Literature Review on Energy Access and Adaptation to Climate Change

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The Adaptation Knowledge and Tools programme is a DFID-funded programme intended to maximise the effectiveness of UK and international investment in climate change adaptation and resilience. The knowledge and tools generated through this programme are expected to promote greater understanding of what constitutes best practice in adaptation, as well as better international cohesion and coordination around adaptation. Through these entry points the programme expects to increase the quality of international and UK adaptation programming and reduce its risk.

Contents

EVIDENCE ON DEMAND
CLIMATE & ENVIRONMENT
INFRASTRUCTURE | LIVELIHOODS

List of Figures

List of Tables

List of Boxes

Executive Summary

Introduction

Despite the understanding and the clear overarching benefits of access to energy in addressing the various dimensions of development and poverty reduction, to date there has been little discussion on energy access within the context of adaptation and building resilience to climate change and climate variability. Energy is generally tackled as a mitigation issue or in relation to energy security, and more recently in relation to providing access to energy services at the household or community level. This literature review was conducted with the aim of carrying out a systematic evidence search to support the idea that there is a synergy between access to energy and climate change adaptation, in particular to show how energy access contributes to reducing vulnerability and building resilience to climate change and climate variability. The core focus of the review being to find existing evidence, highlight where there are clear gaps in evidence and understand the challenges and opportunities for fostering a greater integration between energy access and climate change adaptation. The following research questions have been considered:

1) How has energy access been framed in the context of adaptation and building resilience to climate change and climate variability?
2) What does the literature say in terms of evidence that access to energy increases resilience? Is there any evidence that access to energy contributes to maladaptation?
3) What are the potential challenges and opportunities for promoting access to energy as a means of adaptation?

Conceptual Framework

The conceptual framework used to analyse and present the evidence is aligned to the definitions and the dimensions of resilience described in DFID's Resilience Framework, presented in Brooks et al. (2014), which is built on 4 key elements:

- Element 1: Context ('Resilience of what?')
- Element 2: Disturbance ('Resilience to what?'),
- Element 3: Capacity to deal with disturbance (exposure, sensitivity and adaptive capacity)
- Element 4: Reaction to disturbance (bounce back better, bounce back, recover but worse than before and collapse)

In applying DFID's Resilience Framework this study focusses on 9 dimensions of resilience to assess if access to energy builds resilience:

1) Access to services
2) Adaptive capacity
3) Income and food access
4) Social safety nets
5) Livelihood viability
6) Natural contexts
7) Personal circumstances
8) Institutional and governance contexts
9) Assets

The literature review found that access to energy can contribute to multiple dimensions of resilience at the same time, making it hard to separate evidence out under specific areas of resilience without becoming repetitive. The 9th dimension of resilience 'Assets' was presented under other dimensions (particularly 2 and 3 in the above list) as it overlapped with them considerably.

Methodology

In order to capture the breadth of different types of evidence that might be available, the literature review considered research presented in both peer reviewed published journals and grey literature. The literature search identified over 300 documents, which were screened according to relevance to the review based on the titles, abstracts and key words to identify a long list of literature consisting of 130 studies. This long list was further analysed using a set of classification criteria[1] to identify 34 documents covering both conceptual and empirical findings across the various dimensions of resilience linking to energy access and adaptation to climate change and climate variability.

The literature review managed to capture the vast majority of relevant peer reviewed publications and grey literature that are available in English. Given the length of time to complete the literature review, this review primarily focused on studies that were easily available and could be accessed via websites and databases.

Evidence

The findings of the literature review are presented according to the three core research questions:

How has energy access been framed in the context of adaptation and building resilience to climate change and climate variability?

Most literature identified that access to energy is critical for addressing the various dimensions of resilience and wider social and economic development. The literature indicated that access to energy can support multiple dimensions of resilience at the same time. The conceptual linkages suggest that energy access can help communities reduce their vulnerability to climate change and climate variability, whilst also diversifying livelihoods and increasing their resilience to the effects of climate change. Social and economic benefits of energy access can improve factors that contribute to building resilience to climate change, diversification of livelihoods in particular can build adaptive capacity of individuals and communities.

Alternative technologies such as biogas stoves, improved cook stoves (ICS) and electricity that replace conventional cooking and heating technologies can play a crucial role in reducing fuel wood consumption and pressure on forests. This gives the possibility to reduce deforestation that is widespread in developing countries as a result of unsustainable use of fuel wood.

The potential synergies between development, adaptation and mitigation have emerged over the last few years, particularly with respect to developing national level polices in many developing countries. For many developing countries the primary approach to adapting to climate change is to strengthen the nation’s economy and to increase the resilience of its society. This means proactively reducing the vulnerability of individuals and communities to the impacts of climate change. Adaptation is therefore closely linked to development and should not be treated as a separate issue to development. While energy is a key enabler for achieving these goals, it is also recognised that increasing energy demand (through conventional methods) can have impacts on national greenhouse gas emission levels.

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[1] Classification criteria used: Publication type; Type of research; Type of energy service/ application covered; Source of energy; Links to resilience and/or adaptation; Vulnerable groups covered; Scale of impact; Geographical coverage.

What does the literature say in terms of evidence that access to energy increases resilience?

The emphasis of this literature review was to track the complete chain of evidence from providing access to energy to building dimensions of resilience to Element 3 'Building capacity to deal with disturbance' and on to Element 4 'Reaction to disturbance'. Only a few of the documents reviewed contain evidence demonstrating the link all the way through from access to energy to adaptation and building resilience to climate change and climate variability. These studies that demonstrated empirical evidence of the complete link include: IRENA (2015), AdaptCap (2014), Rural Development Planning Tanzania (2014), Platonova and Leone (2012), Gippner et al. (2013), Jarvie and Nicholsan (2013) and CCKN and IISD (2014). However, more commonly the remaining studies stop short of providing this evidence, and make links only as far as access to energy in building dimensions of resilience, leaving the reader to infer the link to climate change adaptation and building resilience.

The evidence found relating to the 9 dimensions of resilience has been grouped under 3 headings to indicate the completeness of the evidence chain from access to energy through to capacity to deal with climate change and lastly, if energy access actually leads to building resilience:

1. Complete evidence chain: Evidence showing how communities, groups and institutions that have access to energy increased resilience to climate variability and change. The link from energy access all the way through to adaptation or climate resilience was supported with evidence.

A complete evidence chain was found mainly under 'Access to services'. Various technologies such as water supply and purification systems, and information and communication systems adopted for community needs can increase adaptation and resilience through economic, social and environmental benefits. Most technologies require a reliable source of energy to function. The literature reviewed provides some interesting evidence from projects where energy access has provided communities with access to technologies that support adaptation and build resilience to climate change:

- The services mentioned most often in the literature that benefited from access to energy are water, electricity (in the context of energy security and resilient systems), early warning systems and knowledge and information.
- The literature covered a range of different energy applications that provided these services: water pumping and purification, lighting, clean cooking and space heating, Information and Communication technologies (ICTs) (mobile phone charging, radios), energy for small scale enterprises, including food processing and storage.
- The literature considered a range of energy sources, most frequently discussed were: decentralised small scale renewable energy technologies such as micro hydro, solar, wind and biogas. Solar photovoltaic (PV) was most prominent (40% among the most commonly discussed energy sources). Empirical evidence related to solar were found in IRENA (2015), AdaptCap (2014) and Institute of Rural Development Planning Tanzania (2014). Non-renewable sources, such as diesel powered systems and grid connected systems were only mentioned in climate resilient outcomes of Mercy Corps' Energy Programmes presented by Jarvie and Nicholsan (2013) and the case study by CCKN and IISD (2014). Improved cook stoves were identified as a sustainable solution that contributed to multiple dimensions of resilience (e.g.: Dhakal (2012), Institute of Rural Development Planning Tanzania (2014) etc.).
- The literature identified that in areas where there are severe disruptions to grid electricity or no access to reliable gird electricity, or where communities have to depend on expensive options to access these services, off-grid, small-scale, decentralised and community based energy technologies were used for providing access to these services (Gippner et al. (2013) and Cabana (2012)).

