7% of RES, FMC, FMN, FTP, FTV and PFL respectively are using it for machines/appliances. However, the majority of the RES, FMC, FMN, FTP, FTV and PFL sectors – 61.7%, 60.2%, 47.2%, 47.2%, 50% and 57.9% respectively – are using it for more than one purpose.

Question 3-4 explores the fourth type of energy used in these sectors, which is diesel. About 31.1% and 27.2% of the RES sector are using diesel for lighting and heating respectively, especially in the cool area in the east of Libya where boilers with diesel motors are used. 41.7% of those surveyed in the RES sector are using diesel for many purposes, as are 31.9% and 47.6% of the FMC and FMN sectors respectively. The FMC sector uses diesel for heating 15.9% and for powering machines/appliances 52.2%, while in the FMN sector 6.2% of those surveyed use it for lighting, and 46.2% for machines/appliances. 17% and 19.9% of the FTP and FTV sectors are using it for heating, 32.1% and 10.3% of them are using it for machines/appliances and 50.9% and 69.9% of them are using it in more than one role. Additionally, the PFL sector has some respondents located in remote and mobile areas, and therefore 7.9% of the sector is using diesel generators for lighting, 11.4% for heating, 37.9% for machines/appliances and 42.8% for multiple purposes.

Table 7-9: The source of water used by each sector.

Q3-5: Water source used.						
Sector	N	Response %				
		Underground water	Public water (Tap water)	Local home well	Rainwater	More than one
RES	206	-	47.1	2.9	-	50
FMC	113	76.1	-	-	23.9	-
FMN	130	90.8	-	-	9.2	-
FTP	106	46.2	5.7	4.7	6.6	36.8
FTV	136	35.3	17.6	9.6	11	26.5
PFL	140	12.1	57.1	9.3	13.6	7.9

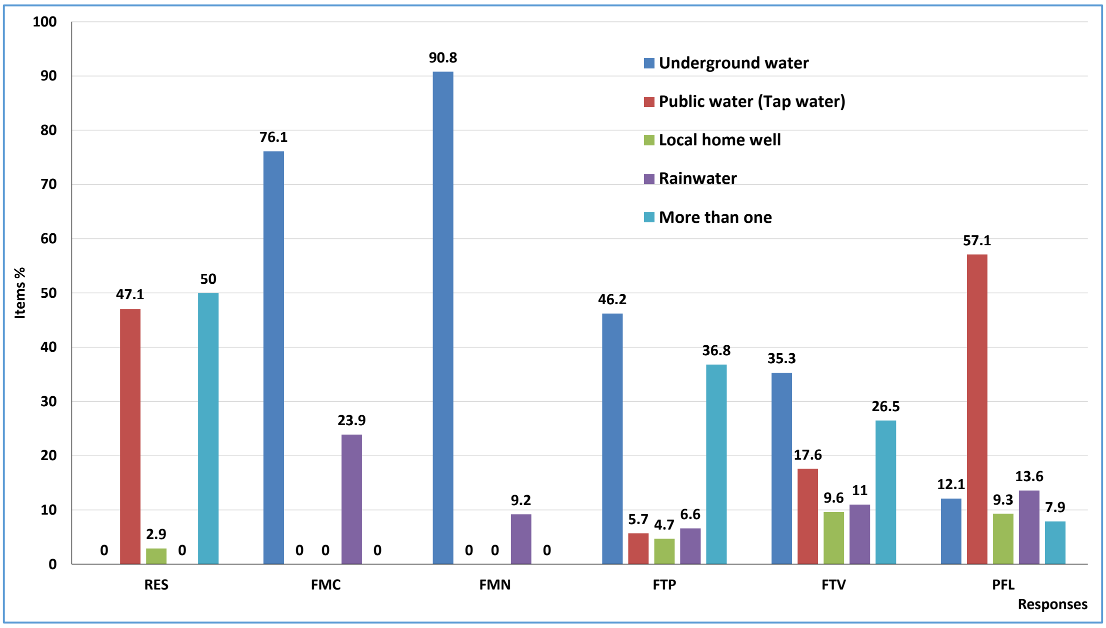


Figure 7-3: The source of water used by each sector.

Question 3-5, as presented in Table 7-9 and Figure 7-3, covers the source of water which is being used in each sector. The result shows that 50% of the RES sector is dependent on multiple water sources, with some storing rainwater in concrete vaults underground or on the ground inside the building as well as using tap water and/or a local home well within the property boundary. 47.1% of RES use only public tap water, in some cases due to their living in apartment buildings, and 2.9% of them depend on private local wells (small production) because their houses are far away from the water grid.

Moreover the results indicated that the majority 76.1% and 90.8% of the commercial and non-commercial farm sectors respectively are using underground water (huge production). However 23.9% and 9.2% of them are dependent on rainwater, as mentioned above, in cases where these farms are far away from electricity and the public water grid (rain-fed farms).

Some of the public and private factories and public facilities inside or outside cities are in places far away from the service networks; therefore they depend on non-grid sources to get the water they need. Although 5.7%, 17.6% and 57.1% of FTP, FTV and PFL respectively are using public tap water, the rest of the factories and public facilities are using underground water, local home wells, rainwater and/or a mix of them.

7.4. The fifth objective

The fifth research objective is “To investigate to what extent the current public energy service is appropriate and sufficient”. In order to achieve this objective, the researcher has written two questionnaire sections, the first section examining the current public energy service and the second section aimed at gathering information related to power and water outages (where they occurred).

7.4.1. The current public energy services

The first section is related to energy availability and price. The researcher designed the third and fourth parts in the research questionnaire to achieve the fifth research objective, and summaries of the per-sector responses about energy services, availability, prices and payment are in the following tables.

Table 7-10: Residential housing responses.

Q4: RES (N=206)						
sub	Items	Response %				
		1	2	3	4	5
1	Electricity services are sufficient and appropriate	13.1	33	9.2	-	44.7
2	The price of electricity is reasonable	19.4	46.1	-	26.2	8.3
3	The price of gas is reasonable	36.4	-	16.5	47.1	-
4	The price of kerosene is affordable	18.9	-	33	38.9	9.2
5	The price of gasoline is reasonable	1.5	8.7	49	29.6	11.2
6	The diesel price are affordable	-	20.4	38.8	27.7	13.1
7	Water Authority services are sufficient and appropriate	12.6	7.8	0.5	79.1	-
8	The price of public water is reasonable	0.5	82	1	10.2	6.3
9	Electricity is always available	11.2	63	1.5	17	7.3
10	Water is always available	-	47.1	0.5	42.2	10.2
11	Gas is always available	8.7	37.9	16.5	36.9	-
12	Pay your energy and water bills	27.7	18.4	27.7	17.5	8.7

1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree

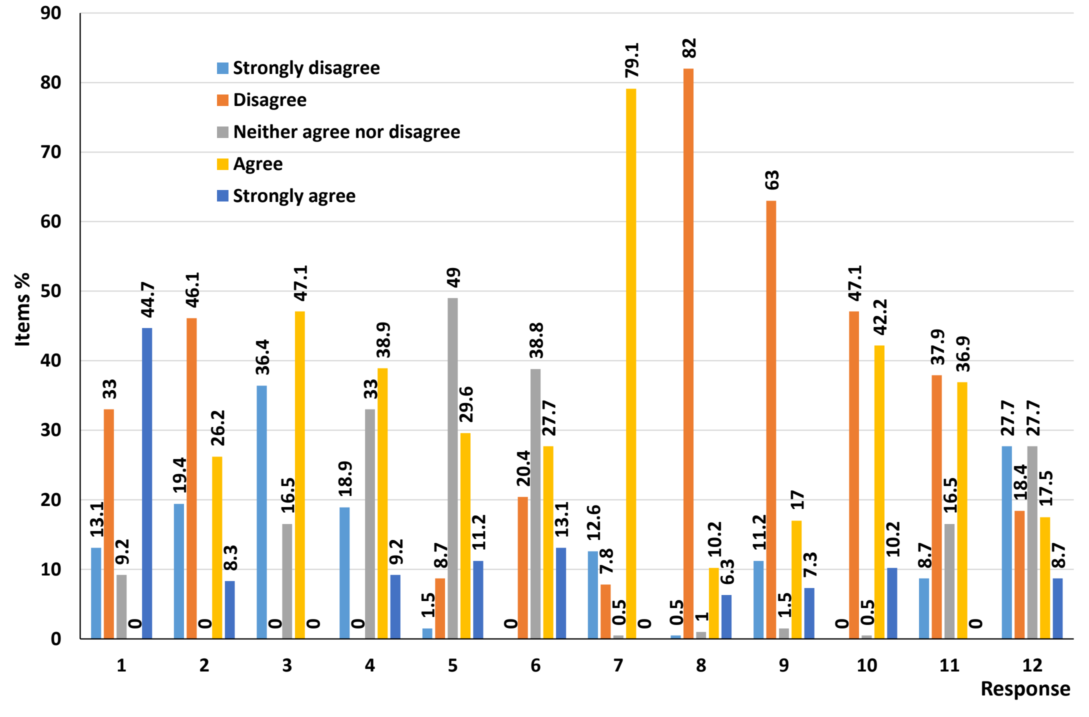


Figure 7-4: Residential housing responses based on Table 7-10.

From Table 7-10 and Figure 7-4, it is clear that there is dissatisfaction in the RES sector about GECOL's electrical services, where 44.1% (13.1% + 33%) strongly disagree or disagree that services are sufficient and appropriate, although 44.7% of them strongly agree, while the majority of the RES respondents are satisfied about the water authority services. While there is significant dissatisfaction about the prices of both electricity 65.5% and tap water 82.5%, there is in general agreement that the fossil fuel prices are acceptable (47.1% gas, 48% kerosene, 40.8% gasoline and 40.8% diesel) with significant numbers neither agreeing nor disagreeing (16.5% gas, 33% kerosene, 49% gasoline and 38.8% diesel). This is because contributors in this questionnaire are comparing between the prices of fossil fuels in other countries, where they are very expensive, and their local prices which is deeply subsidised by the Libyan government as pointed by Affairs (2010) Section 2.3.1.1, although on the other hand, the level of Libyan per-capita income is also low in comparison.

Questions 9, 10 and 11 investigated the extent of the availabilities of electricity, water and gas. Although 74.8%, 47.1% and 46.6% respectively disagree that they are always available, 16.5% neither agree nor disagree about gas availability. The last question in this section is about energy and water payments. 46.1% do not pay at all, with 27.7% not disclosing their status by neither agreeing nor disagreeing with the question. Non-payment may be due to the dissatisfaction with the services identified in the earlier questions.

The next table include the responses of the commercial farm sector.

Table 7-11: Commercial farm responses.

Q4: FMC (N=113)						
sub	Items	Response %				
		1	2	3	4	5
1	Electricity services are sufficient and appropriate	6.2	35.4	8	50.4	-
2	The price of electricity is reasonable	31.9	30.1	4.4	24.8	8.8
3	The price of gas is reasonable	-	40.7	18.6	40.7	-
4	The price of kerosene is affordable	-	10.6	31.9	55.8	1.8
5	The price of gasoline is reasonable	-	0.8	43.4	41.6	14.2
6	The diesel price are affordable	-	10.7	32.7	46	10.6
7	Water Authority services are sufficient and appropriate	16.8	0.9	-	77	5.3
8	The price of public water is reasonable	-	90.3	-	-	9.7
9	Electricity is always available	9.8	63.7	1.8	15.9	8.8
10	Water is always available	-	40.7	0.9	44.2	14.2
11	Gas is always available	22.2	26.5	16.8	31	3.5
12	Pay your energy and water bills	31	28.3	21.2	12.4	7.1

1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree.

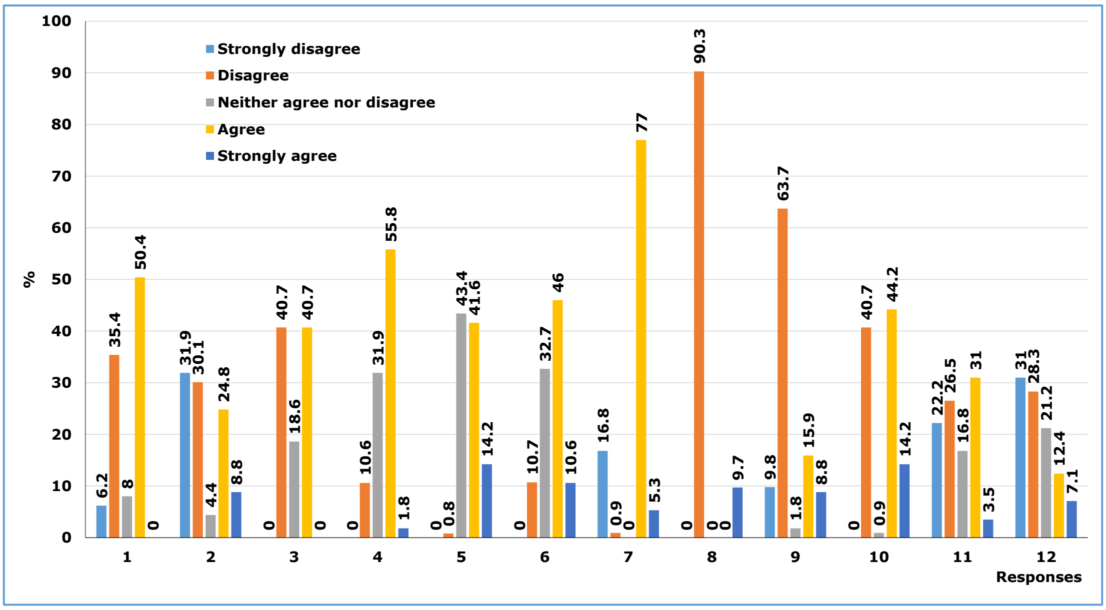


Figure 7-5: Commercial Farm responses based on Table 7-11.

From Table 7-11 and Figure 7-5, it can be seen that 50.4% and 82.3% of FMCs are satisfied with their electricity and water services respectively. However, 62% and 90.3% are dissatisfied with electricity and water prices respectively. While there is agreement that the fossil fuel prices are appropriate (40.7% gas, 57.6% kerosene, 55.8% gasoline and 46.6% diesel), there is also a significant number who neither agree nor disagree (18.6% gas, 31.9% kerosene, 43.4% gasoline and 32.7% diesel). Most interviewees explained that the reason behind their dissatisfaction with the electricity and water services and prices is the cheaper price found in neighbouring countries.

Questions 9, 10 and 11 cover the availability of electricity, water and gas. 73.5%, 40.7% and 48.6% expressed a belief that electricity and gas are sometimes unavailable. However, 58.4% of the respondents said that water is always available. Question 12 looks at the energy and water payments in this sector, with 59.3% not paying at all and 21.2% opting for nondisclosure by neither agreeing nor disagreeing in their answer.

The next table includes the responses from the non-commercial farm sector.

Table 7-12: Non-commercial farm responses.

Q4: FMN (N=130)						
sub	Items	Response %				
		1	2	3	4	5
1	Electricity services are sufficient and appropriate	24.6	35.4	13.8	25.4	0.8
2	The price of electricity is reasonable	27.7	36.9	5.4	20.8	9.2
3	The price of gas is reasonable	2.3	33.1	22.3	42.3	-
4	The price of kerosene is affordable	-	13.1	34.6	51.5	0.8
5	The price of gasoline is reasonable	-	4.6	40	33.1	22.3
6	The diesel price are affordable	10	12.3	35.4	34.6	7.7
7	Water Authority services are sufficient and appropriate	36.2	30.8	10.7	22.3	-
8	The price of public water is reasonable	16.9	60.8	3	8.5	10.8
9	Electricity is always available	9.2	65.4	-	18.5	6.9
10	Water is always available	28.5	46.9	3.1	11.5	10
11	Gas is always available	17.7	26.9	18.5	31.5	5.4
12	Pay your energy and water bills	25.4	16.9	27.7	19.2	10.8

1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree.

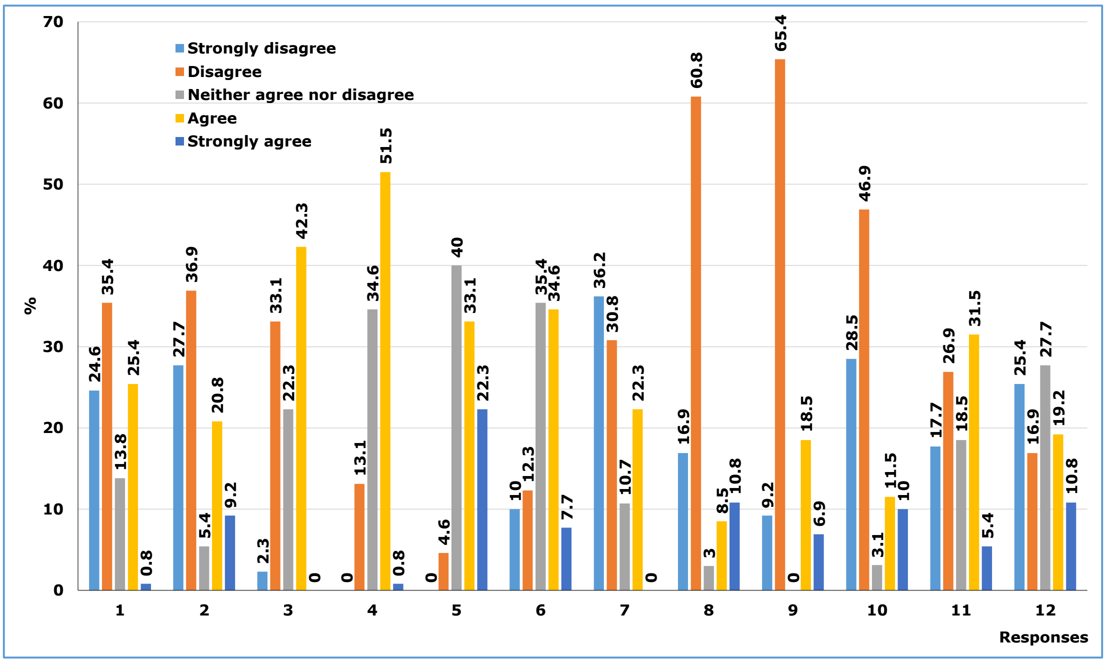


Figure 7-6: Non-commercial farm responses based on Table 7-12.

Table 7-12 and Figure 7-6 show that 60% and 67% of FMNs are dissatisfied about their electricity and water supplies respectively, while 64.6% and 77.7% of them are dissatisfied with the electricity and water prices. Questionnaire results show that there is satisfaction with the fossil fuel prices (42.3% gas, 52.3% kerosene, 55.4% gasoline and 42.3% diesel), with an additional significant number who are neither satisfied nor dissatisfied (22.3% gas, 34.6% kerosene, 40% gasoline and 35.4% diesel). Most interviewees pointed out the same reasons behind their dissatisfactions with the electricity and water services and prices as those written above.

Questions 9, 10 and 11 determine respondent opinions on the availability of electricity, water and gas. 74.6%, 75.4% and 44.6% of the respondents believed that electricity, water and gas respectively were sometimes unavailable, with 18.5% neither agreeing nor disagreeing about gas availability. The last question, on energy and water payments in this sector, revealed that 42.3% do not pay at all, while 27.7% chose not to confirm one way or the other. The non-payment may be due to the revealed dissatisfaction about services and prices.

The next table includes the responses of the public factory sector.

Table 7-13: Public factory responses.

Q4: FTP (N=106)						
sub	Items	Response %				
		1	2	3	4	5
1	Electricity services are sufficient and appropriate	33	19.8	4.7	25.5	17
2	The price of electricity is reasonable	7.5	54.7	3.9	24.5	9.4
3	The price of gas is reasonable	14.2	27.4	13.1	31.1	14.2
4	The price of kerosene is affordable	19.8	17.9	9.5	36.8	16
5	The price of gasoline is reasonable	26.4	16	14.2	16	27.4
6	The diesel price are affordable	23.6	25.5	8.5	24.5	17.9
7	Water Authority services are sufficient and appropriate	22.6	11.3	6.7	34.9	24.5
8	The price of public water is reasonable	14.2	51.9	6.5	14.2	13.2
9	Electricity is always available	11.3	37.7	8.5	23.6	18.9
10	Water is always available	10.4	26.4	2.9	37.7	22.6
11	Gas is always available	11.3	30.2	6.6	39.6	12.3
12	Pay your energy and water bills	32.1	15.1	26.3	20.8	5.7

1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree.

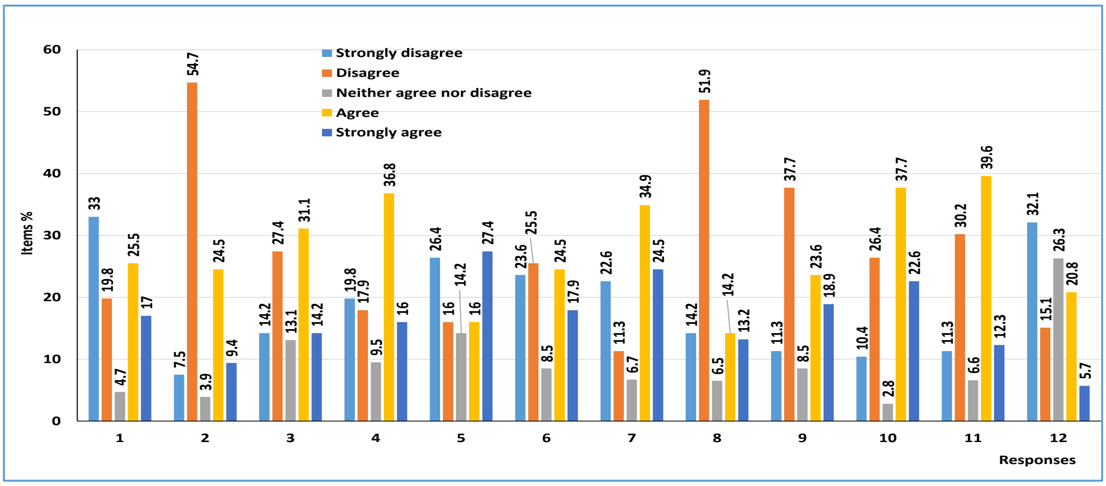


Figure 7-7: Public factory responses based on Table 7-13.

Table 7-13 and Figure 7-7 demonstrate that some 52.8% of the FTP sector is dissatisfied about their electricity services, although 59.4% of them are satisfied with the water authority services. 62.2% are dissatisfied with electricity prices, while 66.1% are dissatisfied with water prices. In contrast, there is satisfaction about prices for three of the types of fossil fuel (45.3% gas, 52.8% kerosene and 43.4% gasoline), with a further significant number who neither agree nor disagree (13.1% gas, 9.5% kerosene, and 14.2% gasoline). There is dissatisfaction on diesel price, with 49.1% either disagreeing or strongly disagreeing with the costs.

The results to questions 9, 10 and 11 demonstrate that 49% of the respondents in this sector thought that electricity is sometimes unavailable, with a further 8.5% who neither agree nor disagree. 60.3% and 51.9% agreed that water and gas are always available. Question 12 demonstrated that 47.2% of the respondents in this sector do not pay at all for their power and water, while 26.3% chose not to disclose their situation. In fact, this sector has factories owned by the government, which use internal settlement payments between the departments in the ministries of finance without the knowledge of customers.

Table 7-14: Private factory responses.

Q4: FTV (N=136)						
sub	Items	Response %				
		1	2	3	4	5
1	Electricity services are sufficient and appropriate	14	35.3	2.2	40.4	8.1
2	The price of electricity is reasonable	19.9	46.3	5.1	18.4	10.3
3	The price of gas is reasonable	5.1	22.8	11	49.3	11.8
4	The price of kerosene is affordable	11.8	19.9	19	35.3	14
5	The price of gasoline is reasonable	23.5	21.3	10.4	27.9	16.9
6	The diesel price are affordable	22.8	19.1	14.7	27.2	16.2
7	Water Authority services are sufficient and appropriate	30.1	25	15.5	23.5	5.9
8	The price of public water is reasonable	11.8	20.6	5.1	36	26.5
9	Electricity is always available	4.4	57.4	9.5	21.3	7.4
10	Water is always available	5.9	14	8	51.5	20.6
11	Gas is always available	15.4	30.1	7.5	36	11
12	Pay your energy and water bills	22.8	20.6	28.7	16.2	11.8

1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree.

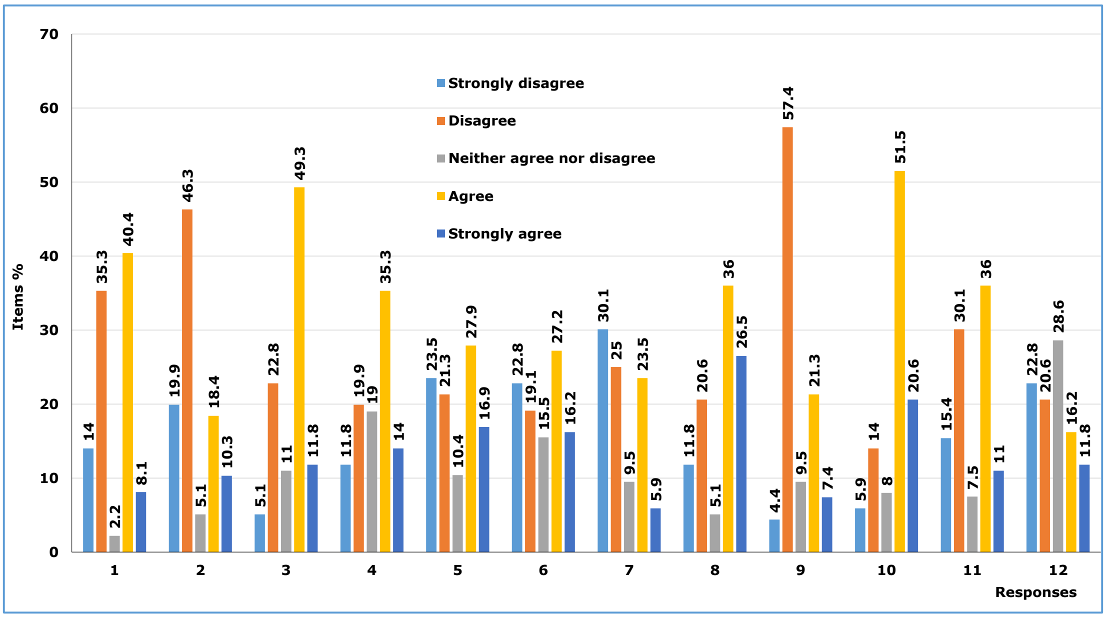


Figure 7-8: Private factory responses based on Table 7-14.

Table 7-14 and Figure 7-8 show that 49.3% and 55.1% of the respondents from the FTV sector are dissatisfied about their electricity and water services respectively. 62.5% of them are satisfied with water authority prices, although 66.2% are dissatisfied with electricity prices. In general there is satisfaction with fossil fuel prices (61.1% gas, 49.3% kerosene 44.8% gasoline and 43.4% diesel), when considering also the number who are neither satisfied nor dissatisfied (11% gas, 19% kerosene, 10.4% gasoline and 14.7% diesel).

Questions 9 through 11 show that 61.8% of the respondents in this sector believed that electricity is sometimes unavailable, with an additional 9.5% who neither agree nor disagree, while 72.1% and 47% agreed that water and gas respectively are always available. Question 12 revealed that 43.4% of this sector do not pay their energy and water bills, with a further 28.6% neither agreeing nor disagreeing, effectively not answering the question . This sector has private factories scattered on some sites outside the range of city planners; therefore they use generators and local wells or rain storage as alternatives to the public network.

Table 7-15: Public facilities responses.

Q4: PFL (N=140)						
sub	Items	Response %				
		1	2	3	4	5
1	Electricity services are sufficient and appropriate	11.4	31.4	8.7	32.1	16.4
2	The price of electricity is reasonable	22.9	35	12.8	15.7	13.6
3	The price of gas is reasonable	12.1	18.6	13.6	35.7	20
4	The price of kerosene is affordable	10	20.7	17.2	40.7	11.4
5	The price of gasoline is reasonable	4.3	12.1	26.5	25.7	31.4
6	The diesel price are affordable	13.6	18.6	40.7	11.4	15.7
7	Water Authority services are sufficient and appropriate	20.7	15.7	7.2	51.4	5
8	The price of public water is reasonable	5.7	37.9	14.3	21.4	20.7
9	Electricity is always available	5	56.4	7.2	20.7	10.7
10	Water is always available	12.9	33.6	5.7	35.7	12.1
11	Gas is always available	7.9	28.6	22.8	40.7	-
12	Pay your energy and water bills	13.6	17.9	27	18.6	22.9

1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree.

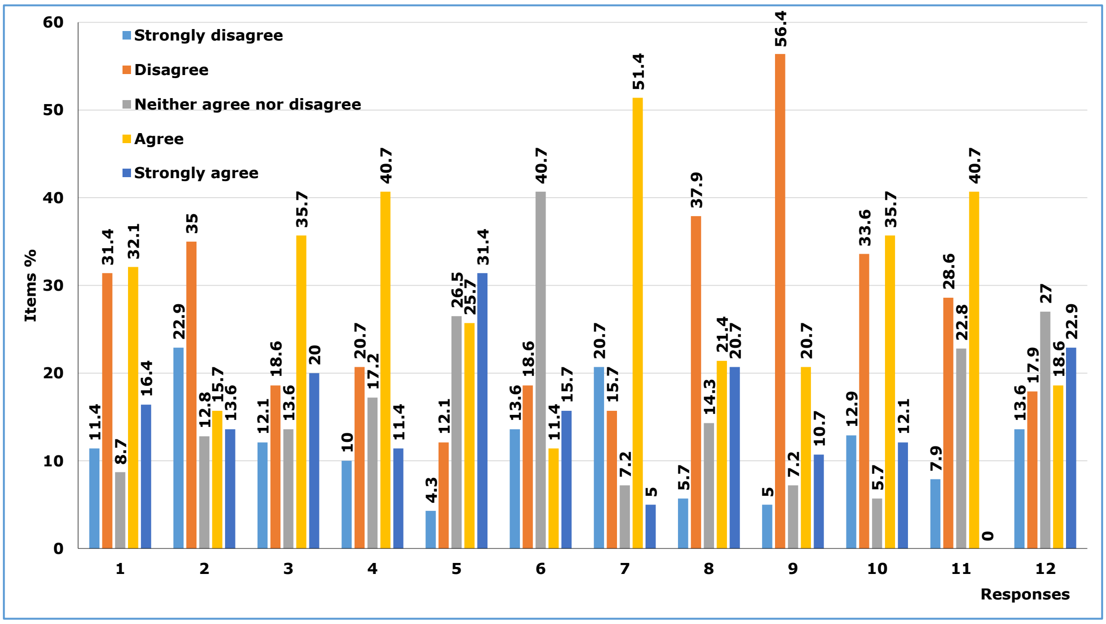


Figure 7-9: Public facilities responses based on Table 7-15.

Table 7-15 and Figure 7-9 explore the answers from the PFL sector. 48.5% and 56.4% of the respondents are satisfied with their electricity and water services respectively. 57.9% and 43.6% of them are dissatisfied with electricity and water prices respectively, with 14.3% neither satisfied nor dissatisfied. There is satisfaction about fossil fuel prices (55.7% gas, 52.1% kerosene 57.1% gasoline and 27.2% diesel), with a significant number with no strong opinion either way (13.6% gas, 17.1% kerosene, and 26.5% gasoline and 40.7% diesel).

Questions9, 10 and 11 show that 61.4% thought that electricity is sometimes unavailable. 47.8% and 40.7% said that water and gas respectively are always available. 5.7% and 22.8% neither agreed nor disagreed. Question 12 demonstrated that 41.5% pay their bills, with 27% opting for nondisclosure.

7.4.2. Causes of power and water outages

This section of the research questionnaire analysis focuses on power and water outages (if they occurred). Summaries of the per-sector responses about the causes of lack and/or outages of energy, water, gas and lighting are displayed in the following table.

Table 7-16: Causes of power and water problems.

Items	Responses	Frequencies % for each sector					
		RES 206	FMC 113	FMN 130	FTP 106	FTV 136	PFL 140
Causes of power outage	Problem with internal	3.9	8	18.5	1.9	2.2	16.4
	home connections						
	General network failure	17.5	31	16.9	22.6	19.1	22.9
	Delivery cost	11.7	8.8	30	7.5	10.3	5
	The source	53.9	48.7	22.3	57.5	59.6	52.1
	No outages	13.1	3.5	12.3	10.4	8.8	3.6
Causes of water outage	Problem with internal	9.2	4.4	-	-	-	17.1
	home connections						
	General network failure	12.6	16.8	29.2	10.4	16.2	32.9
	Delivery cost	12.1	33.6	38.5	7.5	2.9	31.4
	The source	7.3	39.8	24.6	71.7	20.6	12.9
	No outages	58.7	5.3	7.7	10.4	59.6	5.7
Reasons for the lack of gas cylinders	The source	8.7	17.7	17.7	18.9	12.5	6.4
	Not available in the	5.8	8	21.5	15.1	20.6	16.4
	station	13.6	14.2	17.7	7.5	2.9	6.4
	Stations distance	45.6	54	34.6	43.4	61.8	52.9
	Using electricity instead	26.3	6.1	8.5	15.1	2.2	17.9
	No lack						
Reasons for the lack of street lighting	There is no grid	10.2	17.7	41.5	6.6	-	9.3
	From the source	3.4	13.3	12.3	15.1	43.4	15.7
	The public network	33.5	21.2	11.5	8.5	29.4	10
	failure	23.8	24.8	21.5	50	-	40.7
	Stations distance	29.1	23	13.2	19.8	27.2	24.3
	More than one						

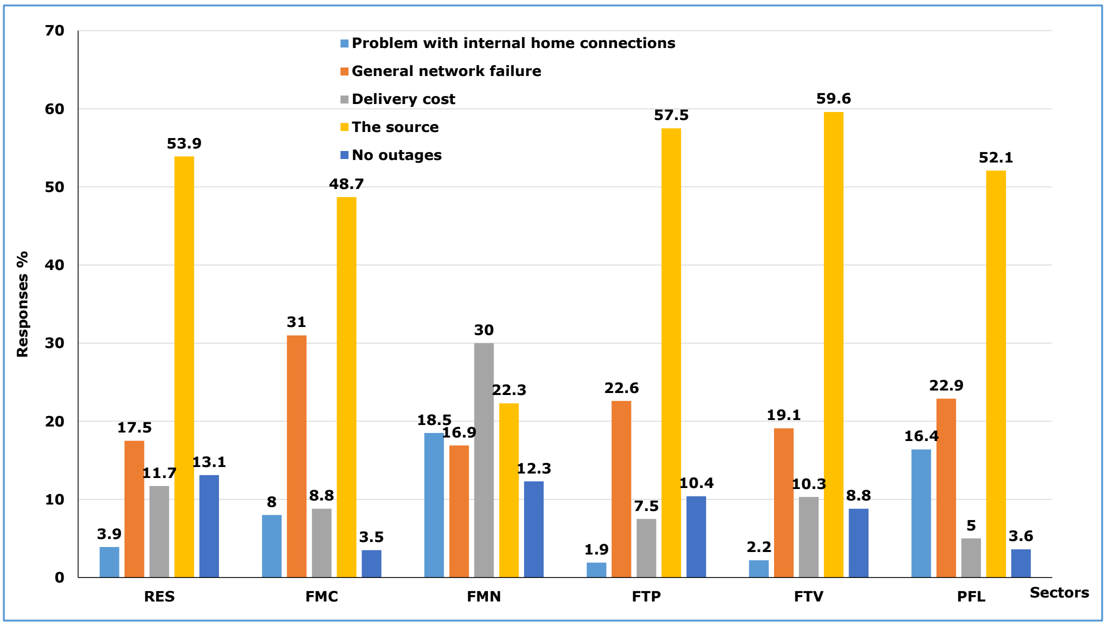


Figure 7-10: Causes of power outage.

Table 7-16 and Figure 7-10 show that the main reason behind the power outages is the source, with 53.9% of RES, 48.7% of FMC, 57.5% of FTP, 59.6% of FTV and 52.1% of PFL confirming that. 30% of FMN, however, believed that the primary reason is the delivery cost. These two causes were followed by general network failure as the second reason for power outages. This is revealed by the responses of 17.5% of RES, 31% of FMC, 16.9% of FMN, 22.6% of FTP, 19.1% of FTV and 22.9% of PFL.

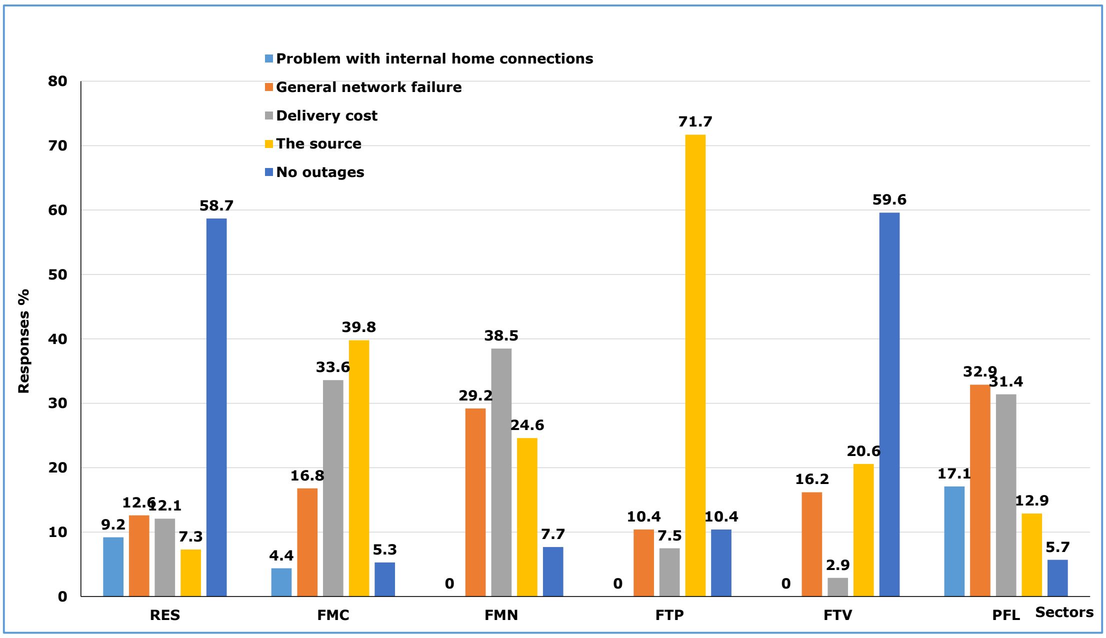


Figure 7-11: Causes of water outage.

As shown in Table 7-16 and Figure 7-11, 58.7% and 59.6% of the RES and FTV sectors respectively confirmed that they suffered no outages at all, while 39.8% and

71.7% of the FMC and FTP sectors respectively believed that the cause of the outages is the source. In addition, 38.5% of respondents from the FMN sector believed that the cause of water outages is the delivery cost. 32.9% of the FFL sector said general network failure is the main cause of water outages.

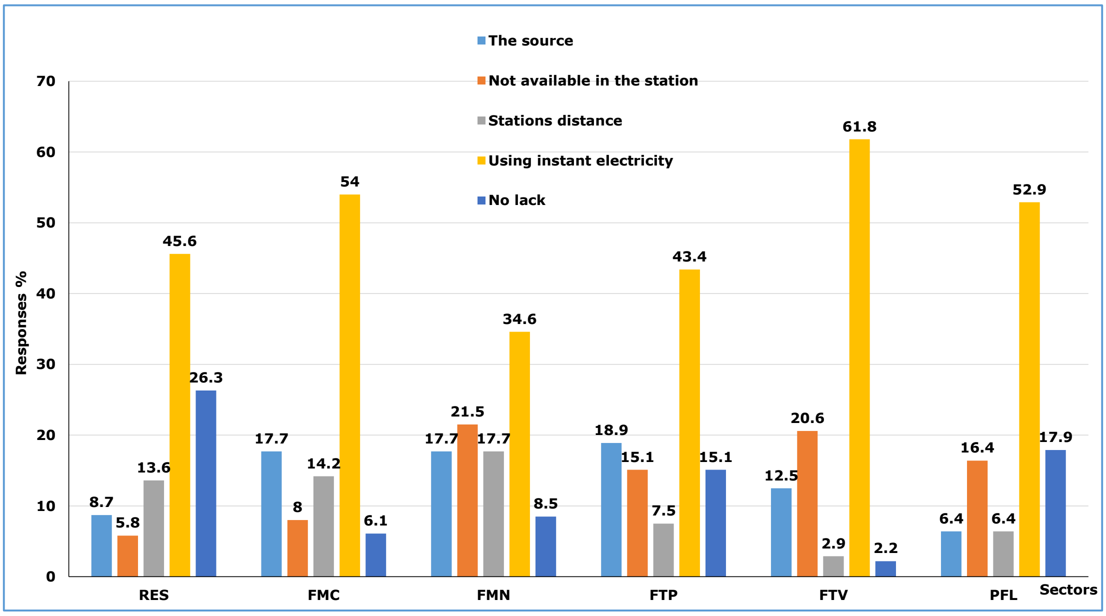


Figure 7-12: Reasons for the lack of gas cylinders.

As seen on Table 7-16 and Figure 7-12, the questionnaire results showed that most of the sectors use electricity instead of gas cylinders, and this is shown by the responses: 45.6% RES, 54% FMC, 34.6% FMN, 43.4% FTP, 61.8% FTV and 52.9% PFL.

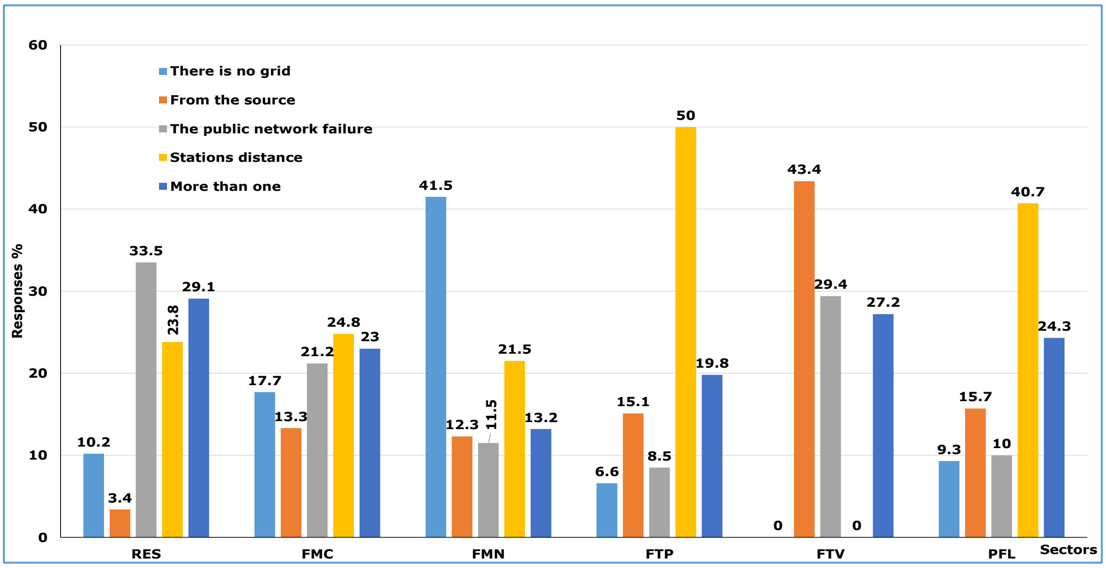


Figure 7-13: Reasons for the lack of street lighting.

Table 7-16 and Figure 7-13 demonstrate that some respondents believe that the reason behind the lack of street lighting is public network failure, as confirmed by 33.5% of the RES sector. 24.8%, 50% and 40.7% of the FMC, FTP and PFL sectors respectively believe the problem is the distance to the nearest power station. 41.5% of FMN respondents blamed the lack of a grid, and 43.4% of the FTV sector said that the lack of street lighting is mainly due to the energy source.

7.5. The sixth objective

This section is focused on the sixth research objective, which is “To study the role of the Libyan government and institutions towards renewable energy technology and the public vision in each sector regarding renewable energy and environmental issues”.

7.5.1. The public vision, government role and environmental issues

This section is related to the role of the Libyan government and institutions towards renewable energy technology and the public vision in each sector regarding renewable energy and environmental issues. The researcher has designed the fifth part of the research questionnaire in order to achieve the sixth objective. The summaries of the results are in the following tables and figures.

Table 7-17: Energy resources, the government's role and environmental issues.

Items	Response	Frequencies % for each sector					
		RES 206	FMC 113	FMN 130	FTP 106	FTV 136	PFL 140
Energy resources							
Do you have any information on other energy sources which can be the best alternative to the current source?	Yes No	33.5 66.5	35.4 64.6	45.4 54.6	59.4 40.6	50.7 49.3	25 75
Do you have any information/ idea about renewable energy?	Yes No	54.4 45.6	61.1 38.9	69.2 30.8	67.9 32.1	59.6 40.4	97.9 2.1
Do you think that renewable energy such as solar and wind is best alternative to the current energy?	Yes No	46.6 53.4	38.1 61.9	50 50	47.2 52.8	41.9 58.1	35.7 64.3
In the case of availability with competitive prices of renewable energy resources and technology are you going to use them?	Yes No	76.2 23.8	70.8 29.2	63.8 36.2	81.1 18.9	80.9 19.1	71.4 28.6
Have you seen this technique used in Libya?	Yes No	29.6 70.4	46.9 53.1	44.6 55.4	48.1 51.9	67.6 32.4	57.1 42.9
Do you expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden?	Yes No	44.7 55.3	32.7 67.3	36.2 63.8	50.9 49.1	27.2 72.8	22.9 77.1
Is there a renewable energy technology markets in Libya?	Yes No	14.1 85.9	16.8 83.2	14.6 85.4	12.3 87.7	15.4 84.6	24.3 75.7
Environmental issues							
Do you have any idea about the environmental damage resulting from the use of electricity and water production plants by traditional fuel?	Yes No	46.1 53.9	50.4 49.6	51.5 48.5	56.6 43.4	33.8 66.2	58.6 41.4
Do you think that the environmental pollution in Libya could be the reason to reconsider continuing to use traditional energy?	Yes No	83.5 16.5	76.1 23.9	74.6 25.4	89.6 10.4	90.4 9.6	83.6 16.4
Do you support the production of energy from environmentally friendly sources?	Yes No	87.4 12.6	95.6 4.4	69.2 3.1	97.2 2.8	93.4 6.6	91.4 8.6
Do you support legislation to reduce and regulate the use of conventional energy?	Yes No	51.9 48.1	90.3 9.7	81.5 18.5	74.5 25.5	79.4 20.6	76.4 23.6
Do you encourage legislation to increase the use of renewable energy	Yes No	76.2 23.8	87.6 12.4	96.9 3.1	97.2 2.8	93.4 6.6	91.4 8.6
Government role							
Does the government engage in the sponsorship of any education or media related programs in reference to renewable energy?	Yes No	4.9 95.1	15.9 84.1	12.3 87.7	14.2 85.8	24.3 75.7	12.9 87.1
Does the educational curriculum include any materials regarding renewable energy?	Yes No	5.8 94.2	3.5 96.5	6.2 93.8	4.7 95.3	9.6 90.4	3.6 96.4

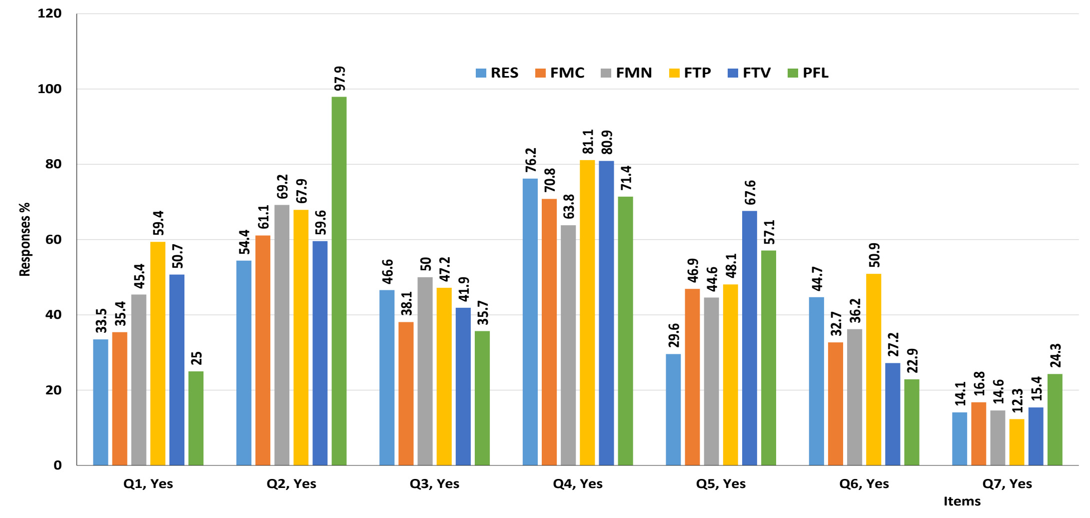


Figure 7-14: Energy resources.

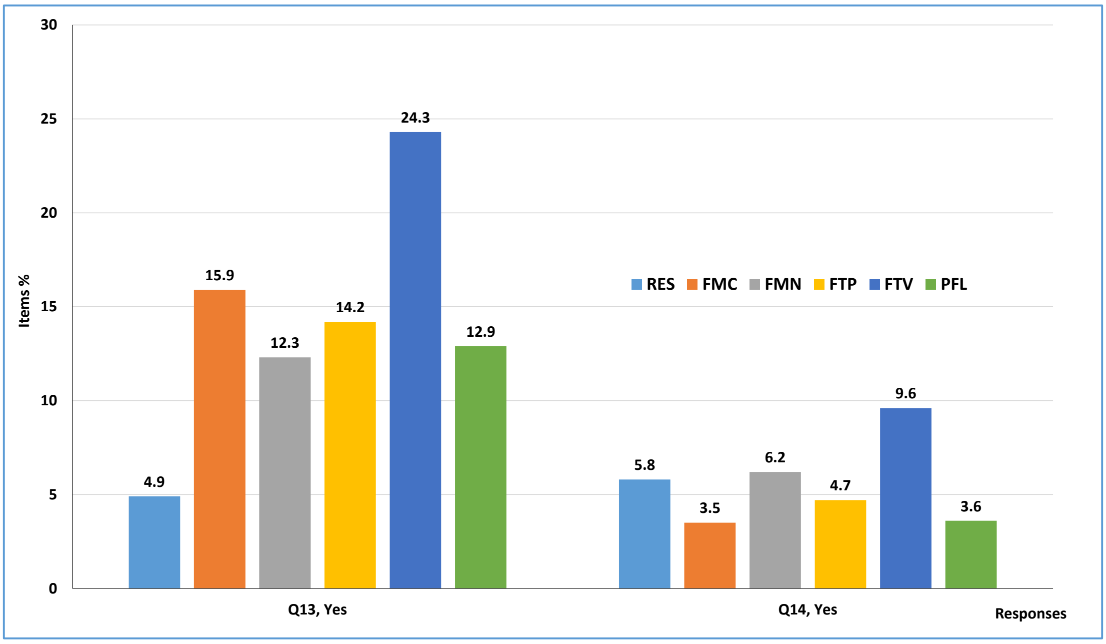


Figure 7-15: Environment issues.

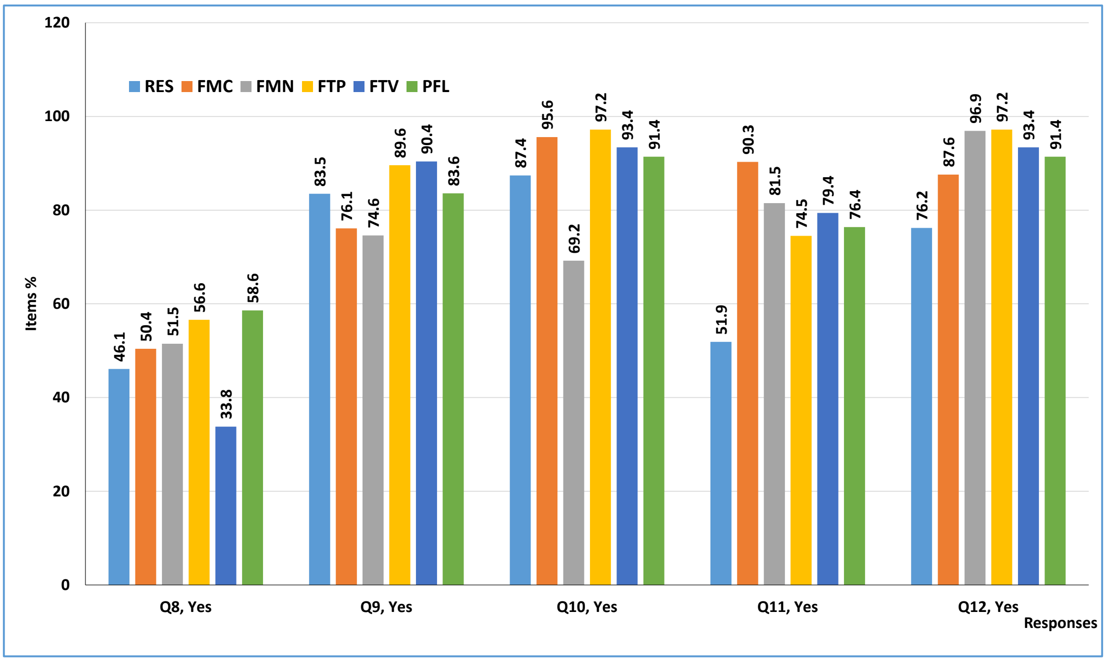


Figure 7-16: Government role.

The responses to the open questions revealed that 59.4% and 50.7% of the FTP and FTV sectors respectively have knowledge about using renewable energy resources as an alternative to the current sources, and 81.1% and 80.9% of them respectively support using renewable energy resources and technology in cases where it is available at competitive prices. 97.2% and 93.4% of them respectively support production of energy from environmentally friendly sources. Furthermore, 97.2% and 93.4% of the same sectors respectively encourage legislation to increase the use of renewable energy resources. This is because these sectors deal with production costs and are consequently suffering from high electricity prices, as discussed in chapters one and two.

The agriculture sector, which suffers the negative impact of environmental issues, is more supportive towards legislation to reduce and regulate the use of conventional energy, as shown by 90.3% and 81.5% of the FMC and FMN sectors respectively.

In addition to the open questions above, the questionnaire had several close-ended questions in order to cover some other issues such as access to renewable energy information. The majority of the PFL sector, with 97.9%, followed by 69.2% of FMN, 67.9% of FTP, 61.1% of FMC, 59.6% of FTV and 54.4% of RES, stated that they have an idea and information about renewable energy resources. The largest positive response was obtained from the PFL sector because this sector includes various types of officials and other educated people in the ministries of health, education, agriculture, industry, economy, planning, justice, and public security, as employees at, for example, schools, hospitals, clinics and polyclinics, nurseries, gardens, parks, police stations, checkpoints and others. When the questionnaire asked whether renewable energy sources, such as solar and wind, are the best alternative to current energy sources, the per-sector responses decreased due to a lack of information about the sale price and availability of technologies, as revealed by the answers of 46.6% of RES, 38.1% of FMC, 50% of FMN, 47.2% of FTP, 41.9% of FTV and 35.7% of PFL. The positive responses increased when the question assumed the availability and competitive prices of renewable energy resources and technology, and this is revealed by responses of 76.2% of RES, 70.8% of FMC, 63.8% of FMN, 81.1% of FTP, 80.9% of FTV and 71.4% of PFL. The sectors’ responses to the question about the availability of renewable energy techniques are 29.6% RES, 46.9% FMC, 44.6% FMN, 48.1% FTP, 67.6% FTV and 57.1% PFL.

The questionnaire also had close-ended environmental issue questions about awareness of the environmental damage which is caused by the traditional fuels used to produce electricity and process water. The positive responses are as follows: 46.1% RES, 50.4% FMC, 51.5% FMN, 56.6% FTP, 33.8% FTV and 58.6% PFL. The sector responses about a reconsideration of the continuing use of traditional energy in order to reduce environmental pollution are clear majorities, with 83.5% RES, 76.1 FMC, 74.6% FMN, 89.6% FTP, 90.4% FTV and 83.6% PFL agreeing. The most positive response related to the potential of renewable energy services to be affordable has been found in the FTP sector, with 50.9% in agreement with Elhage (2008) and Khalil (2009) as mentioned earlier in chapter 2 Section 2.5. The majority of each sector's responses have confirmed that there is no significant renewable energy market in Libya, and this is revealed by 85.9% of the RES respondent votes, 83.2% FMC, 85.4% FMN, 87.7% FTP, 84.6% FTV and 75.7% PFL.

In terms of the Libyan government's role, the results of the questionnaire showed that the respondents believe that the government does not engage in the sponsorship of any education or media-related programmes in reference to renewable energy, with 95.1% RES, 84.1% FMC, 87.7% FMN, 85.8% FTP, 75.7% FTV and 87.1% PFL stating no. Moreover, the vast majority of the participants stated no with regard to whether the educational curriculum includes any materials regarding renewable energy, with 94.2% RES, 96.5% FMC, 93.8% FMN, 95.3% FTP, 90.4% FTV and 96.4% PFL.

7.6. Summary

This chapter demonstrates the outcomes of data analysis achieved from the primary sources (questionnaire). In order to achieve the objectives and answer the research question, the participants of the survey provided responses about the current energy situation, public energy services and the public vision regarding renewable energy and environmental issues, in addition to the roles of the Libyan government and institutions towards renewable energy technology. Data were then prepared, coded and entered into the SPSS (Statistical Package for Social Scientists. V. 22) program, and a series of analyses were carried out to test instrument reliability and validity. Internal consistency is measured by calculating a statistic known as Cronbach's coefficient alpha. Descriptive statistics described the sample and distributions.

The next chapter, will present the results of the specific research questionnaires in order to achieve the last research objective and answer the second research question.

Chapter 8. Analysis of the householders' questionnaire.

8.1. Introduction

In this chapter the researcher shows the results of the householder research questionnaires in order to achieve the research objective "To evaluate the effect of domestic energy consumption and householders' awareness of, and attitudes and behaviour towards overall energy consumption in Libya, and how this could affect peak demand, capacity and the government's energy budget", and answer the second research question.

8.2. Characteristics and features of the questionnaire sample

This work has been conducted by means of a general population survey using a statistically significant sample and number of self-completed questionnaires in different locations across Libya. The self-completed questionnaire technique has been used. The questionnaire, in Arabic, was delivered by hand to every respondent and collected later. The results from this questionnaire, which is used in this study as the main data-collection method directed at a sample of energy consumers in Libya, are used to produce representative findings that can be communicated to Libyan energy users. It has been designed to investigate the main drivers that affect domestic energy use: residence, physical characteristics of houses and residents' energy behaviour (which includes awareness of and attitudes towards energy-saving measures). For this study, a reasonable sample of the population has been selected and their demographic variables defined. The survey was carried out during the year of 2013, and it included some pictures to increase the clarity and to simplify the selection process between the questionnaire answers for the respondents. In order to decide which households are used for the study sample, the current investigation used stratified random sampling, which is divided into non-overlapping groups, i.e. geographical areas across Libya. In addition, electricity consumption data has been obtained to study the total domestic consumption in Libya and to cross reference the findings of the survey as necessary.

8.2.1. Demographic variables

The characteristics of the 429 sampled homes in this study are presented in Table 8-2. From a total survey of 823 questionnaires distributed in the study area (see Table 8-1), 429 valid questionnaires have been received, a 52% response rate (41 received questionnaires were rejected because they were incomplete). The data has been collected taking into consideration other studies in other countries (NIHE, 2001; Yohanis, 2012).

Table 8-1: Sample distribution.

User type	Total (Libya)	Regions					
		Tripoli	Benghazi	Western region	Middle region	Southern region	Green Mountain
Number of residential houses	905,970	317,347	147,569	187,017	135,475	53,669	64,893
Krejcie Distribution (based on 5% degree of accuracy)	384	135	63	79	57	23	27
Number of valid questionnaires received	429	113	66	86	85	35	44

Table 8-2 presents the occupancy characteristics of the surveyed houses. The sample in this study comprises different types of household. A large percentage in this study consists of single or double flats, as they are common houses in the study area, while private apartments or government dwellings often had one, two or three bedrooms. The sample, both in terms of characteristics and size, is considered to be a reasonable representative of current dwelling types in Libya.

Table 8-2: Occupancy characteristics of the surveyed houses.

Number of bedrooms per household	%		Number of occupants	%
1	18		1	1
2	23		2	10
3	39		3	31
4	19		4	6
5	7		5	3
6+	1		6+	49
Household income (LD)	**%**		**Employment status of primary householder**	**%**
< 300	10		Employed	30
300-500	25		Unemployed	8
500-1000	35		Retired	22
1000-5000	29		Child	25
>5000	1		Others	15
Age of primary householder	**%**		**Average age of all householders**	**%**
< 30	3		< 30	41
31-50	46		31-50	36
51-70	32		51-70	20
70+	19		70+	3

8.2.2. General observations

There are significant differences between the average number of occupants per household in the UK and Libya: the average in Libya is 4.5 per household compared to 2.61 for the UK (Yohanis, 2012). The majority of the sampled households in Libya either have three occupants or six and above (31% and 49% respectively); the remaining 20% of the sampled households have one, two, four or five occupants.

The majority of the primary occupants are between 31 and 50 years old and an important proportion of the respondents are in the retirement age range, with 19% over 70 years old. In contrast only 3% of the primary occupants surveyed are under 30 years old. When all the occupants are considered, 3% are over 70 years of age and 41% are under the age of 30. This is an essential point, since those younger age groups may hold different opinions or attitudes towards energy use.

The results demonstrate that 8% of the occupants in the surveyed homes are unemployed and 22% are retired. The 'other' group (15%) includes housewives and students living in single-parent families. Few students are primary occupants of houses. The employed occupants are representative of the general population, with a broad range of occupations. The yearly household income has been divided into five income brackets. The results are based on 429 households, as 45 homes did not wish to disclose their income. 139 of the surveyed households have a low income, due to the householders being permanently disabled and/or being pensioners. The sample also includes 36 households from higher income ranges. The various income groups in the study are considered to be a reasonable representation of the wider population.

8.3. Electricity demand and load variation in Libya

Since our focus is directed to the relationship between energy consumption behaviour by Libyan households and the overall energy demand in Libya, it is reasonably important to find the extent of the link between the electrical local loads and householders' consumption patterns in Libya. In this regard, generally most months in Libya are hot, with a mean temperature exceeding 35°C in the eastern regions, and temperatures can exceed 50°C in the south during the hottest months of the year. In winter, meanwhile, the temperature can fall below 0°C and this is associated with a high rate of electricity consumption (Almathnani, 2006; Mohamed et al., 2013b).

Libya's need for electricity is estimated to grow rapidly (an expected average annual growth rate of 7 to 13%). In order to meet this rise, the Libyan government expects the amount of fossil fuels required for power generation to increase by 250% by the year 2020 (Mohamed et al., 2013a). The fact that the government heavily subsidises current consumption costs is leading to rapid energy demand growth, with customers paying one-third of the cost of generation per kWh (Mohamed et al., 2013a, 2013b). The total electricity generation by the General Electricity Company of Libya (GECOL) in 2012, produced from fourteen main power stations, was about 33,980 GWh and required circa 6 billion m^3 of natural gas, 2.3 million m^3 of light fuel oil and 805 thousand m^3 of heavy fuel oil (Khalil et al., 2009; Mohamed, 2010; Waniss and Karlberg, 2007). GECOL has difficulties in meeting demand with a suitable expansion of capacity; hence power shortages are starting to necessitate programmed electricity cuts in several cities, including the capital city, the second largest city, Bengazhi, and other cities, for six or more hours per day (Affairs, 2010).

One of the most important challenges to the load-management engineers in each electrical energy system is electrical load forecasting. The data received from GECOL during the author's visit to Libya is presented in Figure 2-6. Based on strategic studies of electrical demand forecasts and expansion in production during the period 2013-2020, Figure 2-6 (p 27), demonstrates the peak load of the general network, which was about 6,062 MW during the period between 2002 and 2013 with an annual increase rate of about 10%, excluding the drop in consumption in 2011 due to the period of political instability during that year.