2. Partial evidence chain that could be reliably inferred backwards to complete the evidence chain: Evidence showing how technologies that require energy to function, have had an impact on building resilience to climate variability and change. The link back to energy access was not clearly mentioned in these case studies, but could reliably be inferred.

Evidence in this category was particularly related to 'Access to social safety nets' and 'Access to information'.

- Access to knowledge and information via ICTs helped communities connect with formal and informal support networks (Government, aid agencies etc.) to help recover from the impacts of disasters. Solar lanterns and solar powered radios ICTs helped people access information from the Government and aid agencies during recovery from Typhoon Haiyan in the Philippines (IRIN, 2013).
- Farmers accessing ICTs can build resilience to climate hazards affecting their crops and livestock while also keeping informed of market prices in rural Nepal (Giri and Malakar, 2011) and Peruvian Andes (Cabana, 2012).
- Programmes that link poor communities to ICTs demonstrate that an affordable source of energy could contribute to better uptake of such ICT programmes as the price of batteries was a key barrier to the uptake of the radio programme (Cabana, 2012).

3. Evidence chain stopped short of making the link to climate change or adaptation and building climate resilience, and could not be reliably inferred forwards: Evidence showing how energy access has contributed to some of the dimensions of resilience without necessarily making the link to climate change or adaptation and building climate resilience. The link to adaptation and building resilience if it was mentioned was assumed or unreliably inferred forwards.

Most evidence was related to the following dimensions: Adaptive capacity, Income and food access, Livelihood viability, Natural context, Assets and Personal circumstances.

- Access to energy has contributed to creating new livelihood strategies, diversifying livelihoods, increasing income, making livelihoods more viable and improving food security. CCKN and IISD (2014), Gippner et al. (2013) and Willcox et al. (2015) provide some of these key evidence links. However the evidence stops short of making the link to climate change or and if the impacts have actually improved people's resilience to climate change.
- Case studies highlight that there is great potential to reduce deforestation (e.g.: Institute of Rural Development Planning Tanzania (2014), Dhakal (2012), CCKN and IISD (2014) and Garg et al. (2007)) by replacing fuel wood with sustainable energy sources such as bio gas, ICS, electric cooking powered by small hydro or solar PV, yet the studies reviewed do not provide empirical evidence supporting this.
- There is some evidence on how women, elderly and children can benefit from energy access to improve their personal circumstances, particularly through access to health care facilities, clean water, cleaner cooking and heating options, and reduce time spent collecting fuel wood and water, leaving more time for education and income generating activities. The literature reviewed did not present evidence to support the link that these improved personal circumstances have resulted in building resilience to climate variability and change. (e.g.: Sapkota et al., (2014), Institute of Rural Development Planning Tanzania (2014), AdaptCap (2014) etc.)

Is there any evidence that access to energy contributes to maladaptation?

Very little empirical evidence was found on how energy access contributes to maladaptation, but a few examples mentioned in the literature include:

- Over abstraction of ground water from solar PV-based pumping systems (e.g.: IRENA (2015))

- Charcoal production affecting the growth of woodlands vs livelihoods diversification (e.g.: Atteridge (2013) and Ochieng et al (2015))
- Access to modern energy saving time spent by women and children on collecting fuel wood and water can reduce opportunities to discuss problems faced in the community, disrupting societal coping mechanisms (e.g.: Matinga (2012))
- Potential for large scale energy generation technologies impacting on local ecosystems (e.g. hydro power imposing burdens on fish) (e.g.: IRENA (2015))

Potential challenges and opportunities for promoting access to energy as a means of adaptation?

Opportunities: The following key opportunities have been identified for promoting access to energy as a means of adaptation:

- Promoting energy access through decentralised sustainable options as a part of addressing the technology needs for adaptation. Solar PV for water pumping, desalination and ICTs is a key area that has had successful impacts and widespread uptake so far.
- Promoting resilient energy solutions such as decentralised renewable energy systems and portable cook stoves for communities that face disruptions to their energy supply during disasters (for instance coastal communities who are highly vulnerable to disasters such as typhoons and face severe disruptions to grid electricity).
- Promoting energy access for ICTs to help extremely poor communities, particularly those in very remote areas, to access social safety nets through providing access to knowledge and information using ICTs.
- Including energy access as a component of disaster recovery interventions, which can support economic and social recovery. Solar lighting and ICTs for accessing social safety nets are proven to be successful in disaster recovery processes.
- Expand opportunities for reducing vulnerability to climate change by mainstreaming adaptation into energy sector policies.
- Breaking down the policy and research silos between adaptation and access to energy by identifying local adaptation, mitigation and development policies where energy access is a cross cutting element, and encouraging governments and research bodies to gather evidence to support the links and co-benefits between access to energy and adaptation. Relevant initiatives that would be well placed to gather evidence include the development of measuring, reporting and verification (MRV)/ monitoring and evaluation (M&E) systems that deal with international climate change reporting such as intended nationally determined contributions (INDCs) and the development of national low carbon development strategies and adaptation strategies and plans (Nationally Appropriate Mitigation Actions (NAMA), National Adaptation Programmes of Action (NAPAs) and National Adaptation Plans (NAPs)).

Challenges: Only a few of the documents reviewed in detail identified challenges to promoting energy access as a means of adaptation and building resilience to climate change and climate variability. Most commonly the literature identified challenges with respect to scaling up energy technologies in general (e.g. local capacity, knowledge and skills to install, operate and maintain energy systems, cost of technology, buy in from local authorities etc.) and also the lack of evidence and policy frameworks to help link energy interventions with climate change adaptation. Any further research undertaken should keep these challenges in mind and seek to address them wherever possible.

Conclusions

Strength of evidence

The literature review assessed the strength of evidence using the DFID internal ‘how to’ note on ‘Assessing the Strength of Evidence’ (DFID, 2014) which uses 4 categories (quality, size, context and consistency) to assess the evidence. In addition the analysis also assessed the strength of evidence on how complete the chain of evidence was (full chain, partial chain that could be inferred backwards, evidence chain stopped short of linking access to energy with adaptation or building resilience). The strength of evidence of the literature reviewed for each resilience dimension can be categorised as:

- Strong evidence: access to services
- Moderate evidence: social safety nets, natural context and personal circumstances
- Limited evidence: adaptive capacity, income and food access, institutional and governance and livelihood viability

Gaps in evidence

The following can be highlighted as some of the key gaps that future research and interventions should focus on to harness opportunities and overcome challenges. The gaps have been identified and framed under the first three elements of DFID's Resilience Framework.

Element 1: Context

- While there are some inferred linkages in the literature reviewed that indicate how women, children and the elderly can improve their personal circumstances to build their adaptive capacity to climate change, there is lack of empirical evidence whether the benefits gained from energy access have actually contributed to building resilience to climate change among these vulnerable groups. More empirical and theoretically informed work on the role of gender and other vulnerable groups in energy access and climate change adaptation is needed.
- The evidence reviewed is not sufficient to identify best practice, or at what scale the most successful interventions have been (community, household, institutional or national level), nor specifically what the opportunities and challenges are at different scales. More empirical research is needed related to scale to understand this better.
- Although 'urban' was included in the search string used for the literature search, the literature review did not capture studies that identified conceptual or empirical evidence discussing the linkages between energy access in urban areas and how it contributes to building resilience to climate change among urban populations. Much of the literature review has been on rural and coastal areas. Urban areas (such as urban slums) appear to be understudied regarding both resilience and energy access.
- Lack of information on the context in studies limits the ability to understand what works for certain communities and what would not work. Studies focused more on the technical or policy aspects of implementing access to energy, but it is equally important to understand the physical and cultural context in order to successfully transfer technology and the associated adaptation/resilience outcomes to different communities or different countries and to scale-up. In addition, lack of understanding with respect to context specific information such as cultures, individual, community and institutional needs, local governance and support policies may result in maladaptation.
- Further research needs to be carried out to understand more clearly whether some energy technologies are better at supporting adaptation than others. A number of energy technologies could be used to provide the same service (e.g.: lighting, water pumping, heat for cooking, refrigeration, ICTs etc.) and it is the service that ultimately contributes to adaptation. Some energy technologies have featured more commonly in the literature reviewed (such as solar PV, ICS and biogas), but there was no comparative evidence in the literature to conclude one energy technology was better than another at providing particular services. The most suitable energy technology in any given situation will depend heavily on the local context and the service required.

Element 2: Disturbance

- There is lack of consideration of the shocks and stresses in the literature reviewed, particularly where the evidence chain stops short from linking to adaptation and building resilience to climate change and climate variability. The conceptual findings highlight that the energy access interventions should consider future projections for climate change within a local environment. For an energy solution to support climate adaptation it must also identify the level of impact of climatic change and climate variability on the energy system itself. Although conceptual findings present the need for climate proofing of energy systems, there was very little empirical evidence in the literature reviewed that can confirm the viability of doing so.
- Lack of understanding of the linkages between disturbance and response can lead to making unsuccessful development decisions, thus resulting in maladaptation.

Element 3: Capacity (Exposure, Sensitivity and Adaptive Capacity)

- More case studies are needed to provide empirical evidence on specific situations where energy access has resulted in adaptation and building resilience, particularly on those dimensions of resilience where the link has been inferred. For instance, empirical research on how energy access actually contributes to adaptive capacity to climate change, could build indicators that can be used in the evaluation of adaptive capacity in energy access programmes, and could help guide how context and shocks are factored into future energy access programmes and planning.
- Lack of understanding related to the links between access to energy and adaptation hinders recognising to what extent energy access actually leads to resilience and whether some of these changes are maladaptive, i.e. people/communities do not recover or adapt, they are actually worse off. For instance, how new incomes generated through provision of energy access are being used, and are the new livelihoods created through provision of energy access impacting existing livelihoods and markets.
- Future case studies should capture the key elements (e.g.: financial, political, technical, local physical and cultural context, capacity building requirement, etc.) that impact on the success or failure of the particular intervention, to inform technology transfer and potential to scale-up.
- Cases were identified where attributes such as affordability and reliability were recognised as important aspects of gaining access to services when faced by shocks and stressed (AdaptCap (2014), Gippner et al. (2013), Murphy and Corbyn (2013) and Institute of Rural Development Planning Tanzania (2014). Conceptual and empirical research needs to be furthered to frame how the attributes highlighted in the Global Tracking Framework[2] can be used in practice for measuring energy access and if these attributes contribute to building adaptation or resilience to climate change and climate variability.
- There is a lack of framing around how energy access can result in maladaptation. A clear conceptualisation of maladaptation with respect to energy access is needed to recognise how it can be assessed and captured within existing research that link energy access and building enhanced adaptation and resilience to climate change.

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[2] The Sustainable Energy for All (SE4All) Initiative has produced a SE4All Global Tracking Framework which presents a new definition for energy access based on the performance of the energy supply: ''Access to energy is the ability to avail energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy and safe, for all required energy services across household, productive and community uses'' (Angelou, 2014).

Further research

In order to strengthen and complement the findings of this literature review, further research and investigation is needed, building on the findings of this literature review, through stakeholder and expert interviews and discussions to gather evidence from existing projects. This should include country focused field research including analysing policy and institutional contexts in selected least developed countries to identify if the link between energy access and climate change adaptation has been made or could be made in line with future development plans and goals. An option could be to focus particularly on those countries that are actively attempting to combine development, adaptation and mitigation through policy ideas such as low carbon resilient development, climate compatible development or green growth (such as Ethiopia and Bangladesh). In addition it could focus in countries where any MRV systems (such as Kenya) for international climate change reporting are aiming to gather evidence of the links or synergies between mitigation and adaptation. This research could provide the opportunity to investigate deeper, the linkages between energy access and climate change adaptation, and provide robust and strategic policy and programme recommendations that can also benefit on going planning and preparation around post 2015 development agendas related to sustainable energy, climate change and development.

List of Abbreviations

ASALs	Arid and Semi-Arid Lands
CCKN	Climate Change knowledge Network
DFID	Department for International Development
ESMAP	Energy Sector Management Assistance Program
ICT	Information and Communication Technologies
ICS	Improved Cook Stoves
IDRC	International Development Research Centre
IEA	International Energy Agency
IIED	International Institute for Environment and Development
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
MRV	Measuring, Reporting and Verification
M&E	Monitoring and Evaluation
NAMA	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programmes of Action
NAP	National Adaptation Plans
ODI	Overseas Development Institute
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
R4D	Research for Development
REDP	Renewable Energy Development Project
RSP	Regional Solar Programme
SE4ALL	Sustainable Energy for All Initiative
TNA	Technical Needs Assessment
TV	Television
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WB	World Bank

SECTION 1

Introduction

The World Energy Outlook 2014 states that ''*In developing countries, access to affordable and reliable energy services is fundamental to reducing poverty and improving health, increasing productivity, enhancing competitiveness and promoting economic growth*''. Energy is a critical enabler that can enhance the lives of poor and marginal groups in many ways. Access to electricity allows people to use efficient forms of lighting allowing them to work and study after dark and to access new forms of communication. It enables people to use water pumps to access clean water for household use, reducing the time spent collecting water, particularly by women and children. Electricity also allows farmers to irrigate crops and enables the use of refrigerators to preserve food and medicine. Clean cooking fuel and improved cook stove technologies can reduce the impacts of indoor air pollution, particularly on women and children, and alleviate the burdens associated with the time and effort women and children spend collecting fuel wood. Livelihoods and income generation can be improved through using mechanical power for agriculture production, food processing and other local industries; enabling new income generation opportunities and diversifying livelihoods (International Energy Agency (IEA), 2014). Despite this, today nearly 1.3 billion people are without access to electricity and 2.7 billion people rely on the traditional use of biomass for cooking, which causes harmful indoor air pollution. Most affected populations are from developing and least developed countries in Asia or sub-Saharan Africa and in rural areas (*ibid*).