According to the Information and Planning Department at GECOL, several factors – political, climatic, demographic and economic – are involved in the load forecasting system. It can be seen from Figure 2-6 that the peak load of electricity is increasing gradually, and the possibility of increasing the capacity of existing plants is not economically viable as they need significant expensive maintenance and upgrades. In addition, the establishment of new plants requires time and significant investment, which is one of the many problems facing the current government in Libya at the moment.

Energy insecurity is an existing problem in Libya and has begun to fester since many areas are experiencing a real crisis as a result of complete or relative absence of electricity. As such, the study of the behaviour of the energy consumers and an effort to change it can be an essential part of the solution to the problem of energy security and this can lead to a reduction in the peak load of electricity usage and public spending on energy.

Energy waste reduction in certain places, such as cities, can help the government to redistribute the available energy to areas in need of energy. Figure 8-1 illustrates the monthly variation of the Libyan electrical load and the average readings of temperature in the year 2012 as an example. The data in Figure 8-1 has been provided by the Information and Planning Department at the GECOL, and shows an increased peak load during the winter and summer seasons, months 12, 1 and 2 for winter and 6, 7, and 8 for summer. Figure 8-1 shows also a decrease in monthly loads during spring (months 3, 4 and 5) and autumn (months 9, 10 and 11). This is a clear indication that significant energy is used for space heating and air conditioning.

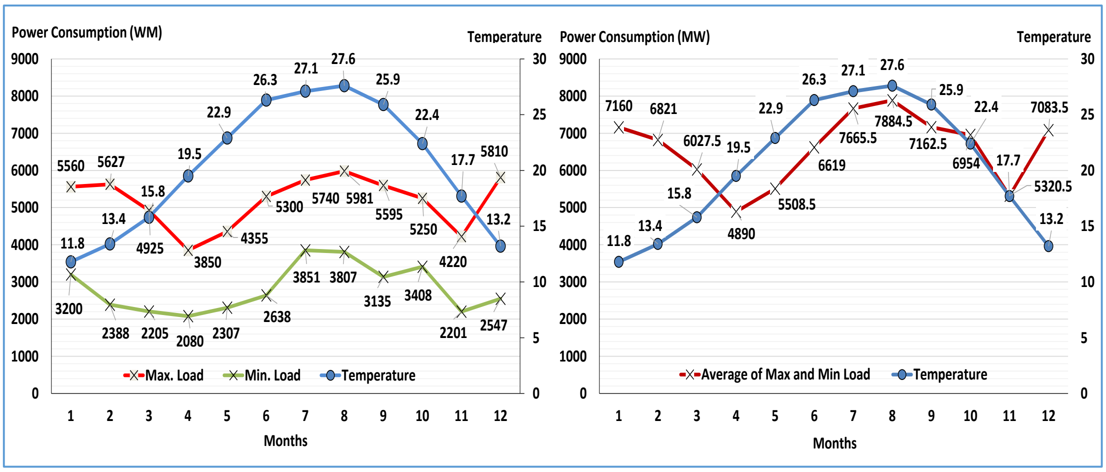


Figure 8-1: The monthly load and the average temperature in 2012.

With the aim of investigating the energy consumption in Libyan homes to achieve better understanding of energy consumption, the following sections present the results of the survey. In order to estimate the financial cost of an appliance's energy use, the authors have used the Libyan Electricity Tariff, as shown in Table 2-7 (p 28).

8.3.1. Cooling, heating and hot water supply systems

Air conditioning, space heating and hot water supply are three major areas of domestic energy consumption. The characteristics of the cooling and heating systems – type, age and frequency of supplementary cooling and heating, controllers for immersion heaters, shower facilities and methods of water heating in the respondents' dwellings

– are demonstrated in Table 8-3. The data shows that 41% of houses have central air-conditioning systems, where 40% are ducted systems (central heating and cooling of most rooms or the entire house simultaneously) and 1% uses multi-split systems (more than one internal unit connected to an external compressor). Only 1% have portable air conditioning and 3% do not have air conditioning systems at all, while 55% of the households have room air conditioning systems (split unit). 82% of homes have cooling and heating with central air conditioning, 10% of the households have heating powered by portable gas cylinders and 6% of homes use other types. 100% of air conditioning systems in Libya are electrical; this implies a requirement for a significant electricity supply to meet the demand arising from the use of air conditioning systems in Libya for both cooling and heating purposes.

In terms of the frequency of use of cooling systems, 60% of householders use it most of the time in summer, while in winter only 9% use cooling most of the time. Heating systems are used most of the time by 55% of the respondents during winter but only 13% use it most of the time during summer.

Table 8-3: Air conditioning and heating systems in the 429 surveyed homes.

Type of domestic air-conditioning system	%	Types of energy for air-conditioning	%
Central air-conditioning system: multi-split-systems	1	Oil	0
Central air-conditioning system: ducted systems	40	Gas	0
Split unit room air-conditioning system	55	Electric	100
Portable air-conditioning system	1	Coal fire	0
none	3		
Frequency of use of cooling in summer	**%**	**Frequency of use of cooling in winter**	**%**
Few times	36	Few times	20
Most of time	60	Most of time	9
Once a week	0	Once a week	0
Never	8	Never	71%
Age of air-conditioning systems	**%**	**Types of energy for heating**	**%**
<5 year	25	None	3%
5-10 years	67	Gas	10
15+	8	Coal fire (charcoal)	1
		oil	5
		Electric	81
Frequency of use of heating in summer	**%**	**Frequency of use of heating in winter**	**%**
Never	41	Never	3
Few times	44	Few times	42
Most of the time	13	Most of the time	55
Once a week	2	Once a week	0
Types of building heating system	**%**	**Age of heating system**	**%**
Cooling and heating with Central Air-conditioners	33	<5 year	41
Gas heater	12	5-10 years	44
Cooling and heating with split units air-conditioning systems	49	15+	15
others	6	Age of heating system	0
Method of kitchen/bathroom taps water heating	**%**	**Types of control for immersion heaters**	**%**
Central heating system	0	Thermostat with Timer/programmer	2
Immersion heating	97	Thermostat	97
Gas heater	1	On/off control only	1
others	2		
Shower facilities		**%**	
Instant Electric shower		1	
Immersion heater shower		99	

In 97% of the homes surveyed, domestic hot water for the kitchen and bathroom taps is provided by immersion heaters. 1%of homes use gas heaters and 2% use another heating method. 99% of the homes use immersion heaters for their showers, while only 1% use instant electric showers.

There is a need to use heating from solar technologies to reduce both wastage of energy and the electrical peak load. Many studies have shown the feasibility of the utilisation of renewable energy technologies in Libya, see for example (Mohamed et al., 2013a).

In relation to immersion heaters, 97% have normal thermostats while 2% have thermostats combined with a timer/programmer which helps to reduce energy use if properly employed. Only 1% of households had on/off control switches to water heaters, this is mainly the case for portable immersion heaters.

8.3.2. Domestic appliances

With the improvement in the style of living in Libya, there has been an increasing use of fridge-freezers, dishwashers, microwave ovens, electric ovens, electric kettles, electric cookers, and tumble driers in households. Table 8-4 and Figure 8-2 show the ownership percentages for various household appliances in the surveyed households.

There have been growing numbers of households with multiple television sets, DVD players and computers, and in general there seems to have been an increase in the number of appliances used in Libyan houses at the time of the current survey compared to the previous five years. For example, 26% of homes now have DVD players in comparison to the prior five years where only 13% had one. Ownership of computers also increased, from 22% five years ago to 84% during the time of the survey. The current survey shows a decrease in the usage of stereo systems, from 35% to 21% in the sample of the study. The percentages of households with a given number of TV sets are as follows: one (31%), two (42%), three (16%), four (4%) and five or more (7%). This increase in TV sets has a significant effect on electricity peak load, not only in relation to the power consumption of the TVs themselves, but also because of the social aspects of TV watching, and the use of air conditioning and lighting systems in different rooms. It has been observed that there is a direct correlation between multiple numbers of TV sets and increased energy requirements for heating/cooling and lighting; i.e. there is the opportunity to reduce heating, cooling and lighting power requirements by using fewer TV sets.

Table 8-4: Percentage of households with particular appliances.

Appliance	Current Year of the survey (2013)	%	Previous five years (2008-2012)	%	Difference
Washing machines	330	77	290	68	9
Fridge-freezers	250	58	115	27	31
Microwaves	30	7	30	7	0
TV sets	750	175	605	141	34
Iron	320	75	298	69	6
Stereo	92	21	152	35	-14
Computer	362	84	95	22	62
Tumble dryers	78	18	24	6	12
Dishwashers	201	47	52	12	35
Electric cooker	163	38	32	7	31
Electric oven	326	76	256	60	16
Electric kettle	180	42	36	8	34
DVD	110	26	56	13	13
Refrigerators	420	98	416	97	1
Video players	91	21	56	13	8
Gas cooker	389	91	415	97	-6
Gas oven	250	58	302	70	-12
Microwave oven	60	14	0	0	14
Video games	122	28	52	12	16
Immersion heater	907	211	580	135	76

% = Current numbers / 429 sample size * 100.

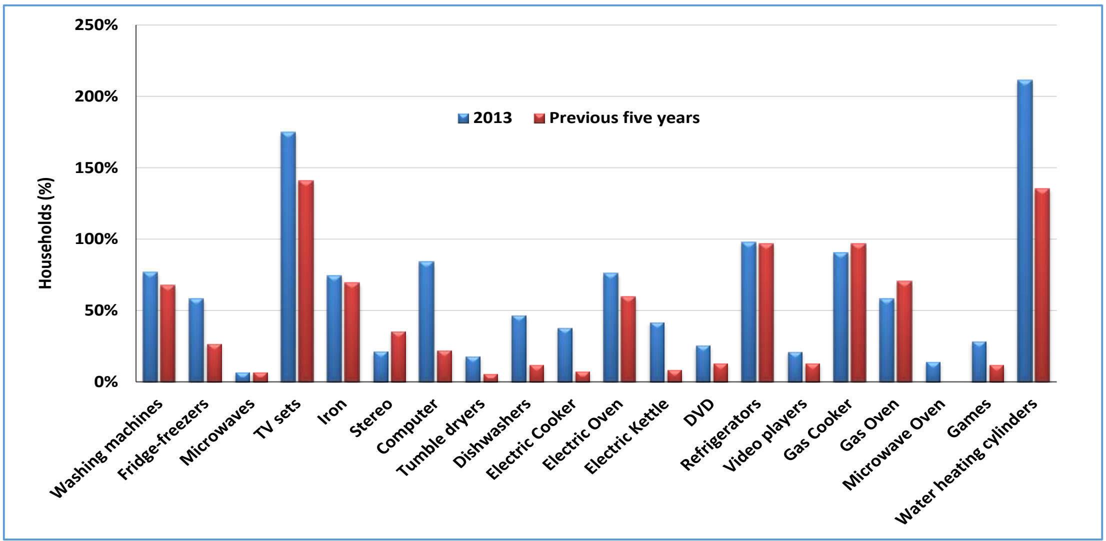


Figure 8-2: The number of appliances (a comparison between the current 2013 survey and the previous 5 years).

Table 8-5 demonstrates that the majority of household appliances have been purchased in the past five years. Full analysis of Table 8-5 shows that more than 66.7% of homes had replaced their washing machine or purchased a new one within this period. Similarly, over 81% of televisions and over 90% of computers had been purchased in the same five-year period. There were, consequently, possibilities to purchase energy-efficient appliances had buyers been made aware of energy issues linked with the rating of appliances, and if they had then chosen to do so.

The analysis shows that there have been increasing purchases of electric cookers, ovens and kettles, 76%, 81% and 87% respectively. On the other hand, there has been a remarkable decrease in the purchase of gas cookers and ovens (36% and 39%). Since the government's construction trend is towards high rise buildings without the use of a gas network (i.e. gas-powered appliances require gas cylinders), people find the use of electric appliances easier and safer than gas appliances in tower buildings. This is in fact another pressing factor from the demand side for electricity in Libya and must be met by sufficient supply; otherwise energy insecurity will be clearly and severely present.

Table 8-5: Percentages of appliances in different age brackets.

Name of appliances	Age brackets(years) Numbers of appliances %				
	<0.5	1-2	3-5	5-10	11+
Washing machines	28.4	12.5	25.8	18.6	14.7
Fridge-freezers	17.6	21.7	33.6	21.5	5.6
Microwaves	12.3	16.5	25.9	33.5	11.8
TV sets	35.9	25.6	19.5	16.2	2.8
Iron	17.5	21.9	25.3	12.4	22.9
Stereo	0	0	5.3	21.1	73.6
Computer	31.1	25.3	33.1	9.2	1.3
Tumble dryers	22.9	15.2	18.9	10.2	32.8
Dishwashers	14.1	15.2	15.6	22.5	32.6
Electric cooker	25.3	28.6	22.3	12.6	11.2
Electric oven	32.3	26.9	21.5	14.6	4.7
Electric kettle	32.9	29.6	24.6	10.6	2.3
DVD	12.6	25.6	24.1	21.2	16.5
Refrigerators	12.6	28.6	22.1	16.9	19.8
Video players	21.6	23.6	16.8	25.4	12.6
Gas cooker	4.4	11.6	19.5	21.9	42.6
Gas oven	6.3	12.5	19.8	33.5	27.9
Microwave oven	0	15.6	28.7	21.8	33.9
Games	25.8	21.3	23.4	16.3	13.2
Immersion heater	3.6	11.4	24.8	25.3	34.9

8.3.3. Householders' awareness of the energy ratings of appliances

This section discusses what the surveyed Libyan households think about the energy ratings of their appliances. Figure 8-3 demonstrates that 91% of householders did not recognise the energy rating of their appliances. Possible explanations could include: the fact that the energy expenditure to income ratio is low enough for many people that they do not need to be concerned about their energy expenditure; possible relative affluence in society; the absence of full understanding of information regarding energy efficiency; the fact that the energy rating of appliances lacks government regulation; or ineffective energy information communication (Cathy, 1999)(Yohanis, 2012). Of the remaining householders, of the 9% who claimed to be aware of their appliances' energy rating the rating submitted via the survey has been found valid for only 2% of households, indicating that 98% of the householders either do not know the actual ratings of their appliances or are not aware of the rating system at all. The vast majority of the surveyed householders have indicated that price, brand and reliability are the main factors taken into account in the selection of a new appliance; only 3% of householders cited energy rating as the main factor, as shown in Table 8-6.

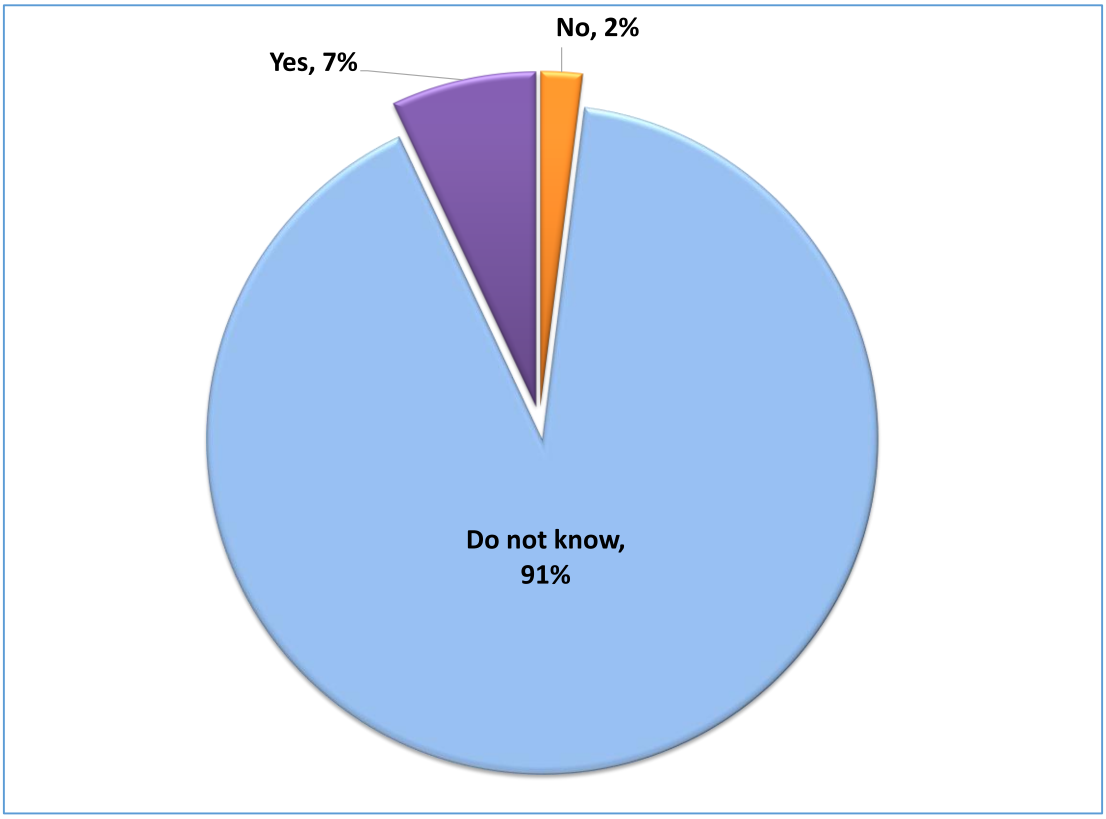


Figure 8-3: Householders' thoughts of the ratings of their household appliances.

Source: Author's own.

Table 8-6: Factors that affect the purchase of household appliances.

Factors that affect purchase of household appliances	Importance
Price	39%
Brand	17%
Reliability	15%
Brand and price	12%
Price and energy rating	11%
Energy rating	3%
Never energy rating	2%
Other	1%

8.3.4. Energy consumption behaviour in Libyan households

There is no significant variance in the number of night and day hours in Libya during the year. However, summer is characterised by warm temperatures and dry winds accompanied with dust, while in winter there is a reduction in temperature and possible rain. Figure 8-4 demonstrates the frequency of the use of washing machines, tumble driers, electric cookers and irons in the surveyed homes in winter and summer. The usage of tumble driers in winter is higher than in the summer, while in the case of washing machines, the frequency of use continued almost the same throughout the year. The frequency of using electric cookers per week in the summer is higher than in winter, but the use of the iron is almost the same in both seasons. Although there is often dust during the summertime, the frequency of drying line use in the summer is more than in winter. In both winter and summer the average number of times washing machines are used per week per household are 3.81 and 3.18 respectively. Some homes use their washing machines over ten times per week and their tumble driers up to ten times per week.

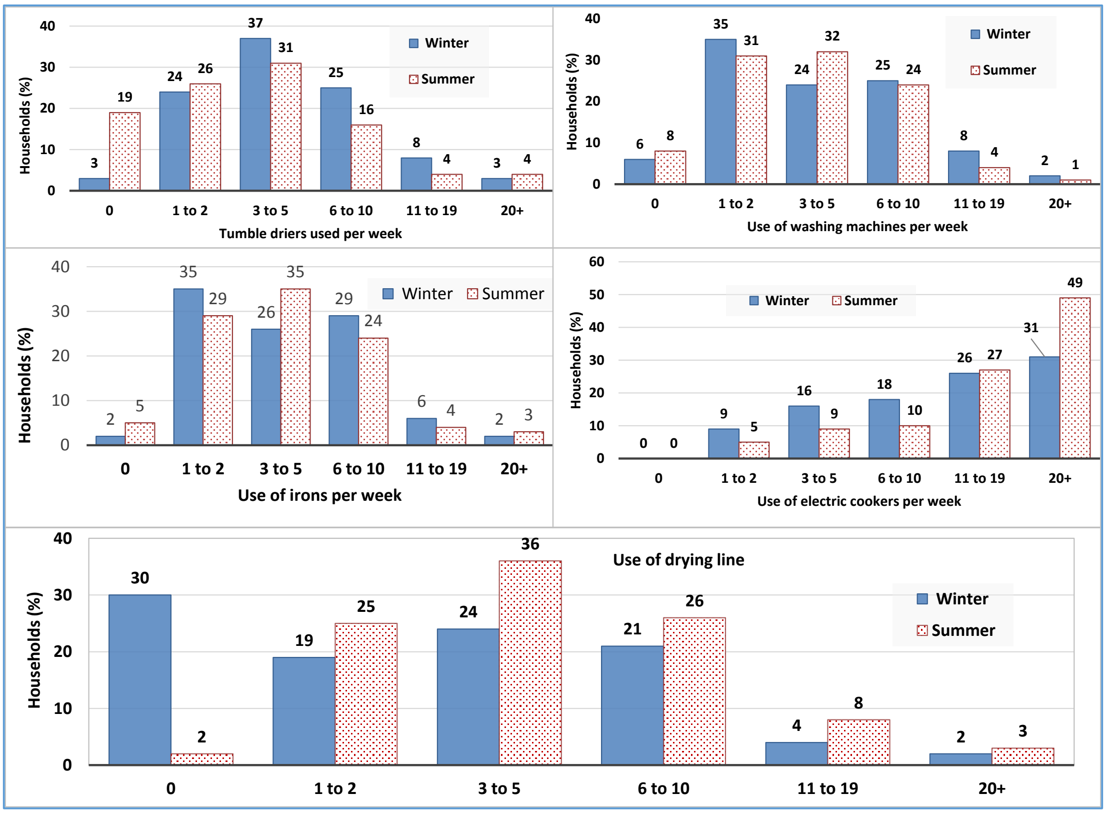


Figure 8-4: Weekly use of some appliances by households in Libya.

Source: Author's own.

In terms of energy consumption, the most used domestic appliances are washing machines, tumble driers, electric cookers and irons. These appliances could use less energy if they had better energy ratings, shorter or cooler washing cycles, reduced frequency of use, or if drying lines were used instead of tumble driers in which there is a possible benefit from the sun, although in dusty weather people might well avoid using them.

8.3.5. Domestic lighting

According to a report from the Libyan Ministry of Planning (IMF, 2012) (Global Insights 2012), the power required to run all the appliances for a home with an area of 450 m^2 inhabited by a typical family was about 85 kWh daily (Huda and Fatema, 2012)(IMF, 2012). According to the householders' survey, it is apparent that 25% of the electricity consumed is used in lighting (DTI, 2003). Therefore, in order to make a significant reduction in domestic energy consumption in Libya, it is recommended that energy-efficient lighting be used; this should be coupled with an expansion of the awareness of the advantages of energy-saving lighting among the Libyan people.

As a consequence of the high prices for energy-efficient lighting and the lack of new regulations or a tax system to limit the use of traditional lighting, the majority of lighting still uses traditional light bulbs. Combating this requires the government, educational institutions and the media to improve the awareness of more sustainable lighting technologies.

The researcher has found that 18% of households use energy-saving lighting somewhere within the house. Figure 8-5 demonstrates the percentages of homes where fluorescent, halogen and traditional light bulbs are used. In Libya traditional bulbs are popular for many reasons. The luminous efficacy of traditional light sources like incandescent bulbs is about 11-12 lm/W, and to truly substitute a 40W incandescent light bulb, the luminous flux must reach at least 450 lm/W (LEDinside, 2011). Old people cannot see very well, they need a strong light, but people of more or less any age still buy traditional bulbs in any case (Yohanis et al., 2005). Many people do not like the new bulbs (BBC, 2013) due to the time required for the bulb to reach full illumination or the quality of light. Furthermore, they are of little advantage in rooms which are rarely used. Halogen bulbs are often used in groups of three, four, or six or more as spotlights within a room, operated by a single switch. In spite of the fact that they are used in fewer homes than traditional or fluorescent tubes, their total number is larger. Halogen bulbs with only 20 lm/W are less efficient than fluorescent tubes which can generate up to 90 lm/W (Labcraft, 2011). Therefore, the usage of fluorescent bulbs is the clear choice from an energy consumption point of view (Yohanis et al., 2005).

As demonstrated in Figure 8-5, 66%, 13% and 4% of households did not have halogen, fluorescent or traditional light bulbs respectively. 13% of households used halogen bulbs inside and 21% outside. 32% of households used fluorescent tubes indoors and 55% outdoors. 61% of households used traditional bulbs inside and 34% outside. Almost 77% of householders leave lights on, both indoors and outdoors, for security reasons when they are out and only 2% use a timer or sensors on any of their lighting at any time. The use of energy-saving light bulbs in the hallway is 21%, in the master bedroom and other bedrooms the proportions are 19% and 17% respectively, in the bathroom 14% and in the kitchen 6% (see Figure 8-6).

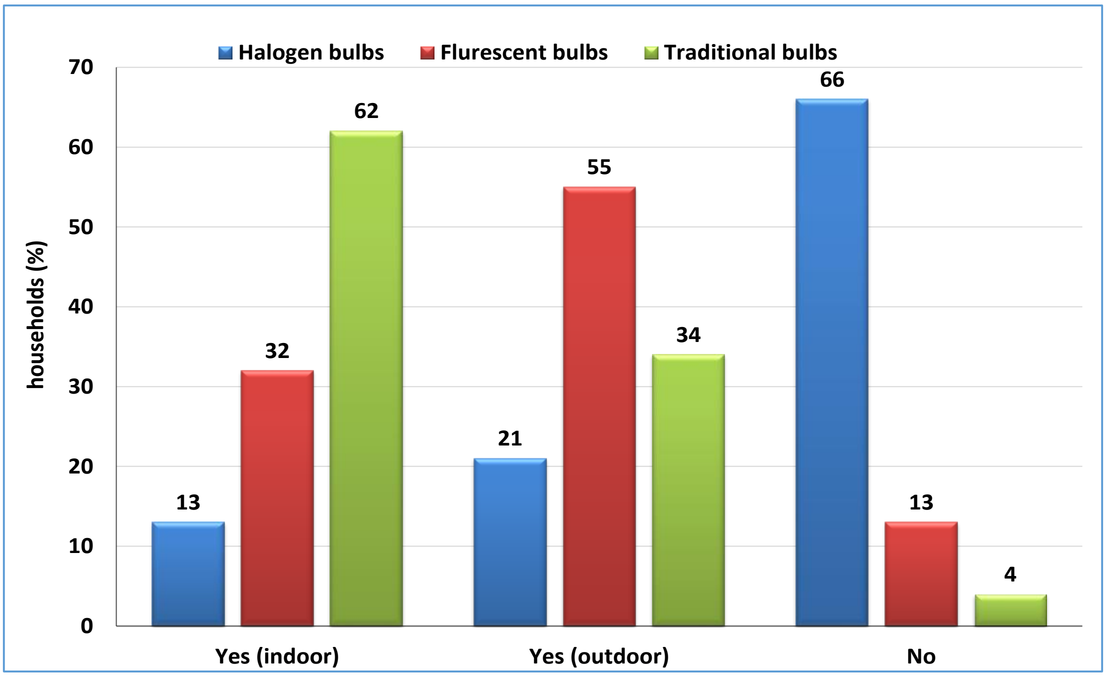


Figure 8-5: Percentage of homes with fluorescent, halogen and traditional lighting.

Source: Author's own.

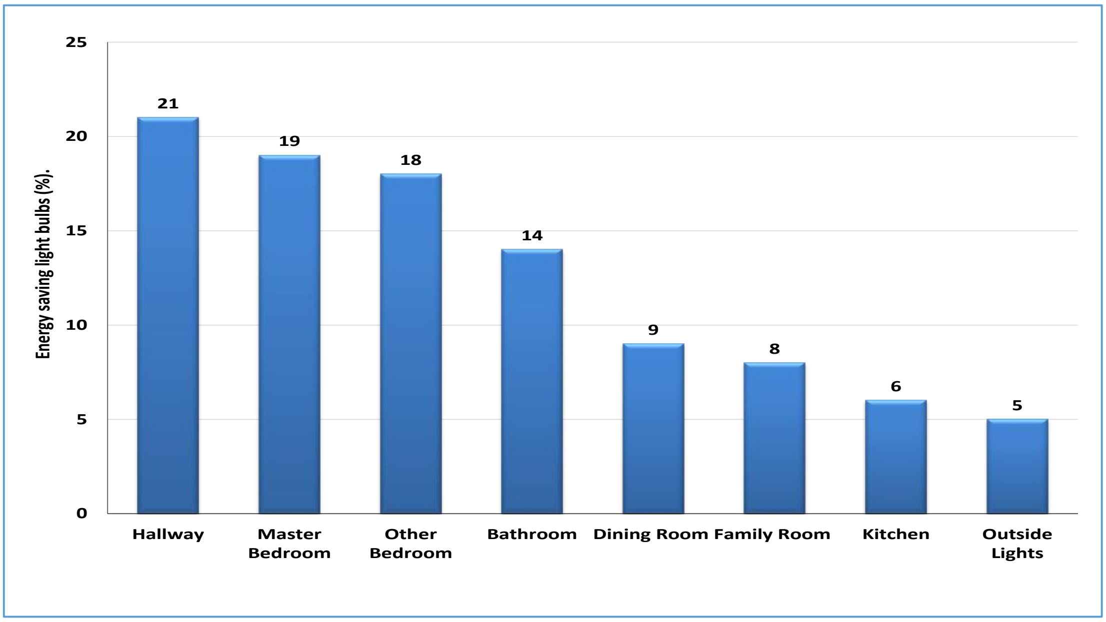


Figure 8-6: Location of energy-saving light bulbs in Libyan households.

Source: Author's own.

The extent to which security lighting is used differs widely, with the duration varying from every single day and all night, to only when residents are out. The number of lights varies from a single light to multiple lights, and the rating of bulbs ranges from 40W to 500W lamps. For this reason, it is not possible to measure the amount of electricity used, but observation has revealed that while the amount of electricity consumed is not huge on a per-dwelling basis, the use of timers would make a useful reduction in the consumption of energy from the network.

The change to more energy-efficient choices could help in saving energy as well as money. An old-fashioned traditional incandescent bulb (60W and 800 lumens) has an expected life of 1,000 hours, compared with fluorescent bulbs (14W and 800 lumens) which have 10,000 hours of life and LED light bulbs (16W and 800 lumens), which could have an average operating life of 25,000 hours.

Focusing on traditional and LED bulbs, the difference of power between them is 44W. If the traditional light bulbs noted in Figure 8-5 were to be replaced by LEDs for Libyan domestic households, the energy savings in one year can be calculated – based on the number of domestic households of 905,970 in Libya – as approximately 170 GWh, which is equivalent to 34 million LD (approximately £17 million). This is a significant reduction of electricity usage, and worth the effort of the government and society as a whole to bring it about.

8.4. Energy behaviour and energy awareness

8.4.1. General awareness of energy issues

Figure 8-7 illustrates the awareness of householders of a number of energy-saving measures. The figure illustrates that residents are in fact aware of many ways that energy can be saved. For example, 64% are aware that a microwave oven is more energy-efficient than a gas or electric oven for cooking or reheating food, 58% are aware that the use of an immersion heater thermostat reduces energy waste, and 43% are aware that using a thermostat for room temperature control can save energy. 62% and 57% are aware of the energy-saving benefits of limiting the temperature during summer in the bedroom and the living room respectively. The 75% of respondents aware that energy can be saved by fixing leaky taps is the highest level of awareness, while only 33% were aware that washing at low temperatures reduces energy expenditure. These statistics reveal that Libyan householders are in fact aware of a good number of energy-efficiency measures, however applying these measures in practice seems to be another issue.

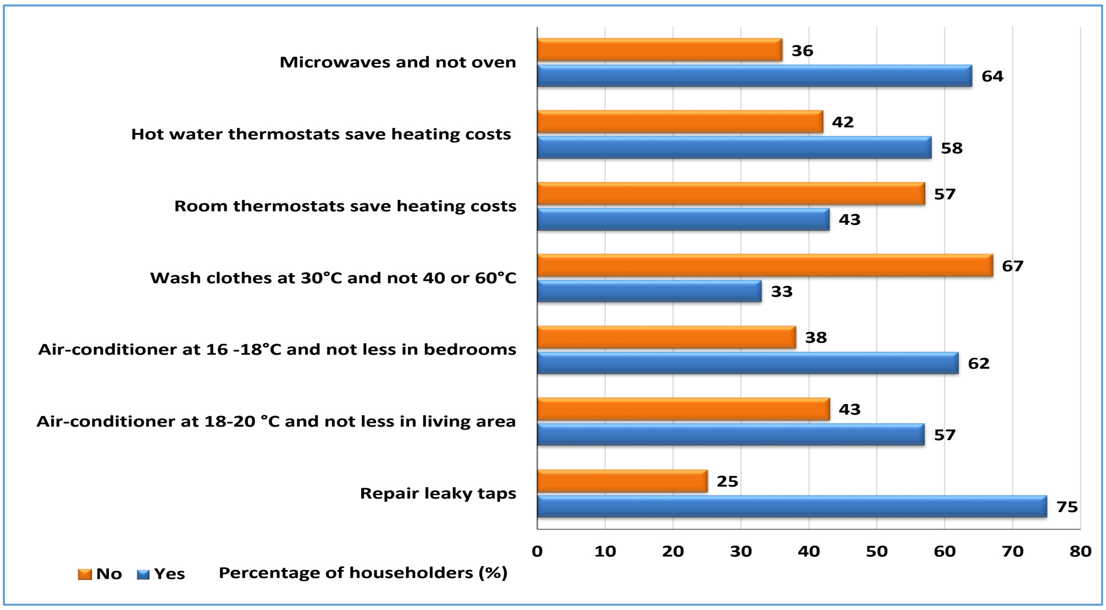


Figure 8-7: Libyan householders' general awareness of some energy-saving measures.

Source: Author's own.

8.4.2. Views on energy-efficiency measures and associated investment

Householders were asked for their opinions on a further variety of energy-saving measures to evaluate their awareness of these specific measures. The results are illustrated in Figure 8-8.

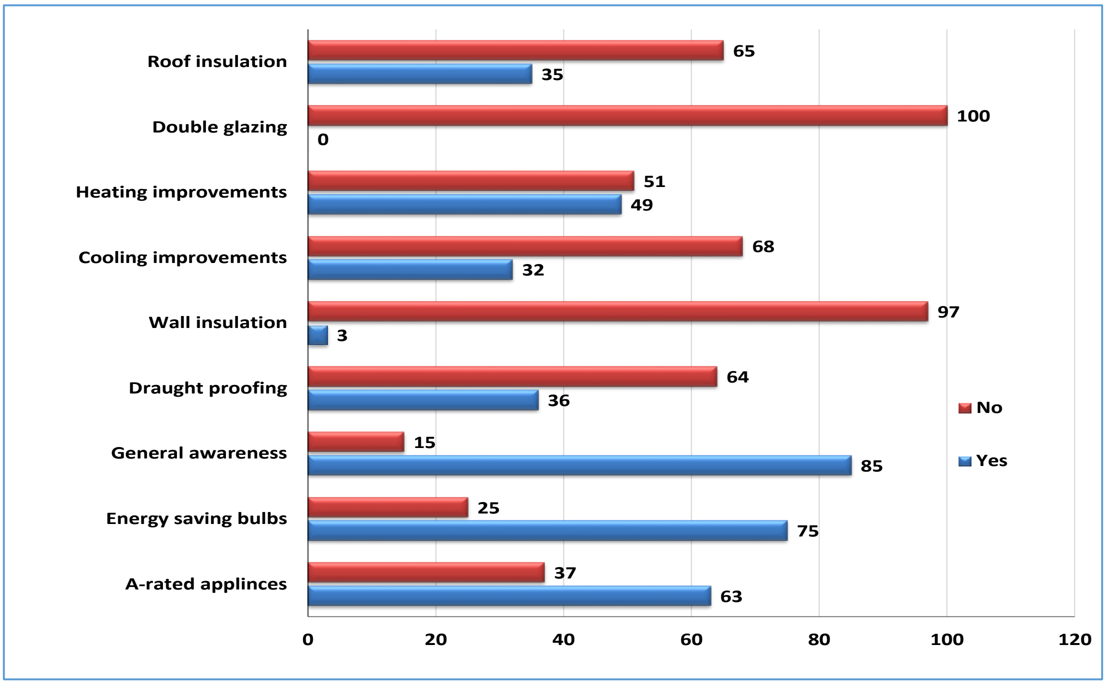


Figure 8-8: Householders' views on general efficiency and energy saving measures.

Source: Author's own.

Only 35% and 3% have considered that roof and wall insulation respectively help to conserve energy. When asked if they would consider upgrading the glazing in their houses to double glazing, there was no interest. With regard to improving their heating systems, which mainly means changing their oil-fired heaters for gas-fired heaters, 49% said yes and 51% said no. Improving cooling systems, which means considering the type of system installed depending on climate, cooling requirements and the specific design of the house, was less popular, with only 32% saying yes.

Figure 8-8 shows that the majority of Libyans are not interested in investing in energy-saving measures. The lack of understanding of and appreciation for energy-saving schemes is disappointing. One could argue that the financial investment related to the installation of these systems might be the problem. On the other hand, only 36% of the respondents considered installing draught proofing, even though the expenditure associated with it might be less significant. On the matter of using A-rated appliances and energy-saving light bulbs, 63% and 75% respectively would consider positive actions; clearly there is a larger appreciation of their benefits.

Figure 8-9 and Table 8-7 present the householders' views on some aspects of sustainability. Figure 8-9 illustrates the answers – ranging from 'strongly disagree' to 'strongly agree' – to the questions on a number of energy-saving matters: 'using green products would assist the environment', 'financial incentives would encourage energy saving', 'energy saving is economical', that there is a 'moral obligation to save energy', and that an 'individual's effort has an influence on the environment'. Above 43% believe that they have an ethical obligation to save energy, and over 60% agreed that individual work to save energy has a positive influence on the environment. More than 33% strongly agreed that energy-saving in the home is economically sensible, while 41% believe that a financial incentive would boost energy saving. 26% believed that 'green' products aid the environment. While it seems that the majority believe individual effort will have a positive impact on energy saving, there is a tendency towards neutrality on the subject of the other sustainability issues.

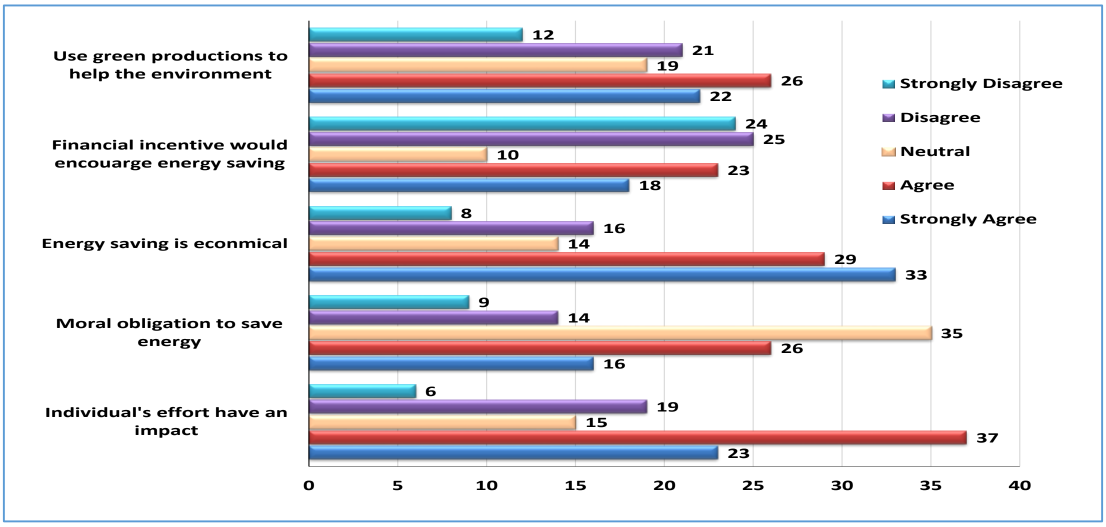


Figure 8-9: Householders' views on energy saving issues.

Source: Author's own.

Table 8-7: Householders' views on energy-saving behaviour.

Theme	Response (%)				
A: never; B: rarely; C: sometimes; D: usually; E: always.	A	B	C	D	E
Invest in energy saving devices	37	29	19	9	6
Leave appliances on standby	9	8	13	38	32
TV on whilst doing other things	5	13	19	41	22
Lower thermostat setting (heat)	42	26	13	11	8
Lower thermostat setting (cool)	35	31	16	12	6
Curtains open when heating is on	13	17	21	23	26
Curtains open when cooling is on	36	26	18	11	9
Only heat rooms that are used	21	17	12	24	26
Only cool rooms that are used	17	22	11	19	31
More clothes before heating	31	20	9	21	19
Less clothes before cooling	23	17	10	23	27
Use daylight as much as possible	16	15	21	27	21
Control of lighting level	22	19	13	22	24
Turn lights off	11	15	21	24	29
Use clothes line	7	12	19	21	41
Dryer at full load	7	12	8	21	52
Dishwasher at full load	6	18	21	24	31
Washing machine at full load	4	9	21	31	35
Match dishwasher cycle to load	12	15	21	24	28
Lids on when cooking	6	9	16	48	21
Shower or half-full bath	3	9	15	22	51
Fill kettle only to requirements	11	21	19	13	36
Use cooker not kettle for boiling water	13	22	19	16	30
Use appropriate size cooking pots	14	21	14	25	26

Table 8-7 demonstrates that only 15% of residents said that they would usually (9%) or always (6%) invest in energy-saving technologies, with an additional 19% saying they would sometimes; the remaining 66% said they would either rarely or never invest in energy-saving technologies. The ratio of those who would leave appliances on standby to those who would not is about 70:30 respectively. However, this gives a promising opportunity for a reduction in energy use; the aim must be to exclude standby usage, not only to decrease energy use, but also for health and safety reasons.

In terms of standby, the number of householders who say they would leave their everyday appliances such as televisions, computers, washing machines, dishwashers, mobile phone chargers, satellite receivers and other video equipment, printers, microwave ovens, air conditioning systems, and audio equipment on standby mode is quite high (70%). This leads to a significant loss of energy and this contributes to the energy security problem in Libya. For example, if digital TVs and satellite receivers (less than ten years old) are left on standby for eight hours per day, with an average TV number of 1.75 per household (750 TVs/429 sample size) and an average standby energy use of 10 watts, the energy wasted in one year will be 10 watts × 1.75 TVs × 8 hours × 365 days / 1000=51.1 kWh per year per household. Consequently, the total electricity used from leaving just this equipment on standby across the Libyan population is (905,970 domestic householders × 70% of households who leave their appliances on standby mode) = 634,179 × 51.1 kWh = 32 GWh. This costs about 32 GWh × 0.20 Dirham = 6.5 million LD yearly (approximately £3.25 million).

Over 17% of the households responding would lower the thermostat settings of their heating systems and over 18% would lower the thermostat settings of their cooling systems. 49% would leave curtains open usually or always when heating is on, and 20% would leave curtains open usually or always when the cooling system is on. Approximately 38% would (never 21% or rarely 17%) not restrict heating and around 39% would (never 17% or rarely 22%) not restrict cooling to only the rooms that are in use. With regard to putting on more clothes before switching on the heating, 51% said they would not. At the other extreme, 40% said they would not put on fewer clothes before switching on the cooling system.

Over 48% would use daylight as much as possible and almost the same number of residents would control the use of lights in their homes: more than 53% believed that they would turn lights off in rooms which are not in use.

Energy use in Libya is growing, and utilising renewable energy could decrease some of the pressure on the energy supply.

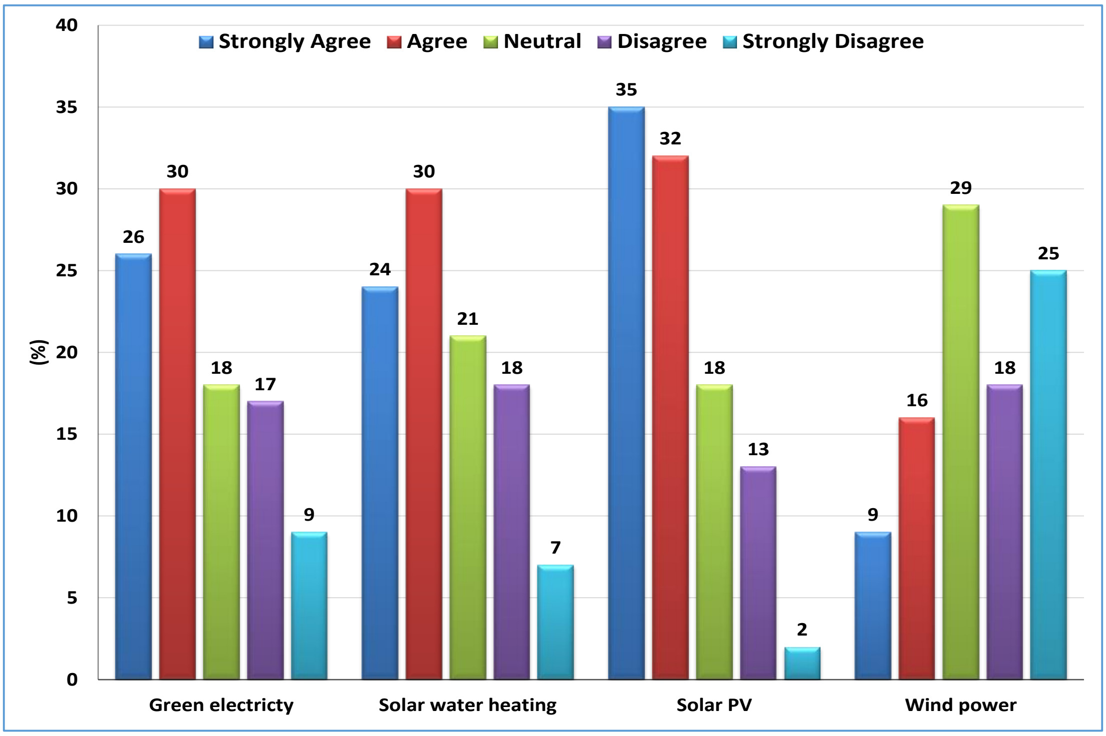


Figure 8-10: Householders' behaviour regarding renewable energy resources and CO_2 reduction schemes.

Source: Author's own.

Figure 8-10 presents the attitudes of householders to renewable energy resources. It shows that more than 56% support green electricity, although a significant number (18%) are neutral on the topic, representing possibly a lack of familiarity with what green electricity is. With regard to the installation of solar water heating systems, solar PV or wind power systems, over 54% expressed support. Those in disagreement in each case are a much smaller group (less than 4%), which is promising.

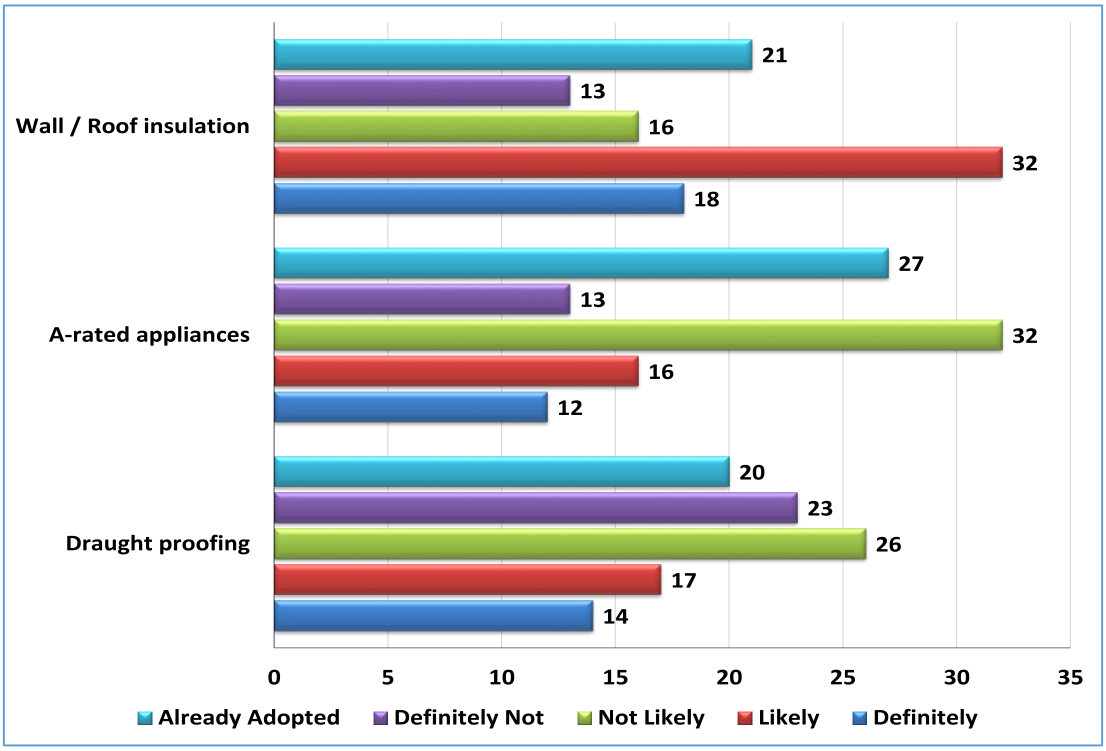


Figure 8-11: Householders' possible future investments in energy-saving measures.

Source: Author's own.

Figure 8-11 presents the future plans of the householders in relation to renewable measures. The householders who have answered that they will definitely pursue a given measure are 18%, 12% and 14% for wall/roof insulation, A-rated appliances and draught proofing respectively. This is a clear indication that most people do not have sustainability measures on their future agenda for energy improvement.

From the viewpoint of a policy maker with the aim of accomplishing a decrease in household energy usage, it would be essential to adopt a strategy that includes a variety of measures and tools, and the delivery of information is just one of them (Carrico et al., 2011). Table 8-8 presents the views of the surveyed householders on the best method of obtaining information on energy issues. Energy bills placed first (56%) followed by TV and newspapers. This is in line with Mullaly's findings (Fatema and Huda, 2012), where 73% believed that utility companies should offer better information concerning the energy consumed by a variety of appliances. A number of researchers have examined the nature of the information required and how best to offer it (Lutzenhiser, 1993)(Stern et al., 2010). This examination has revealed that general energy awareness is good, but that residents' implementation of energy-efficiency measures does not necessarily match their level of awareness.

Table 8-8: Householders' views on the most suitable method of obtaining information on energy issues.

Preferred method of receiving information	Response (%)
Energy bills (monthly or quarterly)	56
Newspapers	14
Telephone helpline	0
Literature	3
TV programmes	25
Radio	2

8.5. Adjustment in occupants' behaviour

To measure the importance of consumer behaviour on energy demand, the information from the survey has been compiled – based on the average characteristic of the Libyan consumers – to present the average behaviour of a Libyan household, as shown in Table 8-9. The table presents estimated average energy (kWh) and cost (LD) to run appliances for one house. The average energy consumption is 37,757.88 kWh per annum. The result for one household can be used with the full number of accounts (households) at the Libyan General Electricity Company, 905,970. The total monthly consumption can therefore be calculated as 905,970 × 3.147 MW = 2,850,626 MWh (circa 2,850 GWh). The total actual cost for the same population is 905,970 accounts × 1,318.516 = 1,194 million Libyan dinars per year (circa £597 million).

To investigate the relevance of improving energy usage behaviour, the author has created an improved scenario, as presented in Table 8-10. The author has made some modifications and improvements in the occupants' behaviour as a sustainability measure, including a scenario of possible reductions in the number of appliances, weekly frequency of use and daily hours of use. The calculations have been done for the same average household as in Table 8-9.

Table 8-9: Estimated average energy (kWh) and cost (LD) to run appliances for one house.

Householders' frequency of use (kWh and cost)										
Appliance	Rating	Number of Appliances	Frequency of use per week	Hours Used Per day	Total kWh used				Total cost (LD)	
					Daily	weekly	monthly	yearly	monthly	yearly
Immersion heater	3000W	3	7	3	27.00	189.0	810	9720	16.200	428.000
Washing machine	1200-3000W	1	3.5	1.3	2.86	10.0	43	515	0.858	10.296
Hairdryer	1000W	1	3	0.3	0.30	0.9	4	46	0.077	0.926
Iron	1000-1800W	1	4	0.3	0.42	1.7	7	86	0.144	1.728
Electric oven	2000-2200W	1	4	1	2.10	8.4	36	432	0.720	8.640
Tumble dryer	2000-4000W	1	3.5	2	6.00	21.0	90	1080	1.800	22.400
Kettle	2200-3000W	1	14	0.2	0.52	7.3	31	374	0.624	7.488
Air-conditioning Room in summer and spring	1000W	3	7	6	18.00	126.0	540	6480	10.800	266.000
Air-conditioner Room in winter and autumn	1000W	3	7	5	15.00	105.0	450	5400	9.000	212.000
Grill/hob	1000-2000w	1	2	1	1.50	3.0	13	154	0.257	3.086
Microwave and oven	700-1100w	1	5	2	1.80	9.0	39	463	0.771	9.257
Vacuum Cleaner	500-1200W	2	5	2	4.40	22.0	94	1131	1.886	23.943
Plasma TV	208-450W	3	7	7	9.09	63.7	273	3273	5.456	105.674
LCD TV	125-200W	4	7	7	6.30	44.1	189	2268	3.780	62.000
Freezer	150W	1	7	5	0.75	5.3	23	270	0.450	5.400
Fridge	40-120W	1	7	5	0.50	3.5	15	180	0.300	3.600
Video, DVD OR CD	100W	3	7	3	0.90	6.3	27	324	0.540	6.480
Desktop computer	80-150W	1	7	4	0.62	4.3	19	223	0.372	4.464
Laptop	20-50W	3	7	3	0.41	2.8	12	146	0.243	2.916
Broadband router	10W	1	7	24	0.24	1.7	7	86	0.144	1.728
Deep fryer	1200W	1	3	1	1.20	3.6	15	185	0.309	3.703
Toaster	800-1500W	1	7	0.3	0.47	3.3	14	167	0.279	3.348
Window fan	200W	4	7	6	4.80	33.6	144	1728	2.880	62.000
Lights	100w Incan	9	7	4	3.60	25.2	108	1296	2.160	28.880
Lights	75w Incan	4	7	6	1.80	12.6	54	648	1.080	12.960
Lights	60w Incan	6	7	3	1.08	7.6	32	389	0.648	7.776
Lights	40W Halogen	6	7	8	1.92	13.4	58	691	1.152	13.824
					113.57	734.181	3146.49	37757.88	62.930	1318.516

Incan: incandescent lamps (traditional old bulbs).

Source: Appliance's rating is Centre for Sustainable Energy (Stern et al., 2010). Remaining data authors' own based on survey.

Table 8-10: Improved average energy consumption and cost for one household.

Householders' frequency of use (kWh and cost)										
Appliance	Rating	Number of Appliances	Frequency of use per week	Hours Used Per day	Total kWh used				Total cost used	
					daily	weekly	monthly	yearly	monthly	yearly
Immersion heater	3000W	2	7	3	18.00	126.0	540	6480	10.800	266.000
Washing machine	1200-3000W	1	2	1.3	2.86	5.7	25	294	0.490	5.883
Hairdryer	1000W	1	2	0.3	0.30	0.6	3	31	0.051	0.617
Iron	1000-1800W	1	2	0.3	0.42	0.8	4	43	0.072	0.864
Electric oven	2000-2200W	1	3	1	2.10	6.3	27	324	0.540	6.480
Tumble dryer	2000-4000W	1	2	2	6.00	12.0	51	617	1.029	12.343
Kettle	2200-3000W	1	7	0.2	0.52	3.6	16	187	0.312	3.744
Air-conditioner Room in summer and spring	1000W	1	7	6	6.00	42.0	180	2160	3.600	62.000
Air-conditioning Room in winter and autumn	1000W	1	7	5	5.00	35.0	150	1800	3.000	62.000
Grill/hob	1000-2000w	1	2	1	1.50	3.0	13	154	0.257	3.086
Microwave and oven	700-1100w	1	3	2	1.80	5.4	23	278	0.463	5.554
Vacuum Cleaner	500-1200W	1	2	2	2.20	4.4	19	226	0.377	4.526
Plasma TV	208-450W	1	7	7	3.03	21.2	91	1091	1.819	22.735
LCD TV	125-200W	1	7	7	1.58	11.0	47	567	0.945	11.340
Freezer	150W	1	7	5	0.75	5.3	23	270	0.450	5.400
Fridge	40-120W	1	7	5	0.50	3.5	15	180	0.300	3.600
Video, DVD OR CD	100W	3	7	3	0.90	6.3	27	324	0.540	6.480
Desktop computer	80-150W	1	7	2	0.31	2.2	9	112	0.186	2.232
Laptop	20-50W	2	7	2	0.18	1.3	5	65	0.108	1.296
Broadband router	10W	1	7	18	0.18	1.3	5	65	0.108	1.296
Deep fryer	1200W	1	2	1	1.20	2.4	10	123	0.206	2.469
Toaster	800-1500W	1	7	0.3	0.47	3.3	14	167	0.279	3.348
Window fan	200W	2	7	2	0.80	5.6	24	288	0.480	5.760
Lights	100w incan	1	7	4	0.40	2.8	12	144	0.240	2.880
Lights	75w incan	2	7	4	0.60	4.2	18	216	0.360	4.320
Lights	60w incan	8	7	3	1.44	10.1	43	518	0.864	10.368
Lights	40W Halogen	14	7	6	3.36	23.5	101	1210	2.016	26.288
					62.391	348.737	1494.587	17935.046	29.892	542.909

[1]Total kWh used: (Daily = rating × hours used per day ÷ 1,000 × quantity of given appliance)

(Weekly = rating × hours used per day ÷ 1,000 × quantity of given appliance × number of uses weekly)
(Monthly = rating × hours used per day ÷ 1,000 × quantity of given appliance × (30 days ÷ 7 days))
(Yearly = rating × hours used per day ÷ 1,000 × quantity of given appliance × (12 months))
Total cost used: account regarding to a company slaps table shows above.

The above table shows the real average of the householders' consumption sample and the cost through the year of 2012. The power consumption is about 3,146.490 kWh monthly, which equals 3.147 MWh.

According to Table 8-10, the improved average monthly consumption of the householders' sample would be 1,494.587 kWh (1.495 MWh). For all 905,970 accounts at the Libyan General Electricity Company, the total can be calculated as 1,354 GWh per month. Using the data from Table 8-10, the total cost will be 905,970 households × 542.909 = 492 million Libyan dinars per year (circa £246 million).

Table 8-10 demonstrates the level of savings in electricity attainable by the reduction in the number of units and/or the duration of use. The focus has been on immersion heaters, kettles, TV sets and vacuum cleaners Reducing the number of TVs (Plasma, LCD) in a household from seven to only two, considering that most Libyan families watch television together. Reducing the number of times vacuum cleaners are used, from five times a week to two with the same duration, and replacing some of the cleaning with other manual systems. Reducing the operating hours of computer desktops and laptops from four to two hours per day; and switching off the broadband wireless router during sleeping hours, should all save the household energy.

The results of these reductions would reflect on the Libyan volume of production as shown in Table 8-11, as well as reducing the necessary fund allocations for electricity in the state budget. The table shows the size of the savings achieved when making some changes to behaviour in the homes under study.

The scenario also reconfigures lighting use, including an expansion in the use of 40W halogen bulbs from six to fourteen and 60W bulbs from six to eight. At the same time, there has been reduction in the usage of old-type bulbs, with 100W bulbs being reduced from nine to one and 75W bulbs from four to two, keeping the total number of bulbs constant (the owner unable to buy the economic bulbs).

Table 8-11 demonstrates the results of the improvement scenario in MWh and the potential savings for one year. It is clear that significant energy savings can be achieved as a result of simple behavioural changes that affect the number of appliances and the number of times they are used in the home. These simple changes could save energy per annum equivalent to a 2GW power station.

Table 8-11: Summary of improvement scenarios in total cost and MWh consumption (per annum).

Household's chosen	MWh consumption	Consumption cost (Libyan dinars)
Current situation (More details in Table 8-10)	37.7	1318.516
Improved sustainable scenario (More details in Table 8-11)	17.9	542.909
Saving MW h and amount per person (Difference between before and after scenario)	19.8	775.607
Total accounts (Population) (In the Libyan General Electricity Company)	905970	
Total saving for the population of (sample × population)	17,938,206	703 million
Real expenses in Libyan's budget of 2012	-	6,000 million
Expected cost after the improvement scenario	-	5,297 million
Expected saving in Libyan's budget	-	703 million
Expected annual saving in Libya's electricity production of (sample × population)	17,938,206 MWh Equivalent to the power of 2 GW Power station	

8.6. Policy implications

GECOL has 71 power plants spread across Libya in fourteen main power stations (14 steam, 32 gas, and 15 combined cycle and other resources) for supplying customers. The company's annual reports show that the quantity of electricity produced is much more than the electricity paid for by its customers, indicating that there could be many customers illegally using electricity without metering. Many regions and major cities in Libya suffer from electricity interruption for many hours, although the state has a number of administrative and economic instruments that can be used to stop this depletion of public money and to conserve energy, such as launching awareness campaigns, privatisation, adoption of the rating agencies used globally, increasing taxes on inefficient imports that would consume a large amount of energy, adoption of direct and indirect subsidy cuts on locally consumed energy, and the adoption of a basic policy towards renewable energy technology to reduce the burden on the traditional sources and preserve the environment. This could lead to competition for the production of energy from other sources, such as wind, sun, waves and others.

It is important for Libya to have a clearer and firmer energy policy that highlights energy security concerns and provides solutions and measures to reduce any energy problems that may face the country. The policy needs to give considerable focus to widening the awareness among the general public of energy related issues, such as energy costs, domestic appliance ratings, energy-saving equipment, tips on how energy can be conserved and the consequences of not changing energy-consumption behaviour. Furthermore, in order to overcome any possible severe energy security problems and provide a sustainable energy supply, the Libyan energy policy needs to provide motivation and support to investment in energy projects, and particularly in renewable energy projects.

8.7. Summary

This chapter has investigated domestic energy use in Libya. Since the focus is directed at the relationship between energy consumption behaviour by Libyan households and the overall energy demand in Libya, it is reasonably important to find the extent of the link between local electrical loads and householders’ consumption patterns. The chapter has outlined the expected annual increase of electricity demand in Libya and the yearly fluctuation. The expected increase would mean that Libya has to invest in new infrastructure that could cost a significant amount of money, or households will face programmed power cuts. A survey of 429 households in Libya has provided comprehensive information regarding the energy situation and demand in the domestic market and people’s behaviour.

It has been found that the government and local communities should take further steps to educate Libyans in relation to the benefits of implementing sustainability measures to reduce energy consumption and carbon emissions, and therefore reduce energy bills for the households and the government, which subsidises energy bills, and hence tackle energy security concerns. This should prevent any programmed power cuts without having to invest in costly new power stations. The study has also found that utilising more efficient appliances and lighting combined with improved behaviour could reduce the energy demands in Libya to an extent almost equivalent to a 2 GW power station.

The next chapter will present the conclusions, findings and recommendations.

Chapter 9. Conclusion findings and recommendations

9.1. Introduction

This chapter concludes this thesis and presents a summary of the entire research project which highlights the research findings as well as the significance of the study. In addition, it provides a general discussion of the empirical findings and ties them into the research questions, and the contribution of the study on two levels, academic and practical, and presents some recommendations for further research.

9.2. Thesis overview

The thesis consists of nine chapters. Chapter one presents the general overview of the thesis, which includes the context and rationale for the study, and the problem definition. In addition, the chapter identifies the research questions, aim, objectives and structure.

Chapters two to four present an analytical review of the literature which identifies the knowledge gap, as well as the present state of knowledge in the field of the energy and renewable energy sectors. The literature review overview is as follows:

Chapter two presents an overview of the state of the energy and environment in Libya. It focuses on the current and future energy situation, energy demand in the electricity and water sectors and current energy prices, as well as the Libyan environmental situation.

Chapter three discusses environmental challenges, the potential of renewable energy to provide opportunities for work which can be reflected as economic growth, and other effects of renewable energy on the Libyan economy. This revealed how renewable energy can create more job opportunities and new challenges of investment, as well as discussing the comprehensive Libyan economic reforms as regards local and foreign investment.

Chapter four addresses the third research objective, demonstrating the relevant literature to provide a background and understand the global renewable energy technologies situation. It covers several issues, such as the global market and an industry literature overview, the global market state, industry trends for each technology, and a summary of the development of renewable energy costs.

Chapter five discusses different research methodologies and methods, and justifies the selection of the particular research methodology and methods that are adopted in this thesis. This chapter clarifies the various available options for the carrying out of field research and the logic for the selection of the specific methodology, strategy and methods applied in this research project. Namely, as this research study is of an exploratory and explanatory nature, it uses both a qualitative and quantitative aspect; specifically a combination of data sampling, collection and analysis methods.