Organisation for Economic Cooperation and Development (OECD) (2006) highlight that the poorest and most marginalised communities have greatest dependence on environmental resources to meet their basic needs, such as forests (for energy, materials and food), land (for farming) and water (for drinking, household use and farming). A study by Johnson and Lambe (2009) linking energy, poverty and climate change highlights that these heavily natural resource dependent economies are not only facing significant depletion and pressures on natural resources and existing ecosystems due to climate change and increasing demand for resources, but also are at the frontline of an urgent need to link energy development strategies and initiatives with efforts to improve adaptive capacity. They further highlight that impacts of climate change will pose increasing challenges to households and communities relying on local ecosystems to meet their energy needs. Thus with both agricultural and forest systems facing greater pressures in a changing climate, it is vital that local communities develop other energy options and alternative livelihoods.

Despite the understanding and the clear overarching benefits of access to energy in addressing the various dimensions of development and poverty reduction, to date there has been little discussion on energy access within the context of adaptation to climate change. Energy is generally tackled as a mitigation issue or relation to energy security, and more recently in relation to providing access to energy services at the household or community level. Little attention has been paid to the potential for local level/community-based energy access in tackling adaptation and building resilience to climate change and climate variability. Renewable energy in particular is an area that is poorly understood in the context of adaptation and has great potential in supporting households and communities to build adaptive capacity and resilience to climate change (Stone, 2013).

This literature review was conducted with the aim of carrying out a systematic evidence search to support the idea that there is a synergy between access to energy and climate change adaptation, in particular to show how energy access contributes to reducing vulnerability and building adaptation and resilience to climate change and climate variability. To achieve this the literature review in particular uses the definitions and the dimensions of resilience described in Department for International Development's (DFID) Resilience Framework, presented by Brooks et al. (2014), which is built on four key elements:

1. Context ('Resilience of what?')
2. Disturbance ('Resilience to what?')
3. Capacity to deal with disturbance (exposure, sensitivity and adaptive capacity
4. Reaction to disturbance.

The literature review sought to identify evidence of the context in which communities, groups and institutions that have access to energy have enhanced resilience to climate variability and climate change. The literature review also sought to identify the linkages between energy access and capacity to adapt, and how energy access influences the capacity to deal with disturbance, primarily focusing on how energy access can buffer sensitivity and enhance adaptive capacity. The literature review sought evidence of the reaction to disturbance, i.e. does energy access lead to collapse, recovery, bounce back or bounce back better?

The literature review aimed to identify how energy access has been framed in the context of climate change adaptation. The core focus of the review was to identify existing evidence, highlight where there are clear gaps in the evidence and understand what the challenges and opportunities are in fostering a greater integration between energy access and adaptation to climate change.

In order to conduct this systematic literature search and identify the evidence base, three research questions have been considered:

1) How has energy access been framed in the context of adaptation and building resilience to climate change and climate variability?
2) a. What does the literature say in terms of evidence that access to energy increases resilience
   b. Is there any evidence that access to energy contributes to maladaptation?
3) What are the potential challenges and opportunities for promoting access to energy as a means of adaptation?

The rest of the report is structured into 6 sections:

- **Section 2** builds the conceptual framework for the study. It presents the key definitions used, presents the various dimensions of DFID's Resilience Framework and presents the hypothetical conceptual linkages between climate shocks and stresses, energy access and building resilience to climate change;
- **Section 3** outlines the approach used for this literature review including the literature search, selection and the assessment. It also presents the limitations of the literature review;
- **Section 4** presents the results of the literature review. It presents the conceptual linkages identified by addressing question 1 above and then moves on to presenting the empirical evidence identified by addressing question 2;
- **Section 5** draws upon the results presented in Section 4 and identifies key opportunities and challenges involved in promoting energy access as a means of adaptation (addressing question 3 above);
- **Section 6** synthesises key insights from the literature review. It highlights key gaps in evidence and questions that the literature has failed to address, thus also providing key areas for future research

SECTION 2

Conceptual Framework

2.1 Definitions and conceptual framing of resilience

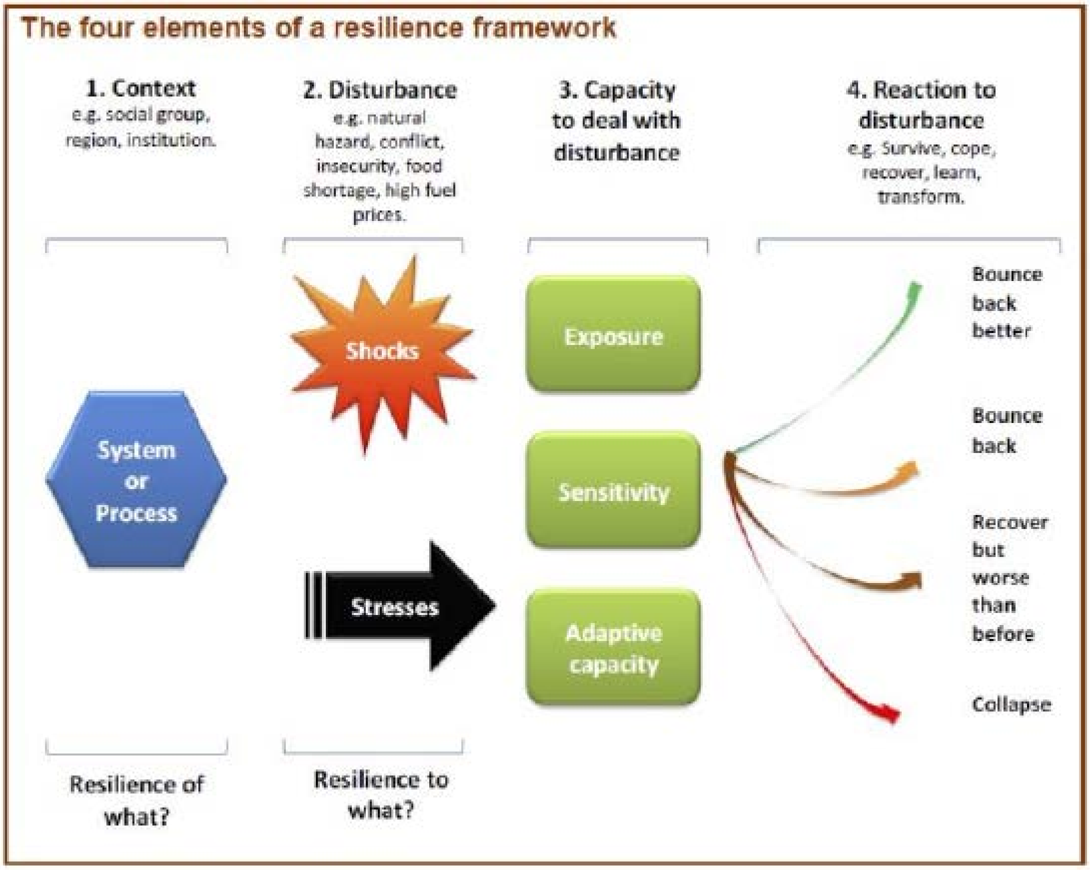
In exploring the linkages between energy access and climate change adaptation and resilience it is useful to define the key concepts. Resilience is a popular and fluid concept that is used to frame and explore how societies continue to thrive and develop under shocks and stresses. Its definitions vary by discipline or sectoral background. It has its roots in ecological systems thinking (e.g. (Holling, 1973) where it is defined as the ability of a system to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes (Resilience Alliance, 2002). It has since evolved into a more holistic concept that brings together elements of society and nature defined as ‘coupled’ systems (Folke, 2006). In the social sciences scholars have also developed definitions of resilience such as “the magnitude of the disturbance that can be absorbed before a system changes to a radically different state as well as the capacity to self-organise and the capacity for adaptation to emerging circumstances” (Adger, 2000), (Adger, 2006), and in the context of adaptation to climate hazards ‘’the amount of disturbance or change that a system can withstand before it changes function –with the attendant loss of wellbeing if the desirable characteristics of human systems are lost’’ (Ensor et al., 2015). Resilience is sometimes considered the flipside of vulnerability to climate change impacts. Vulnerability can be defined as the ‘’degree to which systems are susceptible to, and unable to cope with, adverse impacts of climate change’’ (Klein and Füssel, 2006). Adaptation is defined by the Intergovernmental Panel on Climate Change (IPCC) as ‘’the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects’’ (IPCC, 2014). The IPCC also defines adaptive capacity as, ‘’The potential or capability of a system to adapt to (to alter to better suit) climatic stimuli or their effects or impacts’’ (IPCC, 2014).

DFID defines resilience as:

“the ability of countries, governments, communities, and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses, while continuing to develop and without compromising their long-term prospects”. (Brooks et al., 2014)

DFID has developed a Resilience Framework, illustrated in Figure 1. Brooks et al. (2014) describe DFID’s Resilience Framework as the resilience of a system or process to specific shocks and stresses, in terms of its capacity to deal with these shocks and stresses, and in terms of how the system responds to them (bounce back better, bounce back, recover but worse than before and collapse). Brooks et al. (2014) explain that the resilience framework deliberately contextualises resilience in terms of the system or process whose resilience is of interest (Element 1), the stresses and shocks to which this resilience refers (Element 2), the capacity to deal with disturbance (Element 3), and the reaction to disturbance (Element 4). These elements are presented in more detail in Box 1.

Figure 1. The DFID Resilience Framework



Box 1 The four elements of the DFID Resilience Framework (adapted from Brooks et al., 2014)

The framework describes resilience in terms of four elements:

Element 1: Context, which refers to the system or process whose resilience is being examined (i.e. 'resilience of what?'). Systems might include human populations or social groups, communities, households (and indeed individuals), countries, institutions, regions, ecosystems, infrastructure, etc. Processes might relate to governance or the delivery of services.

Element 2: Disturbance, in the form of a shock or stress to which the system or process of interest is exposed (i.e. 'resilience to what?'). Disturbances can take many forms, and may be climatic, environmental, social, political, or economic in nature. In terms of climate variability and change, these disturbances will take the form of climate hazards and related phenomena, which can be defined as physical manifestations of climate variability and change with the potential to have negative effects on the environment and on society.

Element 3: Capacity to deal with disturbance, which depends on the degree to which the system or process in question is exposed to the disturbance, the sensitivity of the system or process to the disturbance, and the capacity of the system or process to adapt to changes associated with the disturbance. These dimensions describe sets of characteristics of a system or process that make it more or less likely to experience harm when exposed to a disturbance.

Element 4: Reaction to disturbance, in terms of whether the system or process continues to function as it did prior to the disturbance (bounce back), better than it did prior to the disturbance (bounce back better), worse than it did prior to the disturbance (recover but worse than before, or not at all (collapse)). A resilient system will bounce back or recover so that it functions in a way that is similar to or more efficient than the way it functioned before the disturbance, a non-resilient system will collapse or have its functioning significantly impaired as a result of the disturbance. Where recovery is only partial, collapse might occur after successive shocks, with the system or process becoming less resilient after each shock.

Resilience of what?

Box 1 highlights what contexts (system and process) resilience can apply to. Contextualising resilience allows the review to capture whose resilience is of interest and helps to identify specific factors that can make those systems and processes of concern resilient to shocks and stresses.

A DFID study (DFID, 2011) on defining disaster resilience using the DFID Resilience Framework highlights that ''resilience can be identified and strengthened in a social group, socio-economic or political system, environmental context or institution. Each of these systems will display greater or lesser resilience to natural or man-made disasters. More work is needed to differentiate the significance of resilience for different social groups, resources and institutions across a range of different contexts''.

By gaining an understanding of and classifying the various interventions that have taken place according to contextual focus (be it social groups, household level, communities or institutions), it is possible to map out the existing portfolio of climate change resilience activities in a country or geographic region. This can help policymakers and programme designers to understand any gaps and future priorities for funding new programmes. The literature review focused on the resilience of social groups, households, communities and institutions to climate change in the contexts of limited energy access.

Resilience to what?

Principle climate shocks consist of current climate hazards (including droughts, floods, storms, increased rainfall variability, long-term sea-level rise or acidification) exacerbating existing development-related stressors related to chronic poverty, malnutrition, lack of access to energy and so on. Communities already experience climate variability, nevertheless the potential negative consequences of climate hazards on people and the environment poses new challenges to tackling the underlying stressors associated with barriers to poverty reduction. These climate hazards can include rainfall deficits, episodes of intense rainfall that could result in flash/extreme flooding or damages to agricultural crops, tropical storms and longer term slow onset changes such as sea level rise or change in average external temperatures (IPCC, 2014). The underlying vulnerability or stressors, i.e. sensitivity and the exposure of the people or the system will determine the severity of climate hazards and the ability to bounce back better. It is now known that climate change will increase the frequency, severity and likelihood of impacts, which in turn interact with non-climate impacts in ways that will affect people's quality of life, and the extent of loss and damages experienced, thus affecting the extent that a development intervention is impacted, secured (Brooks et al., 2014), (IPCC, 2012) and can deliver mechanisms to build capacity to deal with exposure. The review examined evidence of linkages between resilience of the poor to climate hazards and how energy access enables the poor to build adaptive capacity to respond to and tackle disturbance.

Capacity to respond to and tackle disturbance

The 3 main dimensions of resilience in the DFID Resilience Framework are:

1. Exposure: the factors that determine the extent to which systems or processes within an area subject to a shock are likely to experience the immediate physical impacts of the shock. For example elevation or proximity to shoreline in the case of flooding.

2. Sensitivity: the factors that make systems more or less likely to experience adverse consequences when they are exposed to a shock, including their ability to cope with the shock while it is occurring and to recover after it has occurred.

For example, ''women accounted for up to 80% of those who died during the 2004 Indian Ocean tsunami, and death rates among women were almost four times higher than those among men in the 1991 Bangladesh cyclone. Limited mobility, skills set and social status exacerbated sensitivity to the shock'' (DFID, 2011).

3. Adaptive capacity: the factors that allow systems and processes to anticipate and plan effectively for change, to learn from experiences of previous shocks, and to act on the lessons of that experience.

According to DFID (2011) the resilience of a system or process is seen as a function of its sensitivity and adaptive capacity. Several assets and resources can be used to determine sensitivity and adaptive capacity in the face of shocks and stresses. These assets include social, human, technological, physical, economic, financial, environmental, natural, and political.

2.2 Defining energy access

Section 1 presents the key benefits of energy access that act as an enabler to poverty reduction: providing economic security, improving household health, providing opportunities for women and education and reducing deforestation and other environmental impacts.