Chapters six, seven and eight present the analysis and discussion of the findings of the semi-structured interviews and questionnaire surveys, including a quantitative and qualitative analysis of the data collected by the chosen research methods.

Finally, chapter nine presents the conclusions, findings and research recommendations in order to answer the research questions. Figure 9-1 demonstrates how the research aim and objectives were achieved through the methods adopted, and how they were included in the thesis.

The aim of the research had seven specific objectives. Chapters two through eight, excluding chapter five which dealt with the research methodology, address all seven objectives, whilst chapters one and nine are the introduction and the conclusion respectively.

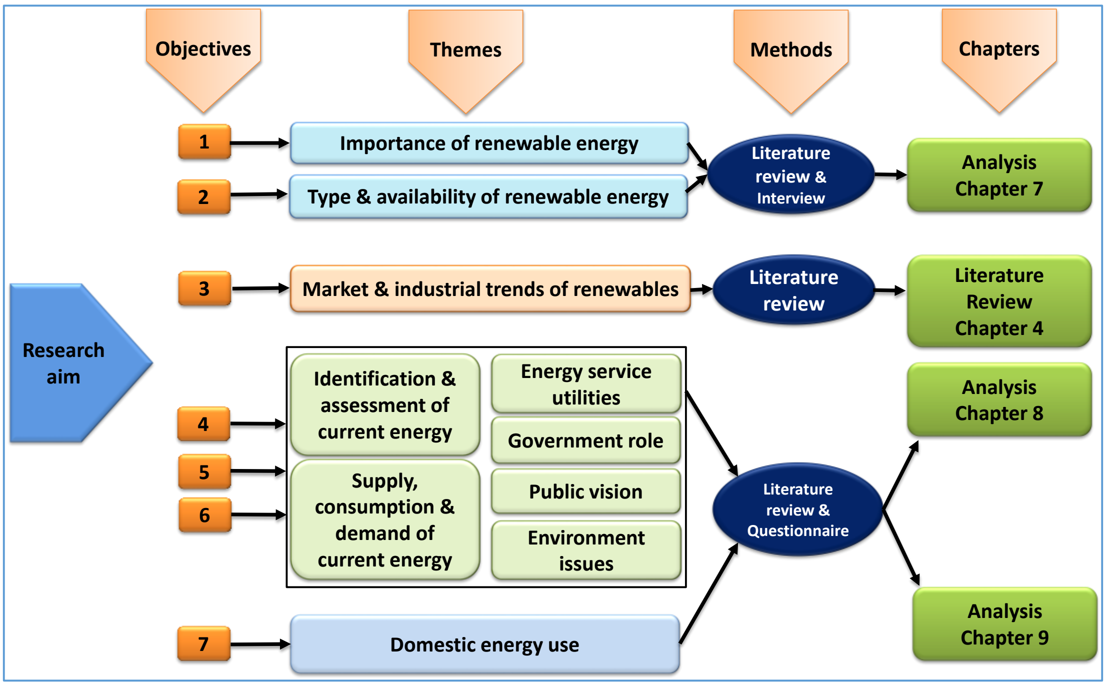


Figure 9-1: The layout of the current study, and how it meets the research aim and objectives.

Source: Author's own.

9.3. Evaluation of the research aim and objectives

The main research questions are answered by achieving the aim of this research. The research aim is to investigate the feasibility of the utilisation of renewable energy resources in Libya by studying the challenges and opportunities for the investment of renewable energy in Libya. This is to achieve an economically, socially and environmentally sustainable energy future.

The aim is achieved by analysing secondary and primary data, and has been accomplished effectively through the research objectives. The results are summarised and classified with respect to the specific theme of each objective as follows:

Objective 1: To study the importance of investing in renewable energy resources in Libya.

Objective 2: To investigate the type and availability of renewable energy resources in Libya.

9.3.1. Theme 1: Importance of renewable energy

This objective is addressed through interviews, and the analysis and discussion presented in chapter six. In total, 55 face-to-face semi-structured interviews were conducted with key people in government organisations and institutions who are responsible for policy making. The analysis of the empirical data was conducted using content analysis, in order to address the first research question.

It is important to understand the situation which is facing Libya as it tries to diversify its economy and reduce its dependency on oil as a source of income and energy. The securing of alternative resources of energy and income is becoming critically important for Libya if it wishes to maintain the same standard of living for future generations and reduce pollution and carbon emissions.

The distribution of electricity in Libya is expensive due to its vast area. Utilisation of renewable energy resources makes distributed systems more feasible due to the fact that energy can be produced closer to the demand centres, decreasing the need for long transmission lines and reducing power loss across those lines.

Comparing the production of electricity by current fossil fuel plants, the research found that the size of the required initial capital and the quantity of the fuel consumed in the production process is too large, and other operating expenses and environmental issues could be avoided in plants using sunlight or wind.

Libya has embarked on building a farm worth 184 million Libyan dinars (LD) in the Al-Fattaih region, which is expected to produce 60 MW and it is not using any type of fuel, and does not need a lot of maintenance. This project will save fossil fuels, specifically about 475,000 barrel of crude oil yearly which would cost about 25 million LD, and reduce carbon dioxide emissions by 120,000 tons, with a kWh cost of about 0.031 LD. It is important here to point out that there are great opportunities in many areas for the creation of wind farms in Libya.

The findings show the potential of renewable energy sources in Libya, as described in section 6.2 which shows the significance of Libyan geography, with a huge desert area on a long coast where there is a high potentiality for both solar and wind energy. Section 6.3.1 introduced the efforts of the Libyan government since 1976 to establish renewable energy projects in Libya. Many important achievements have been made in the past few years which make renewable energy more feasible to use in conjunction with traditional energy resources. The role of renewable energy in any country mainly depends on the availability of the resources such as solar radiation, wind, biomass and geothermal.

The most suitable way to determine the appropriate utilisation of renewable energy is through an assessment of load variation patterns, that is, it is important to find the extent of matching between the local loads and the renewable energy generation schedule. In this regard, most Libyan months are hot, with a mean temperature of more than 35ºC, and this is associated with a high rate of electricity consumption in Libya. Most of the load in these months consists of water pumps, electric fans, space heaters and air conditioning (more details in chapter eight).

Furthermore, it has been found that energy demand is increasing in Libya and that renewable energy could be the solution to cover some of this demand. Renewable energy is not a well-investigated subject in Libya due to the availability of oil. Despite the fact that renewable energy such as solar and wind power, as discussed above, is widely available in Libya, it is still difficult to break the dependency on oil and natural gas, not only for energy supply but also for export revenues.

9.3.2. Theme 2: Type and availability of renewable energy

Libya is exposed to dry and hot winds which blow several times during the year. Libya's neighbouring countries have started to utilise the wind resource in differing amounts, ranging from demonstration projects to commercial-size wind farms, which is a clear indication of its feasibility in that region.

The Libyan renewable energy authority has stated that the average hours of solar brightness is 3,200 hours per year, and that the average solar radiation is 6 kWh per square metre per day. The researcher's calculation has shown that the potential is significant and that solar energy should be utilised in Libya, with each square kilometre receiving solar energy equivalent to $10^6 \times 1.5 / 365 \approx 4110$ barrels of oil per day[6].

[6] According to a report by Franz Trieb of the German Aerospace Centre, every year, each square kilometre (km^2) of desert in the MENA region receives solar energy equivalent to 1.5 million barrels of crude oil.

Therefore, if only 0.1% of Libya's area ($0.001 \times 1.7 \times 10^6$) were used, this would lead to an equivalent of (1.7×10^6 $km^2 \times 0.001$) $\times$ 4110 = 6.986 million barrels of oil per day of energy. This number is five times more than the current Libyan production of oil.

In general, the average wind speed ranges between 2.9 and 5.3 metres per second in a number of areas in Libya. One of the main advantages of the wind in Libya is that there is a correlation between the wind pattern and the pattern of the demand for electric power in most places. As such, the wind and solar energy could provide a good complement to meet peak loads, a good reason for encouraging wind and solar energy projects in Libya.

Most of the interview subjects across the three sectors highlighted the importance of renewable energy resources, with relative differences among them. While participants of both the energy consumption (EC) and energy generation (EG) sectors give equal importance to the utilisation of and investment in this field, the energy policy makers (EPM) gave more importance to renewable energy resources. In general, according to the interviewees, the three sectors aim to achieve three main objectives relative to political, social and environmental matters as follows:

1. Diversifying the sources of energy;
2. Creating possible new employment opportunities; and
3. Preventing environmental pollution.

The majority of the interviewees in the EPM and EG sectors highlighted the following issues:

1. Local industries and investments related to renewable energy should be encouraged;
2. There is a need for local training centres associated with renewable energy in order to increase formal education; and
3. Current production capacity of energy does not meet the demand in Libya.

The next section concerns the third research objective:

Objective 3: To study the global situation of renewable energy technologies in order to identify the market and industrial trends.

9.3.3. Theme 3: Market and industrial trends in renewables technologies

This objective is addressed through the literature review, which is presented in chapter four, in order to address the first research question. The results of this chapter demonstrate the global performance of renewable energy, and how it has continuously grown. This chapter explores some of the dramatic changes to the global energy market, such as the oil spill in the Gulf of Mexico, Japan's Fukushima disaster, the recent political instability in some parts of the world and global warming due to CO_2 emission. These global developments have highlighted the economic, security and human costs of relying too greatly on nuclear energy and fossil fuel, and the significance of the utilisation of renewable energy as an alternative source. Additionally this chapter covers the installed capacity of many renewable energy technologies which have grown rapidly during the period 2009-2013.

The next section is about the fourth, fifth and sixth research objectives.

Objective 4: To identify and assess the current energy supply, consumption and demand in Libya.

Objective 5: To investigate to what extent the current public energy service is appropriate and sufficient.

Objective 6: To study the attitude of the Libyan government and institutions towards renewable energy technology, the public vision in each sector regarding renewable energy, and environmental issues.

These objectives are achieved through the first questionnaire, and the analysis and discussion presented in chapter seven. In this research, self-completion questionnaires were used in order to obtain data. From a total of 1,522 questionnaires distributed in the research area, 831 valid questionnaires were received. These questionnaires captured information from Libyan energy consumers in the factory, housing, farming and public facilities sectors. The analysis of the empirical data was conducted using the Statistical Package for Social Science (SPSS) analysis program, in order to address the second research question.

9.3.4. Theme 4: The identification and assessment of current energy sources

The energy consumption sectors in Libya are the residential housing (RES), commercial farming (FMC), non-commercial farming (FMN), public factory (FTP), private factory (FTV) and public facilities (PFL) sectors. The majority of those surveyed depend on both electricity and fossil fuel, regardless of the source of this energy (network, generators and others), for cooling, heating, water heating, lighting, appliances and machines. The majority of the survey respondents are using the electricity of the public grid although a minority are depending on generators for electricity because of a lack of confidence in the public network due to sudden outages or irregular electricity supply, or because their locations are far away from the sources of electricity and beyond the water and electricity networks.

9.3.5. Theme 5: Supply and demand of current energy

The RES, FMC, FMN, FTP, FTV and PFL sectors use electricity for hot water, lighting, cooling, heating and their appliances. Even the people who do not use electricity from the grid still use electricity for everything. The results also demonstrated that all of the sectors are to some degree using gas cylinders for water heating, heating, cooking and lighting as an alternative to electricity during the periods of outage, while the majority use kerosene and diesel for multiple purposes.

When considering the source of water, which is one of the main sources of energy consumption, the results show that the RES sector depends on many sources of water, such as stored rainwater in concrete vaults underground or inside the building, as well as tap water and/or local home wells inside the property boundary. Those residing in apartment buildings tend to use public tap water only, and a small proportion of the RES sector are dependent on private local wells (small production) in their living areas because their houses are far away from the water grid.

The results indicated that the majority of the commercial and non-commercial farm sectors are using underground water (huge production). The small proportion who are depending on rainwater (rain-fed farms) are in the same situation as the residential respondents mentioned above, that is, they are far away from the electricity and water grids. Similarly some public and private factories and public facilities are in places far away from the services network, making them dependent on local sources for water. Some others use public tap water, while the rest of the factories and public facilities are using underground water, local home wells, rainwater, or a mixture.

9.3.6. Theme 6: Energy service utilities

With regard to the extent to which the current public energy service is appropriate and sufficient, it is clear from the results of the questionnaires that there is dissatisfaction in the RES sector about the electricity service and the prices of both electricity and tap water, while the majority of the RES respondents say that they are satisfied with the water authority services and the fossil fuel prices. The results also show that the majority believe that electricity, water and gas are not always available, and that most of the RES sector do not pay the water or electricity bills.

The responses from the FMC sector show a general satisfaction with both the electricity and water authority services. However, the FMC and FMN sectors are dissatisfied by the prices of both electricity and water, although there is general satisfaction with the fossil fuel prices. The majority say that electricity and gas are sometimes unavailable, but that water is always available. The majority of the FMC sector do not pay the electricity or water bills.

It is clear that there is dissatisfaction in the FMN sector with the electricity and water services, and the majority of them are dissatisfied with both electricity and water prices, and satisfied with the fossil fuel prices. The majority believe that electricity, water and gas are unavailable at times, and most of them do not pay electricity and water bills.

The FTP sector follows the trend of dissatisfaction with the electricity services, although they are satisfied with the water authority services. The majority of respondents from this sector are dissatisfied with both electricity and water prices, and satisfied with the prices of most types of fossil fuel. Most of them said that electricity is not always available, but that water and gas are, and the majority do not pay electricity and water bills at all.

Most of the FTV sector are dissatisfied with both their electricity and water services. The majority of them are satisfied with their water price and the cost of most fossil fuels, but dissatisfied with electricity prices. The majority of them believed that the electricity supply was sometimes disrupted, but that water and gas were consistently available. Most of them do not pay electricity and water bills at all.

The PFL sector is dissatisfied with both the services and the costs of water and electricity, but satisfied with the prices for most types of fossil fuel. The majority of them thought that electricity, water and gas are reliably available, while a minority do not pay the electricity and water bills.

The majority of the RES, FMC, FTP, FTV and PFL sectors confirmed that the main reason behind power outages is the source, while the FMN respondents believed that the reason is the delivery cost. All six sectors placed general network failure as the reason second-most responsible for power outages. The questionnaires from RES and FTV said that there were no water outages at all, while the majority of the FMC and FTP sectors believed that the most typical reason behind water outages is the source, followed by the delivery cost and then general network failure. The questionnaire results show that the majority of all six sectors are using electricity instead of gas cylinders, and believe that the reasons behind the lack of street lighting are public network failures, followed by the distance from power stations, then the source, and finally a lack of access to the grid.

9.3.7. Theme 7: Government role towards renewables technology

In terms of studying the role of the Libyan government towards renewable energy technology, the public vision in each sector regarding renewable energy and environmental issues, the questionnaire results found that the government did not engage efficiently in the sponsorship of any education or media-related programmes in reference to renewable energy. Moreover, the Libyan educational curriculum does not include significant materials regarding renewable energy.

9.3.8. Theme 8: Public vision and environment issues

The results also demonstrate that the majority of the RES, FMC, FMN, FTP, FTV and PFL sectors are aware of and have information about renewable energy resources, and have expressed support for the production of energy from environmentally friendly sources where it is available at competitive prices, and for legislation to increase the use of renewable energy resources. The FTP and FTV sectors are the most interested in using renewable energy resources which are available at competitive prices, to support the production of energy from environmentally friendly sources, and to encourage legislation to increase the use of renewable energy resources. This is because these sectors deal with production costs and are suffering from high electricity prices. The agriculture sector is more supportive of reducing the use of conventional energy because it is negatively affected by the environmental impact of conventional electricity generation. The respondents from the FTP sector expressed the strongest belief that renewable energy services could be affordable. The majority of the sectors' responses have confirmed that there is no renewable energy market in Libya at present.

The majority of the responses from all sectors expressed a belief that there should be a continuing reappraisal of the use of traditional energy in order to reduce environmental pollution, which is caused by the use of traditional fuel in electricity and water production.

The next section concerns the seventh research objective:

Objective 7: To investigate the effect of domestic energy consumption and householders' awareness of, and attitudes and behaviour towards, overall energy consumption in Libya, and how this could affect peak demand, capacity and the government's energy budget.

This objective is achieved through the analysis and discussion of the second questionnaire, presented in chapter eight, which additionally answers the second research question. In this research, a self-completion questionnaire was administered in order to obtain data. From a total of 823 questionnaires distributed in the research area, 429 valid questionnaires were received. This questionnaire captured information from Libyan householders. The analysis of the empirical data was conducted using the SPSS analysis program, in order to address the second research question.

9.3.9. Theme 9: Domestic energy use

Chapter eight investigated domestic energy use and the energy behaviour of householders in Libya. The chapter outlined the expected annual increase and yearly fluctuation of electricity demand in Libya. This expected increase would mean that

Libya would have to invest in a new infrastructure that would cost a significant amount of money, or households will face programmed power cuts.

The survey analysis of Libyan households has provided comprehensive information regarding the energy situation, demand in the domestic market, and people's behaviour. The results show that one of the most important issues, which is a challenge to the policy makers and investors, is the heavy government subsidises. The heavily subsidised energy prices are leading to rapidly rising energy demand, with customers paying one-third of the cost of production per kWh. The combined electricity generation of the General Electricity Company of Libya (GECOL) in 2012 required a large amount of natural gas and fuel oil. GECOL has difficulties in meeting the increased electricity demand with a suitable expansion of capacity, and the resultant power shortages are starting to necessitate programmed electricity cuts in several cities.

The questionnaire results illustrate the attitude of Libyans in relation to renewable energy resources. They demonstrate that the majority support green electricity, although a significant number of people are neutral on the topic, possibly because of a lack of familiarity with what green electricity is. The proper utilisation of renewable energy should ease off part of the pressure on the energy supply as well as assisting the Libyan energy markets both domestically and internationally. The government and local communities should also take further steps to educate the Libyan people in relation to the benefits of implementing sustainability measures to reduce energy consumption and carbon emissions, and therefore reduce the energy bills for the households and the government who subsidises energy bills, thereby tackling energy security concerns in good time. This should prevent any programmed power cuts without having to invest in costly new power stations. The study has also found that utilising more efficient appliances and lighting, combined with improved electricity-consumption behaviour, could reduce the energy demands in Libya to an extent almost equivalent to a 2 GW power station.

9.4. Answering the research questions

This chapter fully addresses the research questions, which are formulated from the research aim and objectives. This section presents a summary of how the questions are addressed.

Q1- What is the possibility of sustaining Libya's position in the current international energy market after oil and natural gas depletion?

This research question is mainly connected with research objectives one and two. The literature review, field visits, conducted interviews and secondary data all inform our knowledge of the importance, type and availability of utilising renewable energy resources in Libya.

The results demonstrated that, most interviewees in the energy policy maker (EPM), energy generation (EG) and energy consumptions (EC) sectors believe in the importance of renewable energy resources, with relative differences amongst them. Of the three groups, the energy policy makers felt most strongly about the importance of renewable energy resources, while participants of both the EC and EG groups gave equal importance to the utilisation of and investment in this field. The majority of respondents from all three groups believe that renewable energy will play an important role in the economy and the environment in Libya in the future.

Most of interviewees in the EPM, EG and EC sectors believed that renewable energy will satisfy energy demands after the expiration of oil. However, a minor proportion of the respondents from these sectors have a lack of knowledge and information with regards to which renewable energy will be the best alternative. It was felt that consumers and producers of energy have limited confidence in renewable energy, or knowledge regarding its capabilities.

With regard to renewable energy types, the results indicated that the majority of the interviewees in the EPM, EG and EC sectors believed that solar energy is the dominant technology for the future, followed by wind energy and wave and tidal. This is consistent with the location of Libya, with its huge desert with exposure to solar radiation throughout the year. Biomass and geothermal are still thought of as unusual, which is also consistent with the nature of the Libyan desert, with a shortage of arable land, animals and a small population.

The majority of the interviewees in the EPM, EG and EC sectors confirmed that renewable energy is available for commercial utilisation in Libya, although none of the interviewees disagreed that there is a lack of commercial opportunities, and some proportion of the respondents from the EG and EC groups were unsure due to a lack of information or knowledge.

Furthermore, there is belief amongst the interviewees from all three sectors that investment in renewables such as solar and wind will help provide good services for local consumption and deal with future demand.

Although Libya is rich in renewable energy resources, it is difficult to break the dependency on oil and natural gas. It is in urgent need of a more comprehensive energy strategy, not just in terms of the country's demand, but also in terms of the revenues that it generates. Libya cannot indefinitely sustain its current position in the international energy market by relying on oil and natural gas resources, and could harness its renewable energy resources not only to meet its own demands for energy, but also a significant part of the international energy market. Investment in renewable energy could enhance the energy markets and secure long-term sustainable energy supplies. It could also provide commercially attractive options to meet specific needs for energy services, especially in remote areas.

Q2- What are the challenges to and opportunities for the utilisation of renewable energy resources in Libya?

This research question is mainly connected with research objectives three to seven. The literature review, field visits, conducted survey and secondary data have been used to identify and assess the market and industrial trends of renewable technologies, the current energy supply, consumption and demand, the energy service utilities, the Libyan government's role and public vision, and the environmental issues and domestic energy consumption in Libya.

The results demonstrate that the new changes of the Libyan foreign investment laws. These changes have created new opportunities by reopening some previously closed sectors to foreign investment and the private sector.

The existing challenge for the Libyan government is to utilise the opportunities presented by renewable energy resources. The Libyan government has started to address issues such as oil reserves and environmental pollution. With regard to the availability of renewable energy, as discussed in this thesis, Libya has the resources to exceed not only the local demand, but also a significant part of the global energy demand through the export of electricity. Several countries in the Middle East have concentrated solar power (CSP) plants built or planned, and some might participate in the plan to export a part of the generated power to the EU.

Another important challenge facing Libya is that despite the country having the highest proven oil reserves of any country in Africa, and one of the highest proven natural gas reserves as of 2013, the conventional resources of energy in Libya are still limited.

Pollution is one of the most important environmental challenges facing Libya. This challenge is associated primarily with the oil industry, but also the electricity and water production sectors, all three of which release a significant amount of CO_2 emissions.

Another important challenge arises from the fact that although significant investments are required for the generation, transmission and distribution of energy, the available public sector funds are insufficient to address the gap. Attracting foreign and private sector participation is critical, especially in the area of generation. Moreover enhancing clear policy regarding renewable energy.

In the meantime, other challenges are facing Libya’s utility supplies. Libya’s electricity demand is expected to experience continuing growth, although current generation is already insufficient for present demands, and water demand with very little recharge has strained the resources of Libyan groundwater. GECOL plans to install desalination technologies with a capacity of one million mcpd prior to the year 2016, and this quantity will require approximately 1.8 TWh/year of energy; this and future water desalination projects will be a major driver for energy demand.

One important challenge is to tackle the effects of energy-consumption behaviour on overall energy consumption and demand through the enhancement of energy efficiency in domestic energy use and the energy behaviour of householders in Libya. As domestic energy use accounts for 36% of the country's total energy consumption, it is imperative that more measures are introduced in households to help the country cope with the growing demand for electricity.

By implementing a range of energy-saving measures – such as fitting energy-efficient light bulbs, vacuuming only twice a week, reducing the number of air conditioners in use, and more – almost 18 million megawatt hours of electricity could be saved per year, equal to the output of a two gigawatt power station.

The results have demonstrated that the most important opportunity for the Libyan energy sectors can be seen in the trend of international performance of renewable energy technologies (market and industrial), which is continuously positive. Additionally, the installation capacities of many renewable energy technologies have grown rapidly in the last decade.

In this respect, the main opportunity is that the majority of the sectors surveyed for this research have information about renewable energy resources, will support the production of energy from environmentally friendly sources as long as it is available at competitive prices, and will encourage legislation to increase the use of renewable energy resources. At the same time, however, the majority of the respondents agreed that there is no renewable energy market in Libya.

Another opportunity lies in the fact that Libya could generate approximately five times the amount of energy from solar power that it currently produces from crude oil. Libya's long hours of strong sunlight throughout much of the year mean that the country could generate enough renewable power to meet and far exceed its own energy demands. with the excess then available for export to the world market.

Indeed, if Libya could harness only a tiny fraction of the renewable energy resources it has available in the form of solar and wind power, not only could it meet its own demands for energy, but also a significant part of the global demand.

Libya has an average daily solar radiation rate of some 7.1 kilowatt hours per square metre per day on a flat part of the coast, climbing to 8.1 in the south of the country. The result shows that if Libya used just 0.1 percent of its landmass to harness solar power, it could produce the energy equivalent to seven million barrels of crude oil daily.

Furthermore, the load pattern shown in Figure 2-8 highlights the possibility of utilising solar energy for providing large sector of loads with almost fixed pattern regarding wind energy resources in Libya, there are several places known by their high wind speeds and long windy times.

Finally, although the challenges are more numerous than the opportunities, the majority of these challenges, indeed, are related to current energy sources. These challenges can be a driver for renewable energy opportunities, which in turn can be considered as a part of the strategy of an energy security solution.

All in all, the main challenges which are facing the Libyan government as it tries to ensure prosperity are diversifying the economy, reforming education, developing entrepreneurship, promoting transparency, opening new marketing channels and funding transactional activity and infrastructure development.

9.5. The significance of the results

The significance of the findings that were identified during this chapter could be summarised as follows:

1. Renewable energy can be used for heating water for domestic water heating, tourist hotels, swimming pool heating, public toilets in urban areas, and many facilities along desert roads which only need between 1 KW and 1 MW of power, such as military checkpoints, border points and restaurants.
1. There is a positive public opinion toward renewable energy, and the number of energy conferences and initiatives confirms this.
2. It is possible to use solar energy across Libya, while wind power can be used in specific areas.
3. There is significant support for renewable energy as one of the future sources of energy.
4. The current production capacity of energy does not have the ability to cover all the requirements of Libya at the current time.
5. The growing demand for energy exceeds the current supply and the capacity of the available power stations.
6. There is lack of legislation governing the legal support for facilitating the spread of renewable energy in Libya.
7. There are limited local or foreign investors in the Libyan markets for many reasons, for example the poor infrastructure and lack of suitable investment laws.
8. The prices of domestic energy are lower than the global ones. Therefore, any local investment would require a much longer period to break even.

9. There is no clear legislation aimed at the types of technical, commercial and environmental issues which must be addressed for the implementation of renewable energy projects in Libya.
10. The research indicates that the cost of renewable energy products will be higher than the current energy prices. This indicates the importance of the government's role in identifying the amount of support needed to encourage renewable energy.
11. The Libyan government's plans for the use of renewable energy are struggling because of the unrest in Libya. These projects have not been implemented, and all projects related to renewable energy are stalled.
12. Despite the existence of a CSERS and REAOL in Libya, there is no accurate database and have been no complete scientific studies on the implementation of renewable energy projects in Libya. The only existing information concerns the sun and wind data readings.
13. In spite of the fact that Libya signed and ratified the Kyoto Protocol in 2006, the government and the industrial sector have not seen any benefits from the protocol as yet.

9.6. Contribution to knowledge

This research provides a number of contributions to knowledge at both an academic and a practical level, as it is an important exploratory and explanatory study. Furthermore, it is an empirical investigation – utilising both qualitative and quantitative methods – into the feasibility of the utilisation of renewable energy technologies, and was conducted in several Libyan regions.

It has been found that there is a need for a clear policy and laws encouraging and regulating the use of renewable energy in Libya. As there are no scientific studies or technical and financial incentives regarding the possibility of implementing renewable energy technologies, this research plays an important role in the development of a strategy for the growth of the Libyan economy, the diversification of the utilised sources of energy, the creation of possible new employment opportunities, and the prevention of environmental pollution. The contribution to knowledge can be summarised as follows:

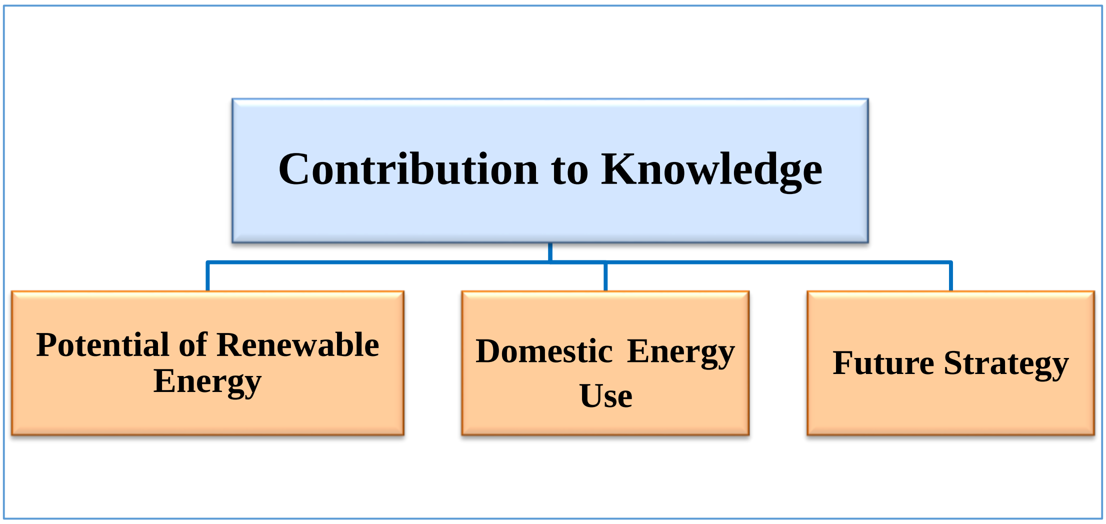


Figure 9-2: Summary of research contribution

1. According to the database of the Centre for Research, Information and Documentation in Libya, this study can be considered to be the first of its type and depth in relation to investigate the feasibility of the utilisation of renewable energy resources in Libya. Therefore, these contribution must help the Libyan policy makers, international and local investors, and academic researchers.
2. Also, being one of the first of its kind, the study highlights the importance of changing Libyan energy-consumption behaviour by raising awareness of the benefits of energy conservation to the current and future generations.
3. This study has introduced the challenges to and opportunities for investment in renewable energy. This will help the government and private investors alike when planning for green energy investment in Libya.
4. Most importantly, Libya is a key oil and gas producer and exporter in the world. This study found that Libya is rich in renewable energy resources, and should these resources be well utilised, this will sustain Libya's position in the international energy market.
5. This study has indicted a strategy for renewable energy, discovered new facts and outlined new areas for future study and research.
6. This contributes to the understanding of the development of sustainable energy practices in Libya by presenting an empirical and analytical study which will expand the literature regarding energy usage and development in Libya.
7. This study provides an understanding of the influences of historical, political, social, economic and environmental contexts in Libya. The study is the first one

that links these factors with sustainable development, which is the most important goal for Libya's future.

8. This study has identified the current situation of suitable renewable energy for Libya, and the feasibility of implementing different scales of renewable energy projects in Libya's residential housing, scattered villages, remote areas, agriculture, industry and public facilities.
9. This study identifies the location of the most suitable renewable energy sources for Libya, and the effects of the current political situation on the renewable energy sector in Libya. Furthermore, it establishes whether renewable energy is a suitable alternative to the currently used ones in Libya.
10. This study offers the Libyan government a strategy for providing sustainable energy resources and sustaining their position in the current international energy market in order to achieve an economically, socially and environmentally sustainable energy future.
11. This study also introduces a strategy for sustainable energy management, and it is expected that such efforts will reduce energy consumption and stop energy pollution.
12. This study raises awareness of the importance of demand management, and gives a better understanding of how sustainable energy development could be effectively managed.
13. The study has presented the levels and mix of energy consumption and its expected future growth. This study has outlined the importance of developing the renewable energy sector in Libya. It has been found that renewable energy could provide an alternative source of energy and provide an opportunity to generate financial revenues as well as reduce the consumption levels of oil and natural gas.
14. In addition, it has been found that energy demand is increasing in Libya and that renewable energy could be the solution to cover some of this demand without the need to build new fossil-fuel power stations. It is obvious, despite the recent political changes in Libya, that renewable energy is still strategically of high importance.
15. Although the focus of this research is on Libya, it has significant potential implementation value and impact on other countries regarding applied energy

practices. Libya is similar in culture and style of living to many other countries around the world, particularly within the MENA region. The impact of this research will be extremely important for those countries and scientific researchers in the field of applied energy.

16. This study can be applied to other countries, such as the UK as an oil producing country, or Japan as a net oil and gas importer.
17. The results indicate that minor adjustments in householders' energy consumption behaviour and the technology used to generate energy could provide significant financial savings and contribute significantly to a reduction in carbon emissions and energy consumption. This will provide a significant benefit to the local economy and the energy sector in Libya, and could provide sustainable energy resources for Europe in the long term.
18. This research asks if we can maintain the Libyan energy market by relying on the currently exploited resources alone. In the same direction, it undertakes an investigation of the existence of alternatives to these energy sources and the possibility of their utilisation locally and internationally.
19. During this period a total of six academic papers were published, comprising three journal articles and three academic conferences as detailed in the list of publications.

9.7. Research Limitation

This study has focused mainly on two types of renewable energy, solar and wind. Further research should focus on the potential of the other renewable energy options in Libya, such as wave, geothermal, biomass and energy from waste.

The focus here has been on understanding the attitudes and awareness of energy policy makers, producers and consumers towards the current energy situation, renewable energy and environmental issues in Libya. Furthermore, the majority of the participants in this study were Libyan. Therefore, the outcome of this study reflects the views of the participants living in Libya, and these views, opinions and perceptions may be influenced by the system, regulations and the culture of the country.

This study focused essentially on studying the challenges and opportunities for the investment of renewable energy in Libya, without targeting a specific group of investors, such as local or foreign investors. Moreover, the research has not presented the financial details of investment in Libya.

Further research is still needed in relation to other renewable energy resources and their potential in Libya.

9.8. Recommendations for further research

The seven objectives of the research as given in Section 1.3.2 were constructed to propose practical suggestions and recommendations to support the adoption of renewable energy resources and tackle the challenges and present the opportunities which exist in the energy sector in Libya. The Libyan government needs to consider all the suggested critical points presented in this research, in addition to the following:

1. Renewable energy technology is still in its early days in Libya and a clear strategy and timetable is needed to take it forward. In particular, work needs to be done to develop the skills and knowledge needed to install and maintain renewable energy systems.
2. Several locations, including a number along the coast, experience high wind speeds which last for long periods of time. If Libya could harness only a tiny fraction of its renewable energy resources, it could meet not only its own demands for energy, but also a significant part of the world's demands through the export of electricity.
3. The availability of renewable energy could provide a good complement to meet peak loads and current energy demand, and this in turn can be a good reason for encouraging wind and solar energy projects in Libya.
4. The results indicate that Libya is rich in renewable energy resources but in urgent need of a more comprehensive energy strategy and detailed implementation, including reasonable financial and educational investment in the renewable energy sector.
5. Solar and wind energy are considered the main sources of renewable energy, ahead of wave and tidal energy. There is a need to attract investment in renewable technologies by enhancing the infrastructure and the existing regulations for foreign investments.
6. Further research needs to focus on:

a. The potential of the other renewable energy options such as wave, tidal, biomass, hydroelectricity, and geothermal power in Libya.
b. Technical problems which might affect the efficiency of implementing renewable energy technologies.
c. Funding problems that may face prospective investors in Libya.
d. Furthermore, more detailed studies about Libyan domestic consumption in order to the establishment of the average Standard Assessment Procedure rating of Libya's houses, as well as defining energy security.

9.9. Final conclusion

The author would like to make the following recommendations for the development of the renewable energy sector in Libya:

- Diversify the resources of energy production in Libya by utilising the available renewable energy, particularly wind and solar;
- Enhance the educational and training system to enable the necessary development in the sector;
- Encourage local industries and investments related to the renewable energy sector to develop new employment opportunities, reduce pollution and provide energy savings for future generations; and
- Enhance the current regulations in order to attract foreign investors in the renewable energy sector.

The significance of this study arises from the fact that the final results should be a stepping stone for other studies to find a sufficient solution to ensure energy security and limit climate change in Libya. Significant investments are required in the generation, transmission and distribution of energy. The public sector is unable to address the funding gap, and attracting foreign and private sector participation is critical, especially in the area of generation.

References

Abdo, H., 2011. UK energy Security: Challenges, Threats and Solution. Energy Sci. Technol. 1, 38–53.

Abdul-Hakim, E., 2006. Sub-Regional Overviews Northern Africa [WWW Document]. United Nations Environ. Program. UNEP. URL http://www.unep.org/dewa/Africa/publications/AEO-2/content/050.htm (accessed 10.28.14).

Abdulwahad, M., 2012. Renewable Energy in Libya: Potentials, Current Situation and Way forward. The Libyan Ministry of Electricity and Renewable Energy, Berlin, Germany.

Abrahamse, W., Steg, L., 2009. How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? J. Econ. Psychol. 30, 711–720.

AENews, 2016. Alternative Energy [WWW Document]. what factors Affect output Wind turbines. URL http://www.alternative-energy-news.info/what-factors-affect-the-output-of-wind-turbines/ (accessed 4.21.16).

Affairs, F., 2010. Provision of Technical Support / Services for an Economical , Technological and Environmental Impact Assessment of National Regulations and Incentives for Renewable Energy and Energy Efficiency Country Report Libya December 2009 , revised April 2010. The Ministry of Foreign Affairs of Denmark.

Africa, S., States, I., 2013. Energy Subsidies in Middle East and North North Africa: Regional fact sheet from the world development indicators 2009 1–4.

Al-Habaibeh, A., Su, D., McCague, J., Knight, A., 2010. An Innovative Approach for Energy Generation form Waves. In: Proceeding of the International Renewable Energy Conference EJREC and GCREEDER 2009. Amman, Jordan.

Ali, A., 2013. Environmental Disclosure in the Libyan Oil and Gas Sector. Nottingham Trent University.

Al-karaghouli, A., David, R., Lawrence, K., 2009. Solar and wind opportunities for water desalination in the Arab regions. Renew. Sustain. Energy Rev. 13, 2397–2407.

Almathnani, M.G.; B.N.; A.M., 2006. UTES potential for space heating and cooling in Libya. In: Thermal Energy Storage : 2006 EcoStock ; [10th International Conference on Thermal Energy Storage] ; May 31 - June 2, 2006, the Richard Stockton College of New Jersey ; Proceedings. Richard Stockton College of NJ, Pomona, NJ, p. 7.

Amaratunga, D., Baldry, D., Sarshar, M., Newton, R., 2002. Quantitative and Qualitative research in the built environment: application of "mixed" research approach". Work Study 51, 17–31.

Andrade, J.A., 2001. The uses of energy in the domestic sector. Energy Build. 33, 525–529.

Andreas, N., Cecilia, B., Liane, T., Anderssonc., D., Anderssona., K., Pär, M., 2014. Effects of continuous feedback on households' electricity consumption: Potentials and barriers. Appl. Energy- Elsevier Sci. Ltd 122, 17–23.

Ang, B.W., Choong, W.L., Ng, T.S., 2015. Energy security: Definitions, dimensions and indexes. Renew. Sustain. Energy Rev. 42, 1077–1093.

Angelis, A. De, 2013. Global Renewable Energy Market [WWW Document]. Energy Util. Mark. URL Companiesandmarkets.com (accessed 9.4.13).

Bait-Elmal, A., 2000. The role of management control systems in Libyan organisations: a Libyan development policy case study with special reference to the industrial sector. Structure.

Bank, W., 2011. World Development Indicators last updated: Dec 12, 2011. [WWW Document]. World Bank. URL World Development Indicators last updated: Dec 12, 2011. http://data.worldbank.org/data-catalog/world-development-indicators?cid=GPD_WDI (accessed 9.23.14).

Barkawi, W., 2014. Libya-Emerging Opportunities. In: Libya 2014-2015 Discovering Business. Allurentis Limited 2014. All rights reserved.

Bassey, M., 1999. Case Study Research in Educational Settings.

BBC, N., 2012. BP Settlement BP Claims Lawyer [WWW Document]. URL http://www.bbc.co.uk/news/business-20336898 (accessed 8.26.13).

BBC, N., 2013. The 60W bulb: A luminary love affairNo Title [WWW Document]. BBC Mag. URL http://www.bbc.co.uk/news/magazine-14715301 (accessed 11.11.13).

Bertoldi, E.P., Atanasiu, B., 2010. Proceedings of the 5th International Conference on Improving Energy Efficiency in Commercial Buildings : IEECB Focus 2008.

Bindra, S.P., Muntasser, M., El Khweldi, M., El Khweldi, A., 2003. Water use efficiency for industrial development in Libya. Desalination 158, 167–178.

Bloomberg, 2011. Global Trends In Renewable Energy Investment [WWW Document]. United Nations Environ. Program. Bloom. New Energy Financ. 2011. URL http://fs-unep-centre.org/sites/default/files/media/sefi2011finallowres.pdf (accessed 9.28.13).

Bloomberg, 2012. Global Trends In Renewable Energy Investment 2012 [WWW Document]. United Nations Environ. Program. Bloom. New Energy Financ. 2012. URL http://fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012.pdf (accessed 9.30.03).

Bloomberg, 2013. Global Trends In Renewable Energy Investment [WWW Document]. United Nations Environ. Program. Bloom. New Energy Financ. 2013. URL http://fs-unep-centre.org/sites/default/files/attachments/gtr2013keyfindings.pdf (accessed 9.5.13).

Blunch, N.., 2008. Introduction to Structural Equation Modelling using SPSS and AMOS. Sage Publication, London.

Bowling, A., 1997. Research Methods in Health. Open University Press, Open University Press, Buckingham.

Brandon, G., Lewis, A., 1999. Reducing household energy consumption : a qualitative and quantitative field study. J. Environ. Psychol. 19, 75–85.

BRANZ, 2005. Household Energy End-use Project, Annual Reports and Study Reports 1995–2004.

Brief, T., 2013. Concentrating Solar Power.

Briefi, B., 2005. www.bwea.com. Nottingham.

Brower, M., Green, D., Hinrichs-rahlwes, R., Sawyer, S., Sander, M., Taylor, R., Giner-reichl, I., Teske, S., Lehmann, H., Alers, M., Hales, D., 2014. 2014.

Bryman, A., 2004. Social Research Methods, 2nd ed. Oxford: Oxford University Press.

Bryman, A., Cramer, D., 1997. Quantitative Data Analysis with SPSS for Windows: A Guide for Social Scientists, Firth. ed. Routledge 29 West 35th Street, New York, NY 10001, London, London.

Burns, R., 2008. Business Research Methods and Statistical Using SPSS. Sage Publication, UK.

Busnaina, I.A.A., 2010. The Effect of Marketing Programmes on Buying Behaviour of Libyan Consumers. Nottingham Trent University.

Carrico, R., Vandenbergh, P., Stern, C., Gardner, T., Dietz, T., Gilligan, M., 2011. Energy and climate change: key lessons for implementing the behavioral wedge. J. Energy Environ. Law 2, 61–67.

Cathy, M., 1999. Home energy use behaviour : a necessary component of successful local government home energy conservation (LGHEC) programs 26.

CBL, 2006. Central Bank Of Libya-the Fiftieth Annual Report. Tripoli- Libya.

CBL, 2009. Economic Bulletin for the Fourth Quarter of 2009. Tripoli- Libya.

Chamberlin, A., 2014. Overview: The Libyan oil economy [WWW Document]. Mark. Realis. Democr. Invest. Manag. URL http://marketrealist.com/ (accessed 10.13.14).

Chua, L.., 2006. Sample Size Estimation Using Krejcie and Morgan and Cohen Statisical Power Analysis: A Comparison. J. Penyelid. IPBL, Jilid 7.

CIA, 2007. Central Intelligence Agency.

CIA, 2016. The World Factbook [WWW Document]. URL https://www.cia.gov/library/publications/the-world-factbook/geos/ly.html (accessed 4.13.16).

Cooper, D.., Schindler, P., 2003. Business Research Methods, Eighth ed. ed. McGraw-Hill/Irwin, a business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020.

Creswell, J., 2003. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 2 nd editi. ed. California: Sage Publications.

CTF, 2013. Climate Investment Funds: Revised CTF Investment Plan for MENA CSP. Washington D.C.

CTNI, 2005. Vision Study for Northern Ireland, the Carbon Trust, UK,.

Daily Times Report, 2014. Global market and industry overview [WWW Document]. Times, Dly. URL http://www.dailytimes.com.pk/business/09-Dec-2013/global-market-and-industry-overview-i (accessed 3.31.14).

DEFRA, 2003. Economic Instruments to Improve Household Energy Efficiency: Consultation Documents on Specific Measures.

DeVellis, 2003. Scale development: theory and applications. Sage Publication, UK.

Dietz, T., 2010. Narrowing the US energy efficiency gap. Proc. Natl. Acad. Sci. U. S. A. 107, 16007–16008.

Dilanthi, A., David, B., Marjan, S., Rita, N., 2002. Quantitative and qualitative research in the built enviroment: application of “mixed” research approach. Work study 51, 17–31.

Druckman, A., Jackson, T., 2008. Household energy consumption in the UK: a highly geographically and socio-economically disaggregated model. Energy Policy 36, 3177–3192.

DTI, 2002. Energy Consumption in the UK. Department of Trade and and Industry, the Stationary Office, United Kingdom.

DTI, 2003. Energy Consumption in the UK. Department of Trade and Industry, the Stationary Office, United Kingdom.

Easterby-Smith, M., 1991. Management Research: An Introduction. London: Sage Publications.

Easterby-Smith, M., Richard, T., Lowe, A., 2002. Management Research: An Introduction, 2nd ed. ed. London: Sage Publications.

EIA, 2011. No Libyan supply disruption may have both direct and indirect effects [WWW Document]. Indep. Stat. Anal. U.S. Energy Inf. Adm. URL http://www.eia.gov/todayinenergy/detail.cfm?id=390 (accessed 9.23.14).

EIA, 2012. Libya: Country Analysis Briefs. 250 Park Avenue, Suite 2000, New York, NY 10017.

EIA, 2013. libya oil and natural gas infrastructure. Energy information administration (eia).

EIA, 2014. Country Analysis Brief : Libya.

Ekhlat, M., Salah, I.M., Kreama, E.N.M., 2007. Development Energy Efficiency and Renewable Energy Libya - National study.

El-ashry, M., 2011. Although much has been done , there ' s so much more to do 4–5.

Elhage, M., Abdoum, R., Bailen, J., Al., E., 2008. Socialist People's Libyan Arab Jamahiriya— Statistical appendix: Washington. Washington.

El-Osta, 1995. Evaluation of wind energy potential in Libya. Appl. Energy- Elsevier Sci. Ltd 675–684.

El-Osta, W., Kalifa, Y., 2003. Prospects of wind power plants in Libya: a case study. Renew. Energy 28, 363–371.

EN, 2013. Libya Strategy Paper and National Indicative Programime 2011-2013.

European Commission, 2010. Country file: Libya.

Fact, R., From, S., World, T.H.E., Indicators, D., East, M., Africa, N., 2009. Middle East and North Africa.

Faraj, B., 2009. Alternative Energy Sources and its role in the production of electric power in Libya.

Fatema, A., Huda, A., 2012. Electrification of builings using solar energy in Libya. In: Solar Energy Sector, Regulation and Policies. International Conference on Soalr energy for MENA region (INCOSOL) Amman, Jorden, 22-23 October 2012.

FE, 2009. The economic impact of the CPRS andmodifications to the CPRS. [WWW Document]. Front. Econ. Pty Ltd, Melb. URL http://malcolmturnbull.com.au/LinkClick.aspx?fileticket=LCfIaswpc64=&tabid=90 (accessed 12.17.11).

Firth, S., Lomas, K., Wright, A., Wall, R., 2008. Identifying trends in the use of domestic appliances from household electricity consumption measurements. Energy Build. 40, 926–936.

Foresight, 2011. The Future of Food and Farming: Challenges and choices for global sustainability: Final Project Report. London. The Government Office for Science, London.

Franz, T., 2011. Project manager for the TRANS-CSP and the associated AQUA-CSP and MED-CSP report.

Froggatt, A., 2011. BBC News - Viewpoint Fukushima makes case for renewable energy [WWW Document]. BBC News. URL http://www.bbc.co.uk/news/world-asia-pacific-12960655 (accessed 1.16.13).

GECOL, 2011. General Electricity Company of Libya Report. Libya.

GECOL, 2013. General Electricity Company of Libya Report. Libya.

GECOL, 2014. Statistics 2012. Tripoli- Libya.

Geer, J.G., 1988. What Do Open-Ended Measure ? online J. 52, 365–371.

Georgy, R.Y., Energy, R., Nrea, A., 2007. Development Energy Efficiency and Renewable Energy Egypt - National study.

Ghauri, P., Gronhaug, K., Kristianslund, I., 1995. Research Methods in Business Studies: A Practical Guide. USA : Prentic Hall.

Gibril, S.E., 1995. Photovoltaic Power Plant for the Southern Region of Libya. Appl. Energy- Elsevier Sci. Ltd 52, 219–227.

Gillingham, K., Newell, G., Palmer, K., 2009. Energy efficiency economics and policy.

Goldman, C., 1985. Measured energy savings from residential retrofits: updated results from the BECA-B project. Energy Build. 8, 137–155.

Goodland, R., 2013. Libya. In: Libya: The Urgent Transition to Environmental Sustainability. R. J. A. Goodland, Tripoli- Libya, p. 152 pp.

Gorman, E., Clayton, P., 1997. Qualitative Research for the Information Professional: A Practical Handbook. London: Library Association Publishing.

Government, L., 2005. Country Profile: Libya. Tripoli- Libya.

Government, L., 2011. The database Centre for Research and Information and Documentation in Libya [WWW Document]. URL www.buhuth.ly

GPCEWGL, 2008. The Libyan General people's Committee for Electricity, Water and Gas. Annual Report. Tripoli- Libya.

GPCEWGL, 2010. The Libya General People's Committee for Electricity, Water, and Gas.

GPCFAAL, 2007. No The General People's Committee of The Financial Audit Authority. Tripoli- Libya.

GPEWGL, 2013. Planning Electrical Power System Studies For Libya. Tripoli- Libya.

Graisa, M., Al-Habaibeh, A., 2011. An investigation into current production challenges facing the Libyan cement industry and the need for innovative total productive maintenance (TPM) strategy. J. Manuf. Technol. Manag. 22, 541–558.

Grein, M., Nordell, B., Mathnani, A. Al, 2007. Energy consumption and future potential of renewable energy in North Africa. Rev. des Energies Renouvelable ICRESD-07 Tlemcen 249–254.

Harris, L.R., Brown, G.T.L., Hong, T., 2010. Mixing interview and questionnaire methods : Practical problems in aligning data 15.

Hassin, E., 2009. Total quality management in Libya: a study of its use in the electrical power generation industry. Environment. Glasgow Caledonian university.

Hiba, A., Jibril, A., 2010. Solar energy experiments and constraints. Egypt.

Hitchcock, G., 1993. An integrated framework for energy use and behaviour in the domestic sector. Energy Build. 20, 151–157.

Huda, A., Fatema, A.-H., 2012. Electrification of Building Using Solar Energy in Libya: Solar Energy Sector, Regulations and Policies. In: International

Conference on Solar Energy for MENA Region (INCOSOL). Amman, Jordan, 22-23 October 2012. INCOSOL 034, Jordan.

Hussey, J., Hussey, R., 1997. Business Research: A Practical Guide for Undergraduate and Postgraduate Students. . New York: Palgrave.

Ibrahim, I., 2014. Corporate Environmental Disclosure: A Case from the Libyan Construction Industry. Liverpool John Moores University.

Ibrahim, S., 2010. Systems, solar cells and its role in expanding he base of contacts in Al-Madar. In: The Libyan Arab International Conference on Electrical and Electronic Engineering LAICEEE 23-26/10/2010.

IEA, 2005. World Energy Outlook 2005, " International Energy Agency, Paris. Paris.

IEA, 2013. World Energy Outlook 2013: Redrawing the energy - Climate MAP.

Imen, B., 2012. Renewable Energy in the GCC Countries. Masdar City.

IMF, 2012. Global Insights 2012: Libyan Ministry of Planning Report 2012.

Ingmar, W.S.T., 2011. Solar photovoltaic electricity Solar generation 6: Solar photovoltaic electricity Electrcity Empowering the World.

IPCC, 2012. Managing the risks of extreme events and disasters to advance climate change adaptation (SREX). Special Report of the Intergovernmental Panel on Climate Change (IPCC). Geneva, IPCC Secretariat.

IRENA, 2013. Renewable Energy and Jobs.

Jaber, J.O., 2002. Prospects of energy savings in residential space heating. Energy Build. 34, 311–319.

Jaffe, B., Stavins, N., 1994. The energy efficiency gap: What does it mean? Energy Policy 22, 804–810.

Jones, I., 1997. Mixing qualitative and quantitative methods on sport fan research (No. 4), The Qualitative Report, online serial, The Qualitative Report, online serial.

José, S., Morillo, - Jesús, Trigo, - Inmaculada, Pérez, - Luis, Ruiz, - Valeriano, Crespo, - Luis, Ruiz, - Alicia, Florencio, - Manuel J., Rodríguez, - Fátima, Tena, - Sol Luca de, Silva, - Silvia, 2013. Current Status of CSP in the world [WWW Document]. Protermo Sol. URL http://www.helioscsp.com/noticia.php?id_not=1853 (accessed 3.20.14).

Judith, B.., 1999. A Guide for First-Time Researchers in Education, Health and Social Science, (4th Editi. ed. Buckingham, Open University Press.

Karbal, M., 2014. Libyan Investment Law : Foreign Oil Companies.

Keiichi, K., Masakazu, L., Peter, V., David, F., 2009. Energy from the Desert: Very Large Scale Photovoltaic System: Socio-economic, Financial, Technical and Environment Aspects. Publishing for a sustainable future. London. Sterling, VA.

Kerlinger, F., 1987. Foundations of behavioral research. New York, NY, Macmillan.

Kershman, S. a., 2001. 25 Years of Experience in Operating Thermal Desalination Plants. Desalination 136, 141–145.

Kezeiri, S., Lawless, R., 1987. Economic Development and Spatial Planning in Libya. In: Kader, B. and El-Wifati, B. (eds) The Economic Development of Libya. Croom Helm, London.

Khaled, E., 2007. Capital Market and Accounting Disclosure in Emerging Economies: The Case of Libya. University of Salford.

Khalil, E.-A., Mohamed, M., Belkasem, E.-O., Salah, S., Osman, S., 2009. Demand Side Management in Libya - A Case Study of the General Electric Company of Libya: Transmission System Operation and Control Department. Tripoli- Libya.

Kilpatrick, R. a. R., Banfill, P.F.G., Jenkins, D.P., 2011. Methodology for characterising domestic electrical demand by usage categories. Appl. Energy 88, 612–621.

Koen, S., Geun, Y., 2011. Behavioural, physical and socio-economic factors in household cooling energy consumption. Appl. Energy- Elsevier Sci. Ltd 88, 2191–2200.

Komoto, K., 2009. Energy from the desert: very large scale photovoltaic systems: socio-economic, financial, technical and environmental aspects, Feasibility of Very Large Photovoltaic Power …. photovoltaic Power System Executive Committee of the International Energy Agency,2009.

Krejcie, R.V., Morgan, D.W., 2006. Determining sample size for research activities. Educ. Psychol. Meas. 30, 607–610.

Kumar, R., 1999. Research Methodology: A Step-by-Step Guide for Beginners. London: Sage Publication Ltd.

Labcraft, 2011. Labcaft Design Lighting, viewed on 22 July 2011 [WWW Document]. URL http://www.labcraft.co.uk/products/market_selector_leisure.php (accessed 11.8.13).

Lam, J.C., 1998. Climatic and economic influences on residential electricity consumption. Energy Convers. Manag. 39, 623–629.

Lawgali, F., 2008. Forecasting water demand for agricultural, industrial and domestic use in Libya. Int. Rev. Bus. Res. … 4, 231–248.

Leach, L., Latta, B., Laurence, T., 2000. Collecting energy-related behaviour information in the real world. Proc. ACEEE Summer Study Energy Efficiency Build. 8, 197–205.

LEDinside, 2011. LED Light Bulbs Evaluation (40 Incandescent Light Bulbs)-Luminous Flux. [WWW Document]. Co. Web. URL http://www.ledinside.com/pricequotes/2011/7/led_bulb_lm_201107 (accessed 11.11.13).

Lee, A.W.H., 2000. Verification of electrical energy savings for lighting retrofits using short- and long-term monitoring. Energy Convers. Manag. 41, 1999–2008.

Lee, S.K., Palmer, E., 1999. An empirical examination of ISO 9000 registered companies in New Zealand. Total Qual. Manag. 10, 887–907.

LFIB, 2007. Ministry of foreign affairs And International Cooperation.

Lutzenhiser, L., 1993. Social and behavioral aspects of energy use. Annu. Rev. Energy Environ. 18, 247–289.

Madomercandy, R., 2007. Investigation of The Feasibility of Renewables in Meeting The Moroccan Primary Energy Deman. Napier University.

Malhotra, N., 2007. Marketing Research: An Applied Orientation, 5th Intern. ed. Pearson Prentice Hall, USA.

Malhotra, N.K., Birks, D.F., 2003. Marketing Research: An Applied Approach, 2nd ed. ed. Harlow: Prentice Hall.

Mandil, C., 2005. WORLD ENERGY OUTLOOK 2005: Middle East North Africa Insights Middle East North Africa. Paris.

Mangan, J., 2004. Combining quantitative and qualitative methodologies in logistics research. Int. J. Phys. Distrib. Logist. Manag. 34, 565–578.

Mangement, C., 2012. The Ministry of Libyan Labour and capacity bulding.

Mangement Commission, 2009. The General Electricity Company of Libya. Tripoli-Libya.

Mangement Commission, 2010. The General Electricity Company of Libya. Tripoli-Libya.

Mansouri, I., Newborough, M., Probert, D., 1996. Energy consumption in UK households: Impact of domestic electrical appliances. Appl. Energy 54, 211–285.

Marconi, E.G., 2014. Grid Connected Doubly Fed Induction Generator Based Wind Turbine under LVRT. Bologna, Italy.

Masson, G., Latour, M., Rekinger, M., Papouts, I.-T.T.M., 2013. Global Market Outlook: For Photovoltaics 2013-2017.

MEREL, 2005. Libyan Ministry of Electricity and Renewable Energy, Annual report 2005 up 2010. Tripoli- Libya.

Millward, B., 2003. No TitleQuantitative Energy Efficiency, Northern Ireland Electricity and the Energy Saving Trust.

Missaoui, R., Mourtada, A., 2010. Instruments and Financial Mechanisms of energy efficiency measures in building sector. World Energy Counc. ADEME.

Mohamed, A., Al-Habaibeh, A., Abdo, H., 2013a. An investigation into the current utilisation and prospective of renewable energy resources and technologies in Libya. Renew. Energy 50, 732–740.

Mohamed, A., Al-Habaibeh, A., Hafez. Abdo, 2013b. the Significance of Utilising Renewable Energy Options Into the Libyan Energy Mix. Energy Res. J. 4, 15–23.

Mohamed, E., 2005. Environment impact assessment for desalination plants in Libya. Case study: Benghazi North and Tobrouk desalination plants. Desalination 185, 31–44.

Mohamed, M., Saleh, I., Ibrahim, M., 1998. Comparative Study In Supplying Electrical Energy To Small Remote Loads In Libya. Renew. Energy 14, 135–140.

Mohamed, Z., 2010. CO2 Emission Factor for the electricity generation system in Libya. In: Proceedings of the Libyan International Conference on Electrical and Electronic Engineering. pp. 23–26.

Mohammed, B., Milad, M., 2010. Wind load characteristics in Libya. World Acad. Sci. Eng. Technol. 63.

Mohammed, Z., 2010. CO2 Emission Factor for the electricity generation systems in Libya. The Libyan International Conference on Electrical and Electronic Engineering LAICEEE 23-26/10/2010, Libya.

Monitor, D.T., 2013. Renewables 2013: Global Status Report, Global market and industry overview (III) [WWW Document]. Dly. Times. URL http://www.dailytimes.com.pk/business/23-Dec-2013/renewables-2013-global-status-report-global-market-and-industry-overview-iii (accessed 1.6.14).

Naief, A., Yacine, R., Alan, K., 2014. Domestic energy consumption patterns in a hot and humid climate: A multiple-case study analysis. Appl. Energy- Elsevier Sci. Ltd 114, 353–365.

Naseem, T., 2008. An Evaluation of The Implementation of Total Quality Management (TQM) Within The Information and Communication Technology (ICT) Sector in Jordan. The University of Huddersfield.

News, M., 2009. http://www.gpc.gov.ly/html/list_decision.php [WWW Document]. URL http://www.gpc.gov.ly/html/list_decision.php (accessed 10.24.09).

NIHE, 2001. NorthernIrelandHouseConditionSurvey, NorthernIrelandHousing Executive. Belfast, UK.

Nilssen, P.A., 2003. Household energy use and the environment—a conflicting issue. Appl. Energy 76, 189–196.

NTC, 2011. The US recognises Libya’s Transitional National Council. [WWW Document]. World Social. Web Site.20 July 2011, http//www.wsws.org/articles/2011/jul2011/pers-j20.shtml,. URL http://www.wsws.org/articles/2011/jul2011/pers-j20.shtml,

Olsen, W., 2004. Tringulation in Social Research: Qualititative and Quantitive Methods Can Really Be Mixed, 4th ed. ed. M. Holborn, Ormskirk: Causeway Press.

Oppenheim, A., 1992. Questionnaire Design, Interviewing and Attitude Measurement, 2nd ed. ed. London: Continuum.

Oppenheim, A., Naftali, A., 2000. Questionnaire Design, Interviewing and Attitude Measurement. London: Continuum.

Owens, J., Wilhite, H., 1988. Household energy behaviour in Nordic countries—an unrealized energy saving potential. Energy 13, 853–859.

Pak, L., Gerald, C., Chan., L.-H., 2009. China’s “Realpolitik” Engagement with Myanmar. China Secur. 5.

Palmborg, C., 1986. Social habits and energy consumption in single-family homes. Energy 11, 643–650.

Patel, M., 2006. Wind and Solar Power Systems, Secod Edit. ed. CRC Press. Boca Raton London NewYork Washington, D.C., USA.

PENN State, 2013. P ADM503: Research Methods [WWW Document]. URL https://courses.worldcampus.psu.edu/welcome/padm503/001/content/01_lesson/02_topic/03_page.html

Poortinga, W., Steg, L., Vlek, C., Wiersma, G., 2003. . Household preferences for energy-saving measures: a conjoint analysis. J. Econ. Psychol. 24, 49–64.

Power, C.S., 2010. Technology Roadmap: Concentrating Solar Power. IEA Technology Roadmaps.

Pratten, J., Mashat, A., 2009. Corporate social disclosure in Libya. Soc. Responsib. J. 5, 311–27.

Presence, E.A., 2012. Renewable energy and the social and economic implications [WWW Document]. J. Natl. Def. URL http://www.lebarmy.gov.lb/ar/news/?31389#.U0VWv_ldUmh (accessed 4.9.14).

REN21, 2010. Renewables 2010: Global status report (Paris: REN21 Secretariat)., Nuclear Safety.

REN21, 2011. Renewables 2011: Global status report (Paris: REN21 Secretariat).

REN21, 2012. RenewableS 2012 Global Status Report (Paris: REN21 Secretariat).

REN21, 2013. RenewableS 2013 Global Status Report (Paris: REN21 Secretariat).

REN21, 2014. RenewableS 2014 Global Status Report (Paris: REN21 Secretariat).

Richard, F., Anita, L., 2008. Research Methods for Construction, Third Edit. ed. Wiley-Blackwell Publishing Ltd.

Riessman, C., 2004. Narrative Analysis. In. Lewis-Beck, M., Bryman, A., and Liao, T. (Eds). In: The Sage Encyclopaedia of Social Science Research Methods (Vols 1-3). Thousand Oaks, Calif.: Sage.

Robinson, V., Meah, A., 2013. Cross-Generational Investigation of the Making of Heterosexual Relationships, 1912-2003 [WWW Document]. ESDS Qualidata UK Data Serv. data Cat. URL http://discover.ukdataservice.ac.uk/catalogue?sn=5190 (accessed 7.6.13).

Robson, C., 1993. Real World Research: A Resource for Social Scientists and Practitioner Researchers. Blackwell Publishers Inc.