The Sustainable Energy for All (SE4ALL) Initiative has produced a SE4ALL Global Tracking Framework which presents a new definition for energy access based on the performance of the energy supply: **''Access to energy is the ability to avail energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy and safe, for all required energy services across household, productive and community uses''** (Angelou, 2014). These attributes can be seen as the drivers that enable the uptake of energy solutions by poor communities.

While most of the literature presented these positive impacts of access to energy, several studies also highlighted that access to energy needs to be combined with several factors to achieve these benefits. For instance, Willcox et al. (2015) highlight that the most significant characteristics of energy access are costs and access to finance, knowledge, skills and access to markets.

2.3 Hypothetical linkages between energy access, resilience and adaptation

The poorest and most marginalised communities often have the greatest dependence on environmental assets for their basic needs, such as forest resources (for energy, materials and food), land (for farming) and water (for drinking, household use and farming). This also makes these communities some of the most vulnerable to climate hazards (OECD, 2006). Climate hazards are exacerbating existing stresses on the environment, affecting poor people's lives directly through impacts on livelihoods, access to water, reductions in crop yields, or destruction of homes, limiting their capacity to recover from climate hazards (IPCC, 2014). Building resilience of livelihoods and infrastructure is a key component in poverty reduction initiatives (OECD, 2006).

While it is clear that development interventions should help poor people to build their adaptive capacity and adapt in anticipatory and planned ways to deal with the exposure to future climate hazards, development also needs to tackle basic needs and underlying or persistent stressors that pose barriers to development. Stressors include a myriad of factors. Features of chronic poverty are also important here, such as discrimination, marginalization, exclusion of the poor, women or elderly etc. Of particular importance to poverty reduction is increasing sustainable energy access for the poor. Given the strong link that energy presents as an enabler that is crucial for enhancing people's livelihoods and wellbeing, lack of access to energy could be a major cause of poverty and a key constraint in building the resilience of livelihoods that are most vulnerable to climate change. Nevertheless, the connection between energy access and adaptation to climate change has only recently started to be explored. Due to this lack of connectivity in policies and projects, the issues around energy access and adaptation remain separated (Murphy and Corbyn, 2013).

The ultimate measure of the effects of energy access on resilience will be the extent to which energy access can be associated with reducing sensitivity and exposure, and increasing adaptive capacity during adverse effects of shocks and stresses, leading to a change in the reactions to disturbance beyond surviving. The challenge is that the success of energy access in building resilience can be measured only if it is possible to measure what would have happened without the energy access under shocks and stresses.

Box 2 Dimensions of resilience (adapted from Brooks et al., 2014)

1. **Access to services**, including water, electricity, early warning systems, public transport, and knowledge and information that helps people plan for, cope with and recover from stresses and shocks.
2. **Adaptive capacity**, including factors that specifically enable people to anticipate, plan for and respond to longer-term changes (for example by modifying or changing current practices and investing in new livelihood strategies), that are not represented by the other dimensions.
3. **Income and food access**, indicative of the extent to which people may be poor or food insecure *before* the occurrence of a stress or shock.
4. **Social safety nets**, including access to formal and informal support networks, emergency relief, and financial mechanisms such as insurance.
5. **Livelihood viability**, in terms of the extent to which an individual's livelihood can be sustained in the face of a shock or stress, or the magnitude of shock or stress that can be accommodated before a livelihood ceases to be viable.
6. **Natural contexts**, including the extent to which coping and adaptation is facilitated or constrained by the quality of built infrastructure (e.g. roads), the quality/functioning of environmental systems/natural resources (e.g. health of ecosystems providing livelihoods), and geographical factors (e.g. remoteness).
7. **Personal circumstances**, including any factors not covered by other dimensions that might make an individual more or less able to anticipate, plan for, cope with, recover from, or adapt to changes in stresses and shocks. These might include health, debt, low socio-economic status, etc.

8. **Institutional and governance contexts**, including the extent to which governance processes, institutional mechanisms, policy environments, conflict, and insecurity constrain or enable coping and adaptation.
9. **Assets,** including physical and financial assets, food and seed reserves, and other assets that can be deployed or realised during times of hardship to help people absorb losses, and recover from stresses and shocks.

Brooks et al. (2014) analyses the dimensions of resilience in some of the existing methodologies and frameworks[3] to propose a set of comprehensive but not prescriptive dimensions that can be used to identify factors that are important features of resilience. These are presented in Box 2.

We used these dimensions as a lens to frame the conceptual linkages between resilience of the poor to deal with disturbance and how energy can act as an enabler. Other frameworks of resilience dimensions include the work of Biggs et al. (2015). Biggs's resilience dimensions are however designed for sustaining ecosystem services and based on social ecological resilience principles. These are arguably therefore less relevant to addressing the specific development perspective that underpins this review. This report draws on 9 dimensions (detailed in Box 2) of resilience to assess the evidence that links resilience, adaptation and energy access.

Table 1 presents the 9 dimensions of resilience from Brooks et al. (2014) along with possible indicators that we looked for in the evidence and the source of these ideas. These dimensions and linkages frame the literature review and the analysis of the evidence, which is presented in Sections 4.2 and 4.3.

Table 1 The 9 dimensions of resilience, possible indicators of linkages and the source of these ideas

Resilience Dimension used in this review	Proposed indicators of linkages between energy access, resilience and adaptation	Source
Resilience Dimension 1: Access to services	e.g. Access to services such as water, early warning systems, Information and Communication Technologies (ICTs) such as radio, TV, mobile phones, and reliable, affordable and resilient types of energy services	Christensen et al., (2006), United Nations Development Programme (UNDP) (2013), Murphy and Corbyn (2013), Stone (2013)
Resilience Dimension 2: Adaptive capacity	e.g. New anticipatory mechanisms that lead to livelihood opportunities, coherent knowledge networks, flexible and adaptive institutions	Christensen et al., (2006), UNDP (2013)
Resilience Dimension 3: Income and food access	e.g. New income and employment, agriculture processes and irrigation systems that improve productivity, increase savings by gaining	Christensen et al., (2006) South Centre (2008)

[3] Seven methodologies were reviewed, from ACCRA, FAO, Oxfam, Tulane University, the University of Florence, WFP, and World Vision/Tufts University.

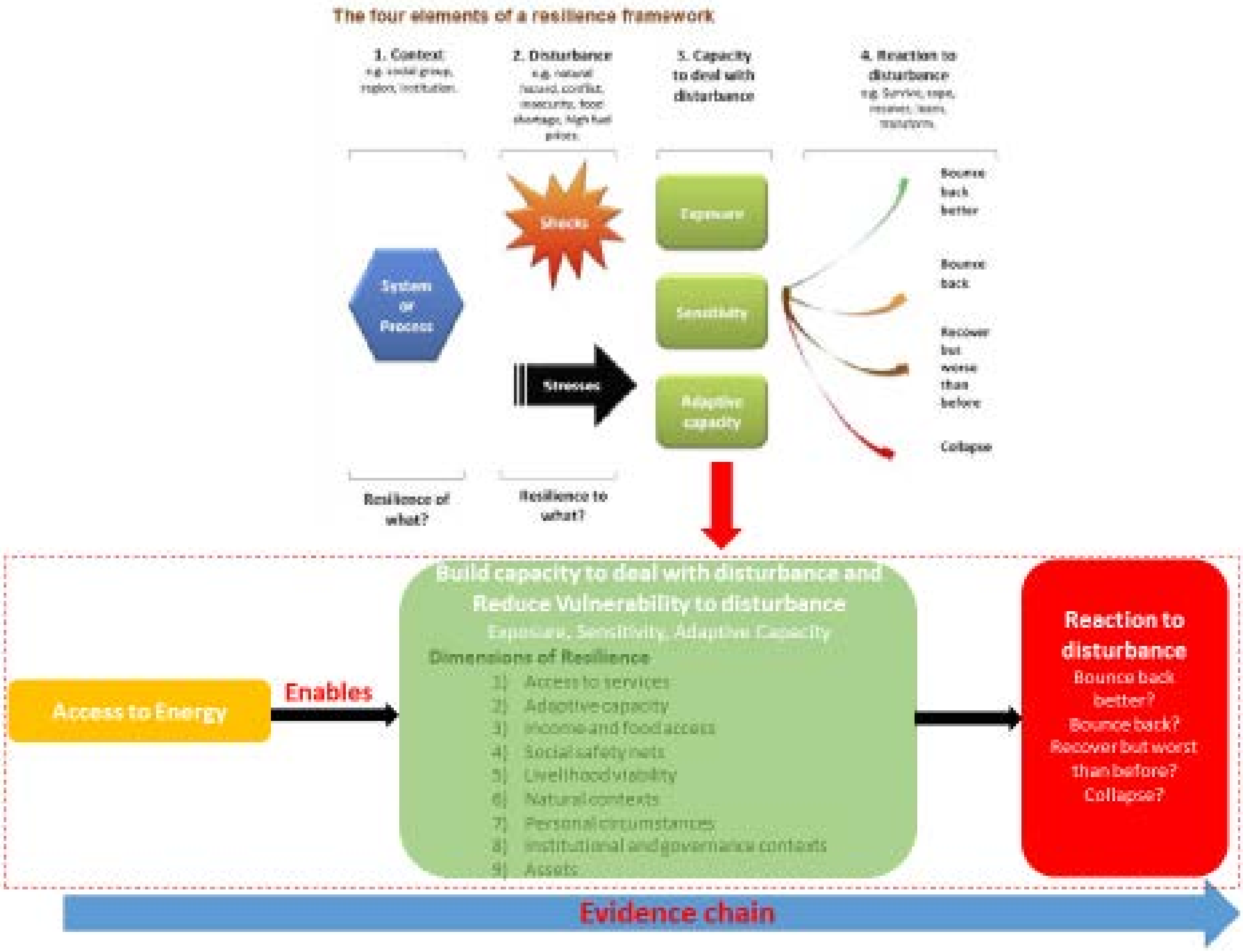
Resilience Dimension used in this review	Proposed indicators of linkages between energy access, resilience and adaptation	Source
	access to cheaper fuel options, increased income by improving productivity and efficient time savings, new enterprises, more productive users	
Resilience Dimension 4 Social safety nets	e.g. Networks that connect with formal and informal support to stakeholders (governments, aid agencies etc.) as part of disaster response that can help recovery from the impacts	Pelham et al. (2001)
Resilience Dimension 5: Livelihood viability	e.g. Resilient livelihoods - particularly by improving access to energy in food production, diversifying livelihoods for co-benefits for poor and marginal groups.	Christensen et al., (2006) South Centre, (2008)
Resilience Dimension 6: Natural context	e.g. Reducing likelihoods of deforestation and pressures on ecosystems, and improving soil fertility	UNDP (2013)
Resilience Dimension 7: Personal circumstances	e.g. Opportunities for women empowerment, social development and wellbeing, improved health and access to health services particularly beneficial for women and children, improved socio-economic status by access to better education, and time savings allowing time to be used more productively	Christensen et al., (2006) South Centre (2008) UNDP (2013)
Resilience Dimension 8: Institutional and governance contexts	e.g. Various policies that are driving the synergies between energy access and adaptation and building resilience to climate change	Fisher (2013) Murphy and Corbyn (2013)
Resilience Dimension 9 (cross cutting): Assets[4]	e.g. Financial assets, food reserves	UNDP (2013)

Figure 2 presents how these proposed conceptual linkages fit within the DFID Resilience Framework. It presents what potential key dimensions of resilience (given in Box 2) can inform how energy access reduces impacts of climate hazards and stresses. The focus of this literature review is to find evidence to support the links between access to energy, building resilience and adaptation, i.e. from access to energy all the way through to the ‘reaction to disturbance’. This literature review uses these 9 dimensions of resilience as a lens to frame the conceptual linkages between resilience of the poor to deal with disturbance and how energy can act as an enabler.

Section 4 sets out the experimental and observational empirical evidence found in the literature review. It uses the conceptual framework to identify the evidence that underpins the theory that energy access leads to resilience (Element 3 & 4: Capacity to deal with and react to disturbance) and whether some of these changes are maladaptive, i.e. people don't recover or adapt, they are actually worse off through unintended actions.

[4] Note that for this review the Resilience Dimension 9 ‘Assets’ has not been presented separately as a conceptual linkage, as it overlaps heavily with several of the other dimensions and so is covered where relevant under other dimensions. For example the dimension of ‘adaptive capacity’ and the conceptual linkage of ‘new livelihood opportunities’, overlaps with financial assets; and the dimension of ‘income and food access’ and the conceptual linkage of ‘agriculture processes and irrigation systems that improve productivity’ overlaps with food reserves and financial assets

Figure 2. Hypothetical conceptual linkages between energy access and dimensions of resilience



SECTION 3

Methodology

3.1 Research questions

This literature review sought to answer the following three questions:

1. How has energy access been framed in the context of adaptation and building resilience to climate change and climate variability?
2. a. What does the literature say in terms of evidence that access to energy increases resilience?
   b. Is there any evidence that access to energy contributes to maladaptation?
3. What are the potential challenges and opportunities for promoting access to energy as a means of adaptation?

The review used the first question in particular to identify the conceptual linkages made in the literature identified in Section 2. The second and the third questions were addressed in more detail as a part of the detailed review.

3.2 Approach for literature searches

In order to capture the breadth of different types of evidence that might be available, it was important to consider research presented in both academic peer-reviewed journal articles and grey literature (for example policy reports, briefing papers, online articles or blogs and programme/project documents). While it is important to use the highest quality literature (mainly from peer reviewed journals), it is important to recognise that some crucial evidence will be found in grey literature. This is particularly evident when research is being presented from developing countries where peer reviewed journals might not be so easily accessible to the researchers, or evidence is coming through a specific project or programme rather than as part of a specific piece of research (for example an impact assessment or evaluation). Haden-Zanker and Mallett (2013) have identified that while grey literature is usually seen to have a lower quality than peer reviewed literature, it can '"help increase the breadth, relevance, topicality and ultimate utility of your review''.

3.2.1 Published and peer reviewed literature

A systematic approach was used to identify evidence from academic peer-reviewed journal articles in order to compile an available evidence base on the linkages between energy access and adaptation or resilience to climate change.