Rose, N., 2004. Libya Energy Report. Oil, Gas Energy Law J.

Russell, L., 2010. DumpDC Gulf Oil Spill Disaster : The Trigger of American Economic Collapse ?

S.C, 2014. Solar Photovoltaics (PV): Solar markets [WWW Document]. decarboni.se Solut. to Clim. Chang. URL http://decarboni.se/publications/renewables-2013-global-status-report/solar-photovoltaics-pv (accessed 6.24.14).

Salah, I., 2006. Prospects of Renewable Energy in Libya. In: International Symposium on Solar Physics and Solar Eclipses (SPSE) 2006. Waw an Namos, Libya. 27-29 March 2006, pp. 153-161.

SAMI, S., 2012. Emissions Trading and Sustainable Development: A Case Study of the Libyan Oil and Cement Industries. The University of Southern Queensland.

Sami, Z., 2013. Ambitious goals in the oil and gas sector. In: Libya Herald. Wahab, Ashraf Abdul. www.libyaherald.com, Libya.

Saunders, M., Lewis, P., Thornhill, A., 2003. Research Methods for Business Students, 3rd edn. ed. London: Financial Times Prentice Hall.

Saunders, M., Lewis, P., Thornhill, A., 2007. Research Methods for Business Students, 4th ed. ed. London: Financial Times Prentice Hall.

Schipper, L., Ketoff, A., Meyers, S., 1982. International residential energy demand use data: analysis of historical and present day structure and dynamics. Energy 7, 205–212.

SCSP, H., 2013. Solar Thermal Energy News: Current Status of CSP in the World. [WWW Document]. HELI SCSP. URL http://www.helioscsp.com/noticia.php?id_not=1853 (accessed 11.12.13).

Sekaran, U., 2003. Research Methods for Business: A Skill Building Approach. New York: John Wiley and Sons.

Seligman, C., Darley, M., Becker, L., 1977. . Behavioural approach to residential energy conservation. Energy Build. 1, 325–337.

Shanks, K.B.P., Lo., S.N.G., Norton, B., 2006. Energy efficient buildings' envelope technologies for social housing refurbishment. J. Hous. Built Environ. 21, 191–202.

Shoab, A., 2012. Development of a Sustainable Water Management Strategy in the Alwahat area of Libya. Nottingham Trent University.

Soares, A., 2004. The influence of Culture on Consumers Exploratory and Risk Taking Behaviour. University of Minho.

Staff, U.S.D. of S., 2013. U.S. Relations with LIbya [WWW Document]. U.S. Dep. State. URL http://www.state.gov/r/pa/ei/bgn/5425.htm#people (accessed 9.23.14).

Stephen, C., 2013. Why Americans are Bullish on Libya as an Investment Destination. In: Libya Herald. Wahab, Ashraf Abdul. www.libyaherald.com, Libya.

Stern, P.C., Gardner, G.T., Vandenbergh, M.P., Dietz, T., Gilligan, J.M., 2010. Design principles for carbon emissions reduction programs. Environ. Sci. Technol. 44, 4847–4848.

Sultan, Y., 2005. Total Quality Management Framework for Libyan Process and Manufacturing Industries. University of Cranfield.

Tagouri, O., 2009. Types of energy in Libya [WWW Document]. URL www.panoramalibya.com (accessed 6.28.09).

Tanaka, N., 2009. Natural Gas: Market Review: International Energy Agency (IEA).

Teketay, D., 2010. Country brief: Libya, State of forests and forestry research in Ethiopia. …. New York,NY 10017.

Teske, S., Onufrio, G., Gianni, A., Rainer, E., Rahlwes, H., 2013. [r] evolution EUROPEAN RENEWABLE " will we look into the eyes of our children and confes s that we had the opportunity ,.

Teske, S., Schaefer, O., Zervos, A., Beranek, J., Tunmore, S., 2008. Energy evolution: a sustainable global energy outlook.

Uche, N., 1995. An Analysis of the Feasibility of Developing a Generic Model for the Implementation of Total Quality Management. Sheffield Hallam Univerrsity.

UK, 2014. General Assembly.

Umar, K., 2013. Attracting foreign investment to Libyan construction market,. In: Libya Herald. Wahab, Ashraf Abdul. www.libyaherald.com, Libya.

UNFCCC, 1997. Kyoto protocol to the United Nations framework convention on climate change. New York.

UNFCCC, 2003. caring for climate a guide to the climate change convention and the kyoto protocol. [WWW Document]. ISBN. URL http://unfccc.int/resource/docs/publications/caring_en.pdf (accessed 1.12.12).

US & FCS, 2006. Doing Business in Libya: A Country Commercial Guide for U.S. Companies. U.S. Foreign Commer. Serv. U.S. Dep. State 17–47.

Votano, J., Parham, M., Hall, L., 2006. Africa Environment Outlook2: Our Enviroment, Our Wealth. Chem. ….

Waddah, B., 2013. Libyan's Investment Needs. Libya Her.

Waniss, O., Karlberg, E., 2007. The Libyan Economy: Economic Diversification and International Repositioning. Springer – Verlag Berlin Heidelberg 2007.

Watkins, K., 2008. Team for the preparation of the Human Development Report 2007 / 2008.

Westergren, K., Hogberg, H., 1999. Monitoring energy consumption in single-family houses.

Wheida, E., Verhoeven, R., 2004. Desalination as a water supply technique in Libya. Desalination 165, 89–97.

Wilhite, L., Wilk, R., 1987. A method for self-recording household energy-use behavior. Energy Build. 10, 73–79.

Wood, G., Newborough, M., 2003. Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design. Energy Build. 35, 821–841.

Workshop, A., 2009. Demand Side Management and Energy Efficiency in the Electricity Sector. Tripoli- Libya.

Yin, K., 1994. Case Study Research: Design and Methods,. Sage Publication, Newbury Park, CA.

Yohanis, G., Mondol, J., Wright, A., Norton, B., 2005. Household Energy Research Project.

Yohanis, G., Norton, B., 2002. Life-cycle operational and embodied energy for a generic single-storey office building in the UK. Energy 27, 77–92.

Yohanis, Y.G., 2012. Domestic energy use and householders' energy behaviour. Energy Policy 41, 654–665.

Yohanis, Y.G., . J.D.M., Alan, W.., Brian, N., 2008. Real-life energy use in the UK: How occupancy and dwelling characteristics affect domestic electricity use. Energy Build. 40, 1053–1059.

Yosaf, K., 1998. Wind atlas for the coastal region of Libya, M.Sc. dissertation. Tripoli University.

Zervos, A., Lins, C., Muth, J., 2010. RE-thinking 2050: A 100% Renewable Energy vision for the European Union. European Renewable Energy Council (EREC).

Appendices

Appendix A : The Interview (English version).

NOTTINGHAM
TRENT UNIVERSITY

Interview Guide

SEMI-STRUCTURED INTERVIEWS

Interview Guide

This guide lists a pre-determined set of questions or issues that are to be explored during an interview. This guide serves as a road map and checklist during the interview and insures that basically the same information is obtained from the interviewees in Libyan energy experts, produces of energy, consumers of energy and others.

Participation form

I am Ahmed Mohamed from Nottingham Trent University, and I am conducting this participate as part of my PhD's thesis: 'Investigation into the Feasibility of the Utilisation of Renewable Energy Resources in Libya'. Your participation will be conducted by answering set of general questions that require personal experience and knowledge through your work area in this organisation, company, or university in energy or renewable.

Name: …………………………………………………………

Position: .……………………………………………………...

Institution: …..……………………………………………………..

Address: …..……………………………………………………….

Phone: .……………………………………………………….

Fax: …..…………………………………………………….

E-mail: ………………………………………………………..

I would like to participate in the research to give my opinion, comments and suggestions from my experience. Will answer the questionnaire and conducted the interview. Yes ☐ No ☐

Remarks:……………………………………………………………………………
………………………………………………………………………………………
………………

INTERVIEW GUIDE

Interview Date: ....

Name of Organisation: ....

Name of Participant: ....

Phone: ....

Email: ....

Position/Title: ....

Introduction

Good Morning/ Afternoon. My name is **Ahmed Mohamed** from Trent University and I am conducting this interview as part of my PhD's thesis:" Investigation into the Feasibility of the Utilisation of Renewable Energy Resources in Libya"

This morning/afternoon I would like to talk to you about your perception of your organization's/ university's/ company's about current energy generation and consumption in Libya and the challenges/opportunities of implementing new renewable energy systems in Libya in the future.

This interview is completely voluntary and confidential if at any time you would rather not answer a question please say so. The information will be used for a report but I will not include your name.

The interview should last about 60-75 minutes and with your permission will be taped. With your agreement I will proceed with the interview.

Interviewees' questions list

Part one:

1/ Demographic Information:

- Interviewee name
- Organisation name
- Position
- Qualifications
- Address
- E-mail

2/ Information about institutions:

- Productions reports.
- Annual reports.
- Activities reports.
- Assessment reports.
- Other issues (shown during the interview analysis)

Part two: interview questions:

3. Do you think renewable energy is available in Libya for commercial utilisation?
4. Do you think renewable energy is important to the development of Libya?
5. Do you think renewable energy will satisfy energy demand following the expiration of oil?
6. Which type of renewable energy do you think has the most potential and could become the most economically feasible for large-scale use?
7. What energy sector do you think could have the best investment opportunities?
8. What are the reasons behind the insufficient electricity production to meet demand?
9. Do you think that an adequate effort was made to promote renewable energy by the Libyan government?
10. When do you expect renewable energy will be used in Libya?

11. What is the public opinion with respect to renewable energy in Libya?
12. Do you expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden?
13. Libya is one of the countries affected by climate change as a result of environmental pollution can that be a calling for reconsideration to continue using conventional energy?
14. Do you expect that the cost of energy production by renewable energy sources will be more or less than the current source?
15. Do you expect/ know that, the Libyan government has planned to reduce carbon emission by using traditional fuel in electricity and water production stations?
16. Do you think that, the Libyan government has clear policy for renewable energy?
17. Do you think that, there are any technical, commercial and environment studies phases required for the implementation of renewable energy projects in Libya?
18. Do you have any information or scientific studies about the use many types of renewable energy in Libya?
19. What has been accomplished of Renewable Energy Authority plan?

The End

Thank you very much for taking the time to complete this interview!

Appendix B :The Interview (Arabic version).

NOTTINGHAM
TRENT UNIVERSITY

استمارة مشاركة

انا احمد محمد عياد طالب بجامعة نوتنجهام ترنت ، هذه المشاركة تتعلق بموضوع دراستى بغرض الحصول على الدكتوراه وموضوعها دراسة جدوى الاستثمار فى الطاقة البديلة او المتجددة فى ليبيا . مساهمتكم ستكون من خلال الإجابة على بعض الأسئلة العامة والتى تتطلب خبرتك ومعرفتك الشخصية من خلال مجال عملك فى هذه المنظمة او الشركة او الجامعة فى الطاقة المتجددة او وظيفتك القيادية . المعلومات التى سوف تقدمها ستستخدم فى البحث مع عدم تضمين اسمك إذا شئت . وللمشاركة إملاء الفراغات أدناه باللغة الانجليزية او العربية

الاسم ....

الوظيفة ....

المؤسسة ....

عنوانك ....

رقم الهاتف ....

الايميل ....

دليل المقابلات الشخصية

هذا الدليل يحصر مجموعة الاسئلة او القضايا التى سيتم تناولها خلال هذه المقابله ، وسيكون هذا الدليل بمثابة خارطة الطريق والمرجعية اثناء المقابلة لضمان تحقيق اهداف هذه المقابلات مع مستهلكين الطاقة بغرض اعادة انتاج الطاقة (شركة الكهرباء وهيئة المياه) ، والمنتجين للطاقة (شركة البريقة وشركة الخليج) والخبراء المختصين فى جامعة الفاتح طرابلس وجامعة قاريونس بنغازى والجهاز المختص بالطاقة المتجدده وكذلك الادارات بالنهر الصناعى وقطاع الانارة العامة.

تاريخ المقابلة ....

اسم الجهة ....

الهاتف ....

الايميل ....

الوظيفة ....

نوع العمل : قطاع عام .... قطاع خاص ....

ان وجد ارفق السيرة الذاتية ....

تقديم

صباح الخير / مساء الخير انا اسمى **احمد محمد عياد** طالب بجامعة نوتنجهام ترنت ، هذه المقابلة ستضمن فى دراستى بغرض الحصول على الدكتوره والمتعلقة بدراسة جدوى الاستثمار فى الطاقة المتجددة فى ليبيا .

هذا الصباح / مساء اود التحدث اليك عن خبرتك ومعرفتك من خلال مجال عملك فى هذه المنظمه او الشركة او الجامعه فى الطاقة المتجدده . هذه المقابلة تطوعية (voluntary) وموثوقة (confidential) فى اى وقت يمكنك عدم الاجابة على الاسئلة ، المعلومات التى سوف تقدمها ستستخدم فى البحث مع عدم تضمين اسمك اذا شئت .

هذه المقابلة ستاخذ حوالى 60 الى 120 دقيقة ، وبعد اذنك سوف تكون هذه المقابلة مسجلة ، بعد موافقتك سنبداء مباشرتا .

قائمة اسئلة المقابلة

الجزء الاول: بيانات المستبين والمؤسسه

1/ بيانات المستبين

- الاسم
- اسم المنظمة
- الوظيفة
- المؤ هل
- العنوان
- الايميل

2/ معلومات عامة حول المؤسسة

- تقارير الانتاج
- التقارير السنوية
- تقارير النشاط
- تقارير التقييم
- مواضيع اخرى (تم عرضها خلال تحليل المقابلات)

الجزء الثانى : اسئلة المقابلة

س3/ هل تعتقد أن الطاقة المتجددة متوفره في ليبيا للاستخدام التجاري؟

س4/ هل تعتقد أن الطاقة المتجددة مهم للتنمية فى ليبيا؟

س5/ هل تعتقد أن الطاقة المتجددة سوف تلبي الطلب على الطاقة في أعقاب انتهاء النفط؟

س6/ اي نوع من انواع الطاقة المتجددة تعتقد ان لديها إمكانات أكثر ويمكن أن تصبح مجدية اقتصاديا للاستخدام على نطاق واسع؟

س7/ ماهو قطاع الطاقة الذى تعتقد لدية افضل فرصة للاستثمار؟

س8/ ما هي الأسباب التي وراء عدم كفاية الانتاج لمقابلة الاحتياجات الفعليه؟

س9/ هل تعتقد ان الحكومة الليبية بذلت مجهودات لتعزيز الطاقة المتجدده؟

س10/ متى تتوقع سيتم استخدام الطاقة المتجددة في ليبيا؟

س11/ ما هو الرأي العام فيما يتعلق بالطاقة المتجددة في ليبيا؟

س12/ هل تتوقع أن إنتاج الطاقة من المصادر المتجددة سوف يوفر الطاقة بأسعار معقولة ويقلل عبء نفقات الطاقة؟

س13/ ليبيا احدى البلدان التي ثاثرت بتغير المناخ نتيجة للتلوث البيئي فهل ذلك يستدعى الدعوة لإعادة النظر في مواصلة استخدام الطاقة التقليدية؟

س14/ هل تتوقع أن تكلفة إنتاج الطاقة من مصادر الطاقة المتجددة سوف يكون أكثر أو أقل من المصدر الحالي؟

س15/ هل تتوقع أن الحكومة الليبية لديها خطة لخفض انبعاثات الكربون الناتج عن استخدام الوقود التقليدي في الكهرباء ومحطات إنتاج المياه؟

س16 / هل تعتقد أن الحكومة الليبية لديها سياسة واضحة للطاقة المتجددة؟

س17/ هل تعتقد أن هناك أي دراسات تقنية او اقتصادية او بيئية كمراحل الدراسات مطلوبة واللازمة لتنفيذ مشاريع الطاقة المتجددة في ليبيا؟

س18/ هل لديك أي معلومات أو دراسات علمية حول استخدام أنواع الطاقة المتجددة في ليبيا؟

س19/ ما تم إنجازه من خطة "هيئة الطاقة المتجددة"؟

انتهت الاسئلة

شكرا لوقتك فى استكمال هذه المقابلة

Appendix C : The Questionnaire (English version).

NOTTINGHAM
TRENT UNIVERSITY

A questionnaire of the PhD research under the title of Investigation into the Feasibility of the Utilisation of Renewable Energy Resources in Libya

Dear Participant

I am a PhD student at the Nottingham Trent University, currently conducting research in the area of renewable energy. This study aims to investigate the challenges and opportunities for investment in renewable energy in Libya. It also will offer the Libyan government a strategy for providing sustainable energy resources, and sustaining their position in the current international energy market.

I would very much appreciate your participation and help since the success of this research depends upon your response, and all responses will be treated with the utmost confidence, the results of the survey will be used for this research purposes only and no attempt will be made to identify an individual or organisation.

I would like to inform you that your contribution is voluntary, and you are free to reject or withdraw at any time without giving any reasons and with no implications for your legal rights. In the case of withdrawing, your collected data will not be used.

Thank you in advance for your participation.

Ahmed Mohamed

Nottingham Trent University

ahmed.mohamed@ntu.ac.uk

Dome -V1 (   ) **Householder consumption**

Part 1 - General information

Please make a tick (√) in the box that reflects your best answer.

1/ Home description:

Private house ☐ Apartment building ☐ Private villa ☐

Government House ☐ Flat ☐ More than one ☐

2/ Home area:

Small less than 120 m^2 ☐ Middle 120 m^2 - 150 m^2 ☐

Large 150 m^2 - 300 m^2 ☐ Very large more than 300 m^2 ☐

3/ The garden of the House

No garden ☐ Annex Small garden ☐ Annex two garden ☐

Annex large garden ☐

4/ Garden area

No garden ☐ Small less than 120 m^2 ☐ Middle 120 m^2 - 150 m^2 ☐ Large 150 m^2 - 300 m^2 ☐ Very large more than 300 m^2 ☐

5/ Home ownership

Private ownership with the responsibility of paying bills ☐

Private property without the responsibility of paying bills ☐

Public ownership with the responsibility of paying bills ☐

The public ownership with no responsibility for the payment of invoices ☐

6/ The Home location

Tripoli ☐ Benghazi ☐ Western ☐

Middle ☐ Southern ☐ Green Mountain ☐

Part 2 - Information related to the energy which is used on the house.

7/ Energy types (Regardless of the energy source is network, generators and others)

Electricity ☐ Fossil fuel ☐ Both ☐

8/ Energy source

Network ☐ Generator ☐ Both ☐

9/ Type of use

a/ Electricity: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

b/ Gas: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

c/ Kerosene: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

d/ / diesel: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

10/ The source of water used for home facilities

Underground water ☐ Public water (Tap water) ☐

local home well ☐ Rainwater ☐ More than one ☐

Part 3 - Information related to energy prices.

11/ Please make a tick (√) in the box that reflects your best answer where:

1= Strongly disagree 2= Disagree 3= Neither agree nor disagree

4= Agree 5= Strongly agree

items	1	2	3	4	5
General company for electricity services are sufficient and appropriate					
The price of electricity is reasonable					
The gas price is reasonable					
The price of kerosene is affordable					
The price of gasoline is reasonable					
The diesel prices are affordable					
Water Authority services are sufficient and appropriate					
The price of public water is reasonable					
Electricity is always available					
Water is always available					

items	1	2	3	4	5
Gas is always available					
Pay your energy and water bills					

Part 4: Information related to power and water outages (if occurred).

12/ Please place a tick (√) in the boxes that reflects your best answer. (You can chose more than one)

a/ Causes of power outage

Problems with internal home connections ☐ General network failure ☐ Delivery cost ☐ The source ☐ No outages ☐

b/ Causes of water outage

Problems with internal home connections ☐ General network failure ☐ Delivery cost ☐ The source ☐ No outages ☐

c/ Reasons for the lack of gas cylinders

The source ☐ Not available in the station ☐ Stations distance ☐

Using instant Electricity ☐ No lack ☐

d/ Reasons for the lack of street lighting

There is no grid ☐ From the source ☐

The public network failure ☐ Stations distance ☐ Others ☐

Part 5: Information about energy resources and environment issues.

13/ Please make a tick (√) in the box that reflects your best answer where:

Yes = Agree No = disagree

Questions	Yes	No
Do you have any information on other energy sources which can be the best alternative to the current source?		
Do you have any information/ idea about renewable energy?		
Do you think that renewable energy such as solar and wind is best alternative to the current energy?		
In the case of availability with competitive prices of renewable energy resources and technology are you going to use them?		
Do you have any idea about the environmental damage resulting from the use of electricity and water production plants by traditional fuel?		

Questions	Yes	No
Do you think that the environmental pollution in Libya could be the reason to reconsider continuing to use traditional energy?		
Do you expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden?		
Is there a renewable energy technology markets in Libya?		
Have you seen this technique used in Libya?		
Do you support the production of energy from environmentally friendly sources?		
Do you support legislation to reduce and regulate the use of conventional energy?		
Do you encourage legislation to increase the use of renewable energy		

14/ If you have any other comments or suggestions you can add them here

....

B &S farms-V1 (   )

Agricultural consumption of

Non-Commercial and Commercial farms

Part 1 - General information

Please place a tick (√) in the box that reflects your best answer.

1/ Farm description

Agricultural production farm ☐ Animal production Farm ☐

Birds Production farm ☐ Fish farm ☐ More than one ☐

2/ Business type

Non-Commercial farm ☐ Commercial farm ☐

3/ The type of agriculture

Rain fed farm ☐ Irrigated Farm ☐

4/ Farm area

Small less than 10000 m^2 ☐ Middle 10000 m^2 - 50000 m^2 ☐

Large 50000 m^2 - 100000 m^2 ☐ Very large more than 100000 m^2 ☐

5/ Farm's facilities

Residential house ☐ Home of workers ☐ Milk productions ☐

Outdoor swimming pool ☐ Shops selling of Lambs and birds meat ☐

More than one ☐

6/ Farm ownership

Private ownership with the responsibility of paying bills ☐

Private property without the responsibility of paying bills ☐

Public ownership with the responsibility of paying bills ☐

The public ownership with no responsibility for the payment of invoices ☐

7/ The farm location

Tripoli ☐ Benghazi ☐ Western ☐

Middle ☐ Southern ☐ Green Mountain ☐

Part 2 - Information related to the energy which is used on the farm.

8/ Energy types (Regardless of the energy source is network, generators and others)

Electricity ☐ Fossil fuel ☐ Both ☐

9/ Energy source

Network ☐ Generator ☐ Both ☐

10/ Type of use

a/ Electricity: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

b/ Gas: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

c/ Kerosene: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

d/ / diesel: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

11/ The source of water used for home facilities

Underground water ☐ Public water (Tap water) ☐

local home well ☐ Rainwater ☐ More than one ☐

Part 3 - Information related to energy prices.

12/ Please place a tick (√) in the box that reflects your best answer where:

1= Strongly disagree 2= Disagree 3= Neither agree nor disagree

4= Agree 5= Strongly agree

Items / Scale	1	2	3	4	5
General company for electricity services are sufficient and appropriate					
The price of electricity is reasonable					
The gas price is reasonable					
The price of kerosene is affordable					
The price of gasoline is reasonable					
The diesel prices are affordable					
Water Authority services are sufficient and appropriate					
The price of public water is reasonable					
Electricity is always available					
Water is always available					
Gas is always available					
Pay your energy and water bills					

Part 4: Assessment of damages as a result of power or water outages (if occurred).

13/ Please place a tick (√) in the boxes that reflects your best answer. (you can chose more than one)

a/ Causes of power outage sure

Problems with internal home connections ☐ General network failure ☐ Delivery cost ☐ The source ☐ No outages ☐

b/ Causes of water outage

Problems with internal home connections ☐ General network failure ☐

Delivery cost ☐ The source ☐ No outages ☐

c/ Reasons for the lack of gas cylinders

The source ☐ Not available in the station ☐ Stations distance ☐

Using instant Electricity ☐ No lack ☐

d/ Reasons for the lack of street lighting

There is no grid ☐ From the source ☐

The public network failure ☐ Stations distance ☐ Others ☐

Part 5: Information about energy resources and environment issues.

14/ Please make a tick (√) in the box that reflects your best answer where:

Yes = Agree No = disagree

Questions / Scale	Yes	No
Do you have any information on other energy sources which can be the best alternative to the current source?		
Do you have any information/ idea about renewable energy?		
Do you think that renewable energy such as solar and wind is best alternative to the current energy?		
In the case of availability with competitive prices of renewable energy resources and technology are you going to use them?		
Do you have any idea about the environmental damage resulting from the use of electricity and water production plants by traditional fuel?		
Do you think that the environmental pollution in Libya could be the reason to reconsider continuing to use traditional energy?		
Do you expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden?		
Is there a renewable energy technology markets in Libya?		
Have you seen this technique used in Libya?		
Do you support the production of energy from environmentally friendly sources?		
Do you support legislation to reduce and regulate the use of conventional energy?		

15/ If you have any other comments or suggestions you can add them here

………………………………………………………………………………………

Indus -V1 ( ) **Industrial consumption (Light/heavy)**

Part 1 - General information

Please place a tick (√) in the box that reflects your best answer.

1/ Factory description:

Small project ☐ Medium factory ☐ Large factory ☐

2/ Business type:

Private ownership ☐ Public ownership ☐

3/ Production type

Leather clothing ☐ Foodstuffs ☐ Building materials ☐ Industrial carpentry ☐ Furniture fittings ☐ Petroleum Industrial ☐ Others ☐

4/ The facilities of the factory:

Workers biulding ☐ Outdoor swimming pool ☐ Shops ☐

Farm ☐ Administrative buildings ☐ More than one ☐

5/ Factory ownership:

Private ownership with the responsibility of paying bills ☐

Private property without the responsibility of paying bills ☐

Public ownership with the responsibility of paying bills ☐

The public ownership with no responsibility for the payment of invoices ☐

6/ The Factory location

Tripoli ☐ Benghazi ☐ Western ☐

Middle ☐ Southern ☐ Green Mountain ☐

Part 2: Information related to the energy which is used on the factory.

7/ Energy types (Regardless of the energy source is network, generators and others)

Electricity ☐ Fossil fuel ☐ Both ☐

8/ Energy source

Network ☐ Generator ☐ Both ☐

9/ Type of use

a/ Electricity: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

b/ Gas: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

c/ Kerosene: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

d/ / diesel: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

10/ The source of water used in the factory

Underground water ☐ Public water (Tap water) ☐

local home well ☐ Rainwater ☐ More than one ☐

Part 3 - Information related to energy prices.

11/ Please make a tick (√) in the box that reflects your best answer where:

1= Strongly disagree 2= Disagree 3= Neither agree nor disagree

4= Agree 5= Strongly agree

Questions	1	2	3	4	5
General company for electricity services are sufficient and appropriate					
The price of electricity is reasonable					
The gas price is reasonable					
The price of kerosene is affordable					
The price of gasoline is reasonable					
The diesel prices are affordable					
Water Authority services are sufficient and appropriate					
The price of public water is reasonable					
Electricity is always available on the farm					
Water is always available on the farm					
Gas is always available					
Pay your energy and water bills					

Part 4: Assessment of damages as a result of power or water outages (if occurred).

12/ Please place a tick (√) in the boxes that reflects your best answer. (you can chose more than one)

a/ Causes of power outage

Problems with internal home connections ☐ General network failure ☐ Delivery cost ☐ The source ☐ No outages ☐

b/ Causes of water outage

Problems with internal home connections ☐ General network failure ☐ Delivery cost ☐ The source ☐ No outages ☐

c/ Reasons for the lack of gas cylinders

The source ☐ Not available in the station ☐ Stations distance ☐

Using instant Electricity ☐ No lack ☐

d/ Reasons for the lack of lighting

There is no grid ☐ From the source ☐

The public network failure ☐ Stations distance ☐ Others ☐

Part 5: Information about energy resources and environment issues.

13/ Please tick (√) in the box that reflects your best answer where:

Yes = Agree No = disagree

Questions	Yes	No
Do you have any information on other energy sources which can be the best alternative to the current source?		
Do you have any information/ idea about renewable energy?		
Do you think that renewable energy such as solar and wind is best alternative to the current energy?		
In the case of availability with competitive prices of renewable energy resources and technology are you going to use them?		
Do you have any idea about the environmental damage resulting from the use of electricity and water production plants by traditional fuel?		
Do you think that the environmental pollution in Libya could be the reason to reconsider continuing to use traditional energy?		
Do you expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden?		
Is there a renewable energy technology markets in Libya?		
Have you seen this technique used in Libya?		
Do you support the production of energy from environmentally friendly sources?		
Do you support legislation to reduce and regulate the use of conventional energy?		
Do you encourage legislation to increase the use of renewable energy		

14/ If you have any other comments or suggestions you can add them here

……………………………………………………………………………………………

Public facilities V1-(   )

Public facilities (Ministries of health, education, agriculture, industry, economy, planning, justice and public security buildings)

Part 1 - General information

Please make a tick (√) in the box that reflects your best answer.

1/ Facility description:

Police stations ☐ Apartment building ☐ School ☐ Hospital ☐

Park ☐ Checkpoint ☐ Bank ☐ House social care ☐

Custom border (airports and harbours) ☐ Mentoring point ☐

Mobile containers ☐ Clinical ☐ Court ☐ More than one ☐

2/ Site area:

Small less than 120 m^2 ☐ Middle 120 m^2 - 150 m^2 ☐

Large 150 m^2 - 300 m^2 ☐ Very Large more than 300 m^2 ☐

3/ / Site's facilities

No facilities ☐ Annex garden ☐ Swimming pool ☐ Restaurant ☐ Shops

More than one ☐ Others ☐

4/ Garden area

No garden ☐ Small less than 120 m^2 ☐ Middle 120 m^2 - 150 m^2 ☐

Large 150 m^2 - 300 m^2 ☐ Very Large more than 300 m^2 ☐

5/ The location of the site

Tripoli ☐ Benghazi ☐ Western ☐

Middle ☐ Southern ☐ Green Mountain ☐

Part 2 - Information related to the energy which is used on the Public facilities:

6/ Energy types (Regardless of the energy source is network, generators and others)

Electricity ☐ Fossil fuel ☐ Both ☐

7/ Energy source

Network ☐ Generator ☐ Both ☐

8/ Type of use

a/ Electricity: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

b/ Gas: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

c/ Kerosene: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

d/ / diesel: Not use ☐ To heat water ☐ Lighting ☐

Cooling ☐ Heating ☐ Machines ☐ More than one ☐

9/ The source of water used in the factory

Underground water ☐ Public water (Tap water) ☐

local home well ☐ Rainwater ☐ More than one ☐

Part 3 - Information related to energy prices.

10/ Please make a tick (√) in the box that reflects your best answer where:

1= Strongly disagree 2= Disagree 3= Neither agree nor disagree

4= Agree 5= Strongly agree

Questions	1	2	3	4	5
General company for electricity services are sufficient and appropriate					
The price of electricity is reasonable					
The gas price is reasonable					
The price of kerosene is affordable					
The price of gasoline is reasonable					
The diesel prices are affordable					
Water Authority services are sufficient and appropriate					
The price of public water is reasonable					
Electricity is always available					
Water is always available					
Gas is always available					
Pay your energy and water bills					

Part 4: Assessment of damages as a result of power or water outages (if occurred).

11/ Please place a tick (√) in the boxes that reflects your best answer. (you can chose more than one)

a/ Causes of power outage

Problems with internal home connections ☐ General network failure ☐ Delivery cost ☐ The source ☐ No outages ☐

b/ Causes of water outage

Problems with internal home connections ☐ General network failure ☐ Delivery cost ☐ The source ☐ No outages ☐

c/ Reasons for the lack of gas cylinders

The source ☐ Not available in the station ☐ Stations distance ☐

Using instant Electricity ☐ No lack ☐

d/ Reasons for the lack of street lighting

There is no grid ☐ From the source ☐

The public network failure ☐ Stations distance ☐ Others ☐

Part 5: Information about energy resources and environment issues.

12/ Please place a tick (√) in the box that reflects your best answer where:

Yes = Agree No = disagree

Questions	Yes	No
Do you have any information on other energy sources which can be the best alternative to the current source?		
Do you have any information/ idea about renewable energy?		
Do you think that renewable energy such as solar and wind is best alternative to the current energy?		
In the case of availability with competitive prices of renewable energy resources and technology are you going to use them?		
Do you have any idea about the environmental damage resulting from the use of electricity and water production plants by traditional fuel?		
Do you think that the environmental pollution in Libya could be the reason to reconsider continuing to use traditional energy?		
Do you expect that the production of energy from renewable sources will provide affordable energy and reduce energy expenses burden?		
Is there a renewable energy technology markets in Libya?		
Have you seen this technique used in Libya?		

Questions	Yes	No
Do you support the production of energy from environmentally friendly sources?		
Do you support legislation to reduce and regulate the use of conventional energy?		

13/ If you have any other comments or suggestions you can add them here

The End

Thank you very much for taking the time to complete this questionnaire!

Appendix D : The Questionnaire (Arabic version).

هذا الاستبيان يتعلق بدراسة دكتوراه بعنوان

التحقيق فى جودة استخدام مصادر الطاقة المتجدده فى ليبيا

تقديم

انا طالب دكتوراه بجامعة نوتنجهام ترنت دراستي تتعلق بجودة الاستثمار فى إنتاج الطاقة الخضراء أو المتجددة فى ليبيا (الطاقة الشمسية والرياح وامواج البحر وغيرها) , وانا اقدر مشاركتكم فى هذه الدراسة من خلال إجابتكم على الأسئلة بالكامل وبكل صراحة ومصداقية . علما بان كل المعلومات التى ستوردونها فى هذا الاستبيان ستكون سرية وسيتم استخدامها بشكل سرى.

تسعى هذه الدراسة للتحقق من إمكانية وجودة الاستثمار من الطاقة المتجددة او البديلة او الامنه والتى تعتبر ليبيا من الدول الغنية بها كطاقة بديلة للطاقة التقليدية (النفط والغاز) حتى تتجنب ليبيا الاعتماد على مصدر واحد للطاقة والدخل. كما ان استمرار ارتفاع أسعار الطاقة التقليدية مع محدودية مصادرها يكون من الحكمة ادخارها للأجيال القادمة كما ان الطاقة الجديدة ستفتح مجال واسع من الخيارات التى يكون ضررها البيئى اقل بكثير من مصادر الطاقة التقليدية كتلوث هواء المدن والمطر الحمضى وتسرب النفط وارتفاع حرارة الارض. فأنظار العالم تتوجه الى الصحراء الليبية كأهم المصادر لإنتاج الطاقة الجديدة . وتسعى هذه الدراسة للتعرف ومقارنة تكلفة انتاج الطاقة من خلال استخدام تقنيات الطاقة المتجددة بمستوياتها المختلفة لانتاج طاقة يمكن الاستفادة منها على المستوى (منزلى/ زراعى/ صناعى / تجارى وغيره) محليا او تصديرها للخارج مع الطاقة التقليدية من حيث السعر والتكلفة والوفرة ودورها فى تحقيق النمو الاقتصادى للدولة وتنويع مصادر الدخل وتطوير المدن وتحديثها وتحقيق الرخاء والرفاهية.

نتيجة هذه الدراسة تعتمد بشكل كبير على دقة إجاباتكم والتى يجب ان تكون موضوعية بحيث تصف الواقع وصفا دقيقا والحالة العامة وليس بوجه الخصوص منطقة مسئوليتك كما اتمنى ان تكون إجاباتكم مدعمه بالمستندات المؤيدة قدر الإمكان .

شكرا لكم مقدما على مشاركتكم فى استكمال هذا الاستبيان.

الطالب / احمد محمد عياد

(ahmed.mohamed@ntu.ac.uk)

Dome -V1 (   )

الاستهلاك المنزلى

الجزء الاول: معلومات عامة

ضع علامة (√) فى صندوق الاجابة التى تراها مناسبة

1/ وصف المنزل

منزل خاص ☐ عمارة سكنية ☐ فيلا خاصة ☐

منزل حكومى ☐ شقة ☐ اكثر من واحد ☐

2/ مساحة المنزل

اقل من 120 م^2 ☐ 120 م^2 – 150 م^2 ☐ 150 م^2 - 300 م^2 ☐ اكثر من 300 م^2 ☐

3/ حديقة المنزل

لا توجد حديقة ☐ حديقة صغيرة ☐ حديقين ☐ حديقة كبيرة ☐

4/ مساحة الحديقة

لا توجد حديقة ☐ اقل من 120 م^2 ☐ 120 م^2 – 150 م^2 ☐ 150 م^2 - 300 م^2 ☐

اكثر من 300 م^2 ☐

5/ ملكية المبنى

ملكية خاصة مع تحمل مسؤولية دفع الفواتير ☐

ملكية خاصة مع عدم تحمل مسؤولية دفع الفواتير ☐

ملكية عامة مع تحمل مسؤولية دفع الفواتير ☐

ملكية عامة مع عدم تحمل مسؤولية دفع الفواتير ☐

6/ موقع المنزل

طرابلس ☐ بنغازى ☐ الغرب ☐ الوسطي ☐ الجنوب ☐ الجبل الاخضر ☐

الجزء الثانى – معلومات تتعلق بنوع الطاقة المستخدمة بالبيت

7/ نوع الطاقة بالبيت (بغض النظر عن مصدر الطاقة سوء كانت من الشبكة العامة او مولد او مصدر اخر)

الكهرباء ☐ الوقود الاحفورى ☐ اكثر من واحد ☐

8/ مصدر الطاقة

الشبكة العامة ☐ مولد خاص ☐ اكثر من واحد ☐

9/ نوع الاستخدام

أ/ الكهرباء

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ب/ الغاز

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ج/ الكيروسين

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

د/ الزيت الخفيف

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

10/ مصدر المياة المستخدمة فى مرافق البيت

مياة جوفية ☐ مياة الشبكة العامة ☐ بئر خاص بالمنزل ☐ خزان تجميع مياة الامطار ☐

اكثر من مصدر ☐

الجزء الثالث- معلومات تتعلق باسعار الطاقة

11/ ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها عندما

(1= غيرموافق بقوة 2= غير موافق 3= لاموافق ولا غير موافق 4= موافق 5= موافق بقوة)

العوامل	1	2	3	4	5
خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر الكهرباء معقول					
سعر الغاز معقول					
سعر الكيروسين مناسب					
سعر البنزين مناسب					
سعر الزيت الخفيف مناسب					
خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر المياة العامة مناسبة					
الكهرباء دائما متوفرة					

المياة دائما متوفرة					
الغاز دائما متوفر					
هل تقوم بدفع فواتير الطاقة والمياة					

الجزء الرابع: معلومات تتعلق بانقطاع الكهرباء والمياة (اذا ماحدثت)

12/ / ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها (يمكن ان تختار اكثر من اجابة)

أ/ اسباب انقطاع الكهرباء

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ب/ اسباب انقطاع المياه

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ج/ اسباب نقص اسطوانات الغاز

من المصدر ☐ لا توجد بالمحطات العامة ☐ موقع البيع بعيد ☐ تفضل استخدام الكهرباء ☐

لايوجد نقص ☐

د/ السبب فى نقص الاضاءة فى الشوارع

لا توجد شبكة عامة ☐ من المصدر ☐ مشاكل بالشبكة العامة ☐ بعد المكان ☐ اخرى ☐

الجزء الخامس: معلومات تتعلق بموضوعات عن مصادر الطاقة والبيئة

13/ ضع علامة (√) فى المربع الذي يعبر عن افضل اجابة لديك حيث

نعم = موافق ولا = غير موافق

السؤال	نعم	لا
هل لديك أي معلومات وجود مصادر اخر للطاقة الذى يمكن أن تكون أفضل بديل للمصدر الحالي؟		
هل لديك أي معلومات/فكرة حول الطاقة المتجددة؟		
هل تعتقد أن الطاقة المتجددة مثل الطاقة الشمسية والرياح أفضل بديل للطاقة الحالية؟		
وفي حالة توافر وبأسعار تنافسية تقنية الطاقة المتجددة هل ستقوم باستخدامها؟		

		هل لديك أي فكرة حول الأضرار البيئية الناجمة عن استخدام محطات إنتاج الكهرباء والمياه بالوقود التقليدي؟
		هل تعتقد أن التلوث البيئي في ليبيا يمكن أن يكون السبب في أن اعادة النظر في الاستمرار في استخدام الطاقة التقليدية؟
		هل تتوقع أن إنتاج الطاقة من المصادر المتجددة سوف توفر الطاقة بأسعار معقولة وتخفف عبء نفقات الطاقة؟
		هل هناك اسواق لتكنولوجيا الطاقة متجددة في ليبيا؟
		هل رأيت هذه التقنية تستخدم في ليبيا؟
		هل تؤيد إنتاج الطاقة من مصادر صديقة للبيئة؟
		هل تؤيد تشريع يعمل على تخفيض وتنظيم استخدام الطاقة التقليدية؟
		هل تشجع ايجاد تشريعات تعمل على زيادة استخدام الطاقة المتجددة

14/ إذا كان لديك أي تعليقات أو اقتراحات أخرى يمكنك إضافتها هنا.............................

B &S farms-V1 (   )

مزارع غير التجارية والتجاري الاستهلاك الزراعى

الجزء الاول: معلومات عامة

ضع علامة (√) فى صندوق الاجابة التى تراها مناسبة

1/ وصف المزرعه

انتاج زراعى ☐ انتاج حيوانى ☐ انتاج طيور ☐

تربية اسماك ☐ اكثر من واحد ☐

2/ نوع النشاط

زراعى غير تجارى ☐ زراعى تجارى ☐

3/ نوع الزراعة

تعتمد على مياه الامطار ☐ مروية ☐

4/ مساحة المزرعة

اقل من 10000 م^2 ☐ 10000 م^2 – 5000 م^2 ☐

5000 م^2 - 10000 م^2 ☐ اكثر من 300 م^2 ☐

5/ مرافق المزرعة

منزل سكنى ☐ منزل عمال ☐ مقر لانتاج امشتقات الحليب ☐ حوض سباحة ☐

مقر لانتاج لحوم الطيور او الحمراء ☐

6/ ملكية المبنى

ملكية خاصة مع تحمل مسؤولية دفع الفواتير ☐

ملكية خاصة مع عدم تحمل مسؤولية دفع الفواتير ☐

ملكية عامة مع تحمل مسؤولية دفع الفواتير ☐

ملكية عامة مع عدم تحمل مسؤولية دفع الفواتير ☐

7/ موقع المزرعة

طرابلس ☐ بنغازى ☐ الغرب ☐ الوسطي ☐ الجنوب ☐ الجبل الاخضر ☐

الجزء الثانى – معلومات تتعلق بنوع الطاقة المستخدمة بالبيت

8/ نوع الطاقة بالبيت (بغض النظر عن مصدر الطاقة سوء كانت من الشبكة العامة او مولد او مصدر اخر)

الكهرباء ☐ الوقود الاحفورى ☐ اكثر من واحد ☐

9/ مصدر الطاقة

الشبكة العامة ☐ مولد خاص ☐ اكثر من واحد ☐

10/ نوع الاستخدام

أ/ الكهرباء

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ب/ الغاز

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ج/ الكيروسين

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

د/ الزيت الخفيف

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

11/ مصدر المياة المستخدمة فى مرافق البيت

مياة جوفية ☐ مياة الشبكة العامة ☐ بئر خاص بالمنزل ☐ خزان تجميع مياة الامطار ☐

اكثر من مصدر ☐

الجزء الثالث- معلومات تتعلق باسعار الطاقة

12/ ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها عندما

(1= غيرموافق بقوة 2= غير موافق 3= لاموافق ولا غير موافق 4= موافق 5= موافق بقوة)

العوامل	1	2	3	4	5
خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر الكهرباء معقول					
سعر الغاز معقول					
سعر الكيروسين مناسب					
سعر البنزين مناسب					
سعر الزيت الخفيف مناسب					

خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر المياة العامة مناسبة					
الكهرباء دائما متوفرة					
المياة دائما متوفرة					
الغاز دائما متوفر					
هل تقوم بدفع فواتير الطاقة والمياة					

الجزء الرابع: معلومات تتعلق بانقطاع الكهرباء والمياة (اذا ماحدثت)

13/ / ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها (يمكن ان تختار اكثر من اجابة)

أ/ اسباب انقطاع الكهرباء

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ب/ اسباب انقطاع المياه

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ج/ اسباب نقص اسطوانات الغاز

من المصدر ☐ لا توجد بالمحطات العامة ☐ موقع البيع بعيد ☐ تفضل استخدام الكهرباء ☐

لايوجد نقص ☐

د/ السبب فى نقص الاضاءة فى الشوارع

لا توجد شبكة عامة ☐ من المصدر ☐ مشاكل بالشبكة العامة ☐ بعد المكان ☐ اخرى ☐

الجزء الخامس: معلومات تتعلق بموضوعات عن مصادر الطاقة والبيئة

14/ ضع علامة (√) فى المربع الذي يعبر عن افضل اجابة لديك حيث

نعم = موافق ولا = غير موافق

السؤال	نعم	لا
هل لديك أي معلومات وجود مصادر اخر للطاقة الذى يمكن أن تكون أفضل بديل للمصدر الحالي؟		
هل لديك أي معلومات/فكرة حول الطاقة المتجددة؟		

هل تعتقد أن الطاقة المتجددة مثل الطاقة الشمسية والرياح أفضل بديل للطاقة الحالية؟		
وفي حالة توافر وبأسعار تنافسية تقنية الطاقة المتجددة هل ستقوم باستخدامها؟		
هل لديك أي فكرة حول الأضرار البيئية الناجمة عن استخدام محطات إنتاج الكهرباء والمياه بالوقود التقليدي؟		
هل تعتقد أن التلوث البيئي في ليبيا يمكن أن يكون السبب في أن اعادة النظر في الاستمرار في استخدام الطاقة التقليدية؟		
هل تتوقع أن إنتاج الطاقة من المصادر المتجددة سوف توفر الطاقة بأسعار معقولة وتخفف عبء نفقات الطاقة؟		
هل هناك اسواق لتكنولوجيا الطاقة متجددة في ليبيا؟		
هل رأيت هذه التقنية تستخدم في ليبيا؟		
هل تؤيد إنتاج الطاقة من مصادر صديقة للبيئة؟		
هل تؤيد تشريع يعمل على تخفيض وتنظيم استخدام الطاقة التقليدية؟		
هل تشجع ايجاد تشريعات تعمل على زيادة استخدام الطاقة المتجددة		

15/ إذا كان لديك أي تعليقات أو اقتراحات أخرى يمكنك إضافتها هنا.............................

Indus (   )

الاستهلاك الصناعى الخفيف والثقيل

الجزء الاول: معلومات عامة

ضع علامة (√) فى صندوق الاجابة التى تراها مناسبة

1/ وصف المصنع

مصنع صغير ☐ مصنع متوسط ☐ مصنع كبير ☐

2/ نوع النشاط

مشروع خاص ☐ مشروع عام ☐

3/ نوع الصناعة

ملابس ومنسوجات ☐ صناعات غذائية ☐ مواد بناء ☐ النجارة ☐

الاثاث ☐ صناعات بترولية ☐ اخرى ☐

4/ مرافق المصنع

منزل عمال ☐ مقر لانتاج امشتقات الحليب ☐ حوض سباحة ☐

مقر لانتاج لحوم الطيور او الحمراء ☐

6/ ملكية المبنى

ملكية خاصة مع تحمل مسؤولية دفع الفواتير ☐

ملكية خاصة مع عدم تحمل مسؤولية دفع الفواتير ☐

ملكية عامة مع تحمل مسؤولية دفع الفواتير ☐

ملكية عامة مع عدم تحمل مسؤولية دفع الفواتير ☐

7/ موقع المزرعة

طرابلس ☐ بنغازى ☐ الغرب ☐ الوسطي ☐ الجنوب ☐ الجبل الاخضر ☐

الجزء الثانى – معلومات تتعلق بنوع الطاقة المستخدمة بالبيت

8/ نوع الطاقة بالبيت (بغض النظر عن مصدر الطاقة سوء كانت من الشبكة العامة او مولد او مصدر اخر)

الكهرباء ☐ الوقود الاحفورى ☐ اكثر من واحد ☐

9/ مصدر الطاقة

الشبكة العامة ☐ مولد خاص ☐ اكثر من واحد ☐

10/ نوع الاستخدام

أ/ الكهرباء

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ب/ الغاز

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ج/ الكيروسين

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

د/ الزيت الخفيف

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

11/ مصدر المياة المستخدمة فى مرافق البيت

مياة جوفية ☐ مياة الشبكة العامة ☐ بئر خاص بالمنزل ☐ خزان تجميع مياة الامطار ☐

اكثر من مصدر ☐

الجزء الثالث- معلومات تتعلق باسعار الطاقة

12/ ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها عندما

(1= غيرموافق بقوة 2= غير موافق 3= لاموافق ولا غير موافق 4= موافق 5= موافق بقوة)

العوامل	1	2	3	4	5
خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر الكهرباء معقول					
سعر الغاز معقول					
سعر الكيروسين مناسب					
سعر البنزين مناسب					
سعر الزيت الخفيف مناسب					
خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر المياة العامة مناسبة					
الكهرباء دائما متوفرة					
المياة دائما متوفرة					
الغاز دائما متوفر					
هل تقوم بدفع فواتير الطاقة والمياة					

الجزء الرابع: معلومات تتعلق بانقطاع الكهرباء والمياة (اذا ماحدثت)

13/ / ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها (يمكن ان تختار اكثر من اجابة)

أ/ اسباب انقطاع الكهرباء

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ب/ اسباب انقطاع المياه

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ج/ اسباب نقص اسطوانات الغاز

من المصدر ☐ لا توجد بالمحطات العامة ☐ موقع البيع بعيد ☐ تفضل استخدام الكهرباء ☐

لايوجد نقص ☐

د/ السبب فى نقص الاضاءة فى الشوارع

لا توجد شبكة عامة ☐ من المصدر ☐ مشاكل بالشبكة العامة ☐ بعد المكان ☐ اخرى ☐

الجزء الخامس: معلومات تتعلق بموضوعات عن مصادر الطاقة والبيئة

14/ ضع علامة (√) فى المربع الذي يعبر عن افضل اجابة لديك حيث

نعم = موافق ولا = غير موافق

السؤال	نعم	لا
هل لديك أي معلومات وجود مصادر اخر للطاقة الذى يمكن أن تكون أفضل بديل للمصدر الحالي؟		
هل لديك أي معلومات/فكرة حول الطاقة المتجددة؟		
هل تعتقد أن الطاقة المتجددة مثل الطاقة الشمسية والرياح أفضل بديل للطاقة الحالية؟		
وفي حالة توافر وبأسعار تنافسية تقنية الطاقة المتجددة هل ستقوم باستخدامها؟		
هل لديك أي فكرة حول الأضرار البيئية الناجمة عن استخدام محطات إنتاج الكهرباء والمياه بالوقود التقليدي؟		
هل تعتقد أن التلوث البيئي في ليبيا يمكن أن يكون السبب في أن اعادة النظر في الاستمرار في استخدام الطاقة التقليدية؟		
هل تتوقع أن إنتاج الطاقة من المصادر المتجددة سوف توفر الطاقة بأسعار معقولة وتخفف عبء نفقات الطاقة؟		
هل هناك اسواق لتكنولوجيا الطاقة متجددة في ليبيا؟		
هل رأيت هذه التقنية تستخدم في ليبيا؟		
هل تؤيد إنتاج الطاقة من مصادر صديقة للبيئة؟		
هل تؤيد تشريع يعمل على تخفيض وتنظيم استخدام الطاقة التقليدية؟		
هل تشجع ايجاد تشريعات تعمل على زيادة استخدام الطاقة المتجددة		

15/ إذا كان لديك أي تعليقات أو اقتراحات أخرى يمكنك إضافتها هنا.............................

Public facilities V1-(   )

المرافق العامة مبانى الوزارات والمحاكم والامن

الجزء الاول: معلومات عامة

ضع علامة (√) فى صندوق الاجابة التى تراها مناسبة

1/ وصف للمرفق

مركز بوليس ☐ مبنى طوابق ☐ مدرسة ☐ مستشفى ☐

حديقة ☐ نقطة تفتيش ☐ مصرف ☐ دار رعاية ☐

نقطة حدودية ☐ مركز مراقبة ☐ مقر مؤقت ☐ عيادة ☐ محكمة ☐ اكثر من واحد ☐

2/ مساحة الموقع

اقل من 120 م^2 ☐ 120 م^2 – 150 م^2 ☐

150 م^2 - 300 م^2 ☐ اكثر من 300 م^2 ☐

3/ مرافق الموقع

لاتوجد مرافق ☐ مرفق حديقة ☐ حوض سباحة ☐ مطعم/مقهى ☐

محلات ☐ اكثر من واحد ☐

4/ مساحة الحديقة

لاتوجد حديقة ☐ اقل من 120 م^2 ☐ 120 م^2 – 150 م^2 ☐

150 م^2 - 300 م^2 ☐ اكثر من 300 م^2 ☐

5/ موقع المزرعة

طرابلس ☐ بنغازى ☐ الغرب ☐ الوسطي ☐ الجنوب ☐ الجبل الاخضر ☐

الجزء الثانى – معلومات تتعلق بنوع الطاقة المستخدمة بالبيت

6/ نوع الطاقة بالبيت (بغض النظر عن مصدر الطاقة سوء كانت من الشبكة العامة او مولد او مصدر اخر)

الكهرباء ☐ الوقود الاحفورى ☐ اكثر من واحد ☐

7/ مصدر الطاقة

الشبكة العامة ☐ مولد خاص ☐ اكثر من واحد ☐

8/ نوع الاستخدام

أ/ الكهرباء

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ب/ الغاز

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

ج/ الكيروسين

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة ☐ التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

د/ الزيت الخفيف

لا تستخدم ☐ تدفئة المياه ☐ الاضاءة التبريد ☐ التدفئة ☐ الالات ☐ اكثر من واحد ☐

9/ مصدر المياة المستخدمة فى مرافق البيت

مياة جوفية ☐ مياة الشبكة العامة ☐ بئر خاص بالمنزل ☐ خزان تجميع مياة الامطار ☐

اكثر من مصدر ☐

الجزء الثالث- معلومات تتعلق باسعار الطاقة

10/ ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها عندما

(1= غيرموافق بقوة 2= غير موافق 3= لاموافق ولا غير موافق 4= موافق 5= موافق بقوة)

العوامل	1	2	3	4	5
خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر الكهرباء معقول					
سعر الغاز معقول					
سعر الكيروسين مناسب					
سعر البنزين مناسب					
سعر الزيت الخفيف مناسب					
خدمات الشركة العامة للكهرباء كافية ومناسبة					
سعر المياة العامة مناسبة					
الكهرباء دائما متوفرة					
المياة دائما متوفرة					
الغاز دائما متوفر					
هل تقوم بدفع فواتير الطاقة والمياة					

الجزء الرابع: معلومات تتعلق بانقطاع الكهرباء والمياة (اذا ماحدثت)

11/ / ضع علامة (√) فى الصندوق المناسب لافضل اجابة تراها (يمكن ان تختار اكثر من اجابة)

أ/ اسباب انقطاع الكهرباء

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ب/ اسباب انقطاع المياه

مشاكل بالتوصيلات الداخلية ☐ ضعف الشبكة العامة ☐ مشاكل التوصيل ☐ من المصدر ☐

لاتوجد انقطاعات ☐

ج/ اسباب نقص اسطوانات الغاز

من المصدر ☐ لا توجد بالمحطات العامة ☐ موقع البيع بعيد ☐ تفضل استخدام الكهرباء ☐

لايوجد نقص ☐

د/ السبب فى نقص الاضاءة فى الشوارع

لا توجد شبكة عامة ☐ من المصدر ☐ مشاكل بالشبكة العامة ☐ بعد المكان ☐ اخرى ☐

الجزء الخامس: معلومات تتعلق بموضوعات عن مصادر الطاقة والبيئة

12/ ضع علامة (√) فى المربع الذي يعبر عن افضل اجابة لديك حيث

نعم = موافق ولا = غير موافق

السؤال	نعم	لا
هل لديك أي معلومات وجود مصادر اخر للطاقة الذى يمكن أن تكون أفضل بديل للمصدر الحالي؟		
هل لديك أي معلومات/فكرة حول الطاقة المتجددة؟		
هل تعتقد أن الطاقة المتجددة مثل الطاقة الشمسية والرياح أفضل بديل للطاقة الحالية؟		
وفي حالة توافر وبأسعار تنافسية تقنية الطاقة المتجددة هل ستقوم باستخدامها؟		
هل لديك أي فكرة حول الأضرار البيئية الناجمة عن استخدام محطات إنتاج الكهرباء والمياه بالوقود التقليدي؟		
هل تعتقد أن التلوث البيئي في ليبيا يمكن أن يكون السبب في أن اعادة النظر في الاستمرار في استخدام الطاقة التقليدية؟		
هل تتوقع أن إنتاج الطاقة من المصادر المتجددة سوف توفر الطاقة بأسعار معقولة وتخفف عبء نفقات الطاقة؟		
هل هناك اسواق لتكنولوجيا الطاقة متجددة في ليبيا؟		
هل رأيت هذه التقنية تستخدم في ليبيا؟		
هل تؤيد إنتاج الطاقة من مصادر صديقة للبيئة؟		
هل تؤيد تشريع يعمل على تخفيض وتنظيم استخدام الطاقة التقليدية؟		
هل تشجع ايجاد تشريعات تعمل على زيادة استخدام الطاقة المتجددة		

13/ إذا كان لديك أي تعليقات أو اقتراحات أخرى يمكنك إضافتها هنا.............................

النهاية شكرا جزيلا لوقت الثمين ولاكمال الاستبيان

Appendix E : Status of Renewable Energy Technologies:

Power Generation (Characteristics and Costs).

Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE- U.S. cents/kWh)
Bioenergy combustion: Boiler/steam turbine Co-fire; Organic MSW	Plant size: 25-200 MW Conversion efficiency: 25-35% Capacity factor: 50-90%	800-4,500 Co-fire: 200-800	5.5-20 Co-fire: 4-12
Bioenergy gasification	Plant size: 1-10 MW Conversion efficiency: 30-40% Capacity factor:40-80%	2,050-5,500	6-24
Bioenergy anaerobic digestion	Plant size: 1-20 MW Conversion efficiency: 25-40% Capacity factor:50-90%	Biogas: 500-6,500 Landfill gas: 1,900-2,200	Biogas: 6-19 Landfill gas: 4-6.5
Geothermal power	Plant size: 1-100 MW Conversion factor: 60-90%	Condensing flash: 2,100-4,200 Binary: 2,470-6,100	Condensing flash: 6-13 Binary: 7-14
Hydropower: Grid-based	Plant size: 1MW-18,000 + MW Plant type: reservoir, run-of-river Capacity factor:30-60%	Projects >300MW: < 2,000 Projects >300MW: 2,000-4,000	2-12
Hydropower: Off-grid-rural	Plant size: 1-20 MW Conversion efficiency: 25-40% Capacity factor:50-90%	1,175-3,500	5-40
Ocean power: Tidal range	Plant size: <1 to>250 MW Capacity factor:23-29%	5,290-5,870	21-28
Solar PV: Rooftop	Peak capacity: 3-5 kW (residential); 100 kW (commercial); 500 kW (industrial) Capacity factor:10-25% (fixed tilt)	2,275 (Germany; average residential) 4,300-5,00 (USA) 3,700-4,300 (Japan) 1,500-2,600 (Industrial)	20-46 (OECD) 28-55 (non- OECD) 16-38 (Europe)
Solar PV: Ground-mounted Utility-scale	Peak capacity: 2.5-250 MW Capacity factor:10-25% (fixed tilt) Conversion efficiency: 10-30% (high end is CPV)	1,300 – 1,950 (Typical global) Averages: 2,270 (USA); 2,760 (Japan); 2,200 (China); 1,700 (India)	12-38 (OECD) 9-40 (non- OECD) 14-34 (Europe)
Concentrating solar thermal power (CSP)	Types: parabolic trough, Fresnel, tower, dish Plant size: 50-250 MW (Fresnel) Capacity factor:20-40% (no storage); 35-75% (with storage)	Trough, no storage: 4,000-7,300 (OECD); 3,100-4,050 (non-OECD) Trough, 6 hours storage: 7,100-9,800 Tower, 6-15 hour storage: 6,300-10,500	Trough and Fresnel: 19-38 (no storage); 17-37 (6h. storage) Tower: 20-29 (6-7h. storage); 12-15 (12-15h. storage)

Wind: Onshore	Turbine size: 1.5-3.5 MW Capacity factor: 25-40%	1,750-1,770 925-1,470 (China and India)	5-16 (OECD) 4-16 (non- OECD)
Wind: Offshore	Turbine size: 1.5-7.5 MW Capacity factor: 35-45%	3,000-4,500	15-23
Wind: Small-scale	Turbine size: up to 100 kW	3,000-6,000 (USA); 1,580 (China)	15-20 (USA)

Source: (Bait-Elmal, 2000)

Appendix F : Status of Renewable Energy Technologies:

Hot Water/ Heating/Cooling (Characteristics and Costs).

Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE- U.S. cents/kWh)
Bioenergy heat plant	Plant size: 0.1-1 MW_{th} Capacity factor: ~50-90% Conversion efficiency: 80-90%	400-1,200	4.7-29
Domestic pellet heater	Plant size: 5-100 MW_{th} Capacity factor:15-30% Conversion efficiency: 80-95%	360-1,400	5.6-36
Bioenergy CHP	Plant size: 0.5-100 MWth Capacity factor: ~60-80% Conversion efficiency: 70-80% for heat and power	600-6,000	4.3-12.6
Geothermal space heating (buildings)	Plant size: 0.1-1 MW_{th} Capacity factor:25-30%	1,865-4,595	10-27
Geothermal space heating (district)	Plant size: 3.8-35 MW_{th} Capacity factor:25-30%	665-1,830	5.8-13
Ground-source heat pumps	Plant size: 10-350 MW_{th} Capacity factor:25-30%	500-4,000	7-23
Solar thermal: Domestic hot water systems	Collector type: flat-plate, evacuated tube (thermosiphon and pumped system) Plant size: 2.1-4.2 kW_{th} (single family); 35 kW_{th} (multi-family) Efficiency: 100%	Single- family: 1,100-2,140 (OECD, new build); 1,300-2,200 (OECD, retrofit) 150-635 (China) Multi-family: 950-1,850 (OECD, new build); 1,140-2,050 (OECD, retrofit)	1.5-28 (China)
Solar thermal: Domestic heat and hot water systems (combi)	Collector type: same as water only Plant size: 7-10 kW_{th} (single family); 70-130 kW_{th} (multi-family)	Single- family: same as water only Multi-family: same as water only	5-50 (Domestic hot water) district heat: 4 and up (Denmark)

	70-3,500 kW_{th} (district heating); >3,500 kW_{th} (district heat with seasonal storage) Efficiency: 100%	district heat (Europe): 460-780; with storage: 470-1,060	
Solar thermal: Industrial process heat	Collector type: flat-plate, evacuated tube, parabolic trough, liner Fresnel Plant size: 100 kW_{th}-20 MW_{th} Temperature range: 50-400 ºC	470-1,000 (without storage)	4-16
Solar thermal: Cooling	Capacity: 10.5-500 kW_{th} (absorption chillers); 8-370 kW_{th} (absorption chillers) Efficiency: 50-70%	1,600-5,850	n/a

Source: (REN21, 2013)

Appendix G : Status of Renewable Energy Technologies:

Transport Fuels (Characteristics and Costs).

Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE- U.S. cents/kWh)
Biodiesel	Soy, rapeseed, mustard seed, palm, jatropha, waste vegetable oils and animal fats	Rang of feedstocks with different crop yield per hectare; hence, production costs vary widely among countries. Co-products include high- protein meal.	Soybean oil: 45-90 (Argentina/USA) Palm oil: 30-100 (Indonesia/Malaysia/ Thailand/Peru) Rapeseed oil: 120-140 (EU)
Ethanol	Sugar cane, sugar beets, corn, cassava, sorghum, wheat (and cellulose in the future)	Rang of feedstocks with wide yield and cost variations. Co-products include animal feed, heat and power from bagasse residues. Advanced biofuels are not yet fully commercial and have higher costs.	Sugar cane: 45-80 (Brazil) Corn (dry mill): 60-120 (USA)

Source: (REN21, 2013)