A systematic literature search was undertaken using Web of Science (Bolean OR/AND). A keyword search using a string of keywords (see Appendix A) was used to build a database of relevant documents. The literature search string was built on expert knowledge. The search took into account differences in American and English spelling and terminology. Truncation (*) was used at the end of word stems to allow all forms of the word to be searched. The following hierarchy tiers were selected for the search on the basis of fulfilling the objectives of the literature review: level 1 energy access, level 2 energy sources and uses, level 3 climate related risk, vulnerability and resilience (with associated terms), and finally level 4 and 5 relate to the impacted target individuals and groups and the geography and regions. Following the selection of an extensive list of key words it was necessary to make around 300 combinations of these keyword searches on Web of Science. This allowed a comprehensive search of all literature to be conducted. All references identified during each stage were recorded in Excel along with their abstracts.

3.2.2 Grey literature and policy documents

To capture the inter-linkages between energy access and adaptation that are documented outside peer-reviewed literature, a top-down approach was employed, using the project teams' own knowledge on the subject matter, building on a number of existing reports or research briefings already in circulation of experts involved in the review. The grey literature search also included the use of several databases and website searches to identify key project reports, policy documents, blogs, articles and other relevant grey literature. These databases included:

- Google Scholar (also using 'cited by' function)
- Google Search
- Energypedia
- weADAPT — adaptation planning, research and practice
- Clean Energy Info Portal - Reegle
- Eldis
- United Nations Framework Convention on Climate Change (UNFCCC)-Technical Needs Assessments (TNA)
- Green Growth Knowledge Platform
- Research for Development (R4D) website (DFID)
- Organisational publication web pages and data bases - International Institute for Environment and Development (IIED), International Institute for Sustainable Development (IISD), Overseas Development Institute (ODI), World Bank (WB), Energy Sector Management Assistance Program (ESMAP), International Renewable Energy Agency (IRENA), Practical Action and Stockholm Environmental Institute (SEI).

Similar to the peer-reviewed article search the identified literature was recorded in Excel along with their abstracts.

3.3 Selection of literature, study quality assessment and detailed review

3.3.1 Study inclusion criteria

Given that over 300 documents were found, particularly in the search for peer-reviewed articles, an initial screening was conducted based on the abstract of the document.

Relevance: The relevance was primarily based on if the study provided any conceptual or empirical linkages to energy access and adaptation and building resilience to climate change.

Geographical scope: It was agreed with DFID that the primary focus was on studies that present conceptual or empirical evidence focusing on developing countries.

Methodological Approach: The DFID internal 'how to' note on 'Assessing the Strength of Evidence' (DFID, 2014) was used as a guide to identify the type of research, research design and research methods employed. This literature review included both primary and secondary research studies. The majority of the studies were secondary, non-systematic reviews.

Language: The focus was on studies in English language.

3.3.2 Selection of literature

Following the completion of the searches, literature was screened by the experts according to relevance to the review. This initial screening was based on the title, abstract and the key words (where available). This enabled the experts to identify a long list of literature (consisting of 130 studies), which were then inserted into a spread sheet with classification criteria. These criteria included:

- Publication type (peer reviewed (PR), grey literature (GR) or policy document (PD));
- Type of research (e.g. primary, secondary, conceptual, theoretical, qualitative, quantitative etc.);
- Type of energy service/ application covered (e.g. cooking, heating, lighting, productive use, irrigation, ICT etc.);
- Source of energy (wind, hydro, biomass, solar photovoltaic (PV), fossil fuels, human/animal power);
- Links to resilience and/or adaptation;
- Vulnerable groups covered (e.g. women, girls, extreme poor, tribal etc.);
- Scale of impact (household, business, communities, national, regional);
- Geographical coverage.

The review of abstracts was split among two researchers. When the abstract was not clear enough, a quick screening of the full report using search terms was undertaken. This initial review of classification helped to ensure the short listing for the detailed review included studies that showed if energy access has been addressed in the context of climate change adaptation (in answering question 1).

While the priority was to identify studies that could show actual evidence and findings linking energy access to adaptation and building resilience to climate change and variability, it was recognised that the literature captured in the search under the following descriptions must also be considered due to lack of evidence that made the above link:

- Studies that show access to various energy services have had an impact on building resilience to climate change and variability without particularly describing the source of energy;
- Studies that show how energy access has contributed to dimensions of resilience (See Figure 2) without necessarily making a link to climate variability and/or climate change.

A final list of 34 documents were identified for the detailed review by analysing the spread sheet using the classification criteria. The analysis ensured that the 34 documents covered both conceptual and empirical findings across the various dimensions of resilience linking to energy access and adaptation to climate change.

3.3.3 Quality assessment of literature

Classification of the studies also included identifying the methodological approach used by each study, i.e. primary or secondary according to DFID's internal How-to-note. The quality assessment was only applied to the short listed documents (see Section 7 References).

Two different sets of criteria were used for assessing the quality of literature depending on if it was primary research or secondary research. The criteria used are DFID's principles of quality for primary research studies on quality assessment of secondary review studies.

Criteria for primary and secondary research are presented in tables 2 and 3 below:

Table 2 Criteria for assessing quality of primary research studies

Principals of quality	Associated components
Conceptual Framing	1. The study acknowledges existing research 2. The study constructs a conceptual or theoretical framework 3. The study poses a research question 4. The study outlines a hypothesis
Transparency	1. The study presents or links to the raw data it analyses 2. The author recognises limitations/weaknesses in her work
Appropriateness	1. The study identifies a research design 2. The study identifies a research method 3. The study demonstrates why the chosen design and method are good ways to explore the research question
Cultural Sensitivity	1. The study explicitly consider any context specific cultural factors that may bias the analysis or findings
Validity	1. The study has demonstrated measurement validity 2. The study is internally valid 3. The study is externally valid
Reliability	1. The study demonstrates measurement reliability 2. The study demonstrates that its selected analytical technique is reliable
Cogency	1. The author 'signpost' the reader throughout 2. The conclusions are clearly based on the study's results

Table 3 Criteria for assessing quality of secondary research studies

Criteria
• The author states where they have searched for relevant studies to be included in the review/ The study acknowledges existing research • Author attempts a quality assessment of the studies they found • Study's findings are demonstrably based on the studies it reviewed

In addition to the above DFID principles, critical judgment was also used which is more subjective to the reviewers' knowledge, to identify the level of sophistication of the studies in relevance to the research questions. Critical judgment used the following levels of quality:

1. List of linkages (Lowest quality)
2. Listing of concrete changes pre and post access to energy (quantitative and qualitative findings)
3. Establishing actual linkages between energy access and adaptation to climate change (Highest quality)

The overall quality of the study depended on the comprehensiveness of how the principles of quality were addressed:

- High: Comprehensively address multiple principles of quality
- Moderate: Some deficiencies in attention to principles of quality
- Low: Major deficiencies in attention to principles of quality

The synthesis of evidence included studies of all levels of quality, however, the majority of studies were of moderate quality.

3.3.4 Detailed review of literature

The 34 final studies were all reviewed in detail using an information extraction template. The detailed review template is given below. For each study a word document was created filling in details required in the template presented in Appendix B.

3.4 Limitations of the literature review

The literature review captured the majority of relevant peer-reviewed publications and grey literature that are available in English. Several relevant publications that needed to be purchased (e.g. books) were not included in the review. However some were accessed by writing directly to the authors.

Given the length of time available to complete the literature review, it primarily focused on studies that were easily available and could be accessed via websites and databases. Although a few conversations were carried out with some experts working in energy access and adaptation research areas to get a sense of the breadth of evidence available, this review did not actively interview authors or project managers on relevant publications.

SECTION 4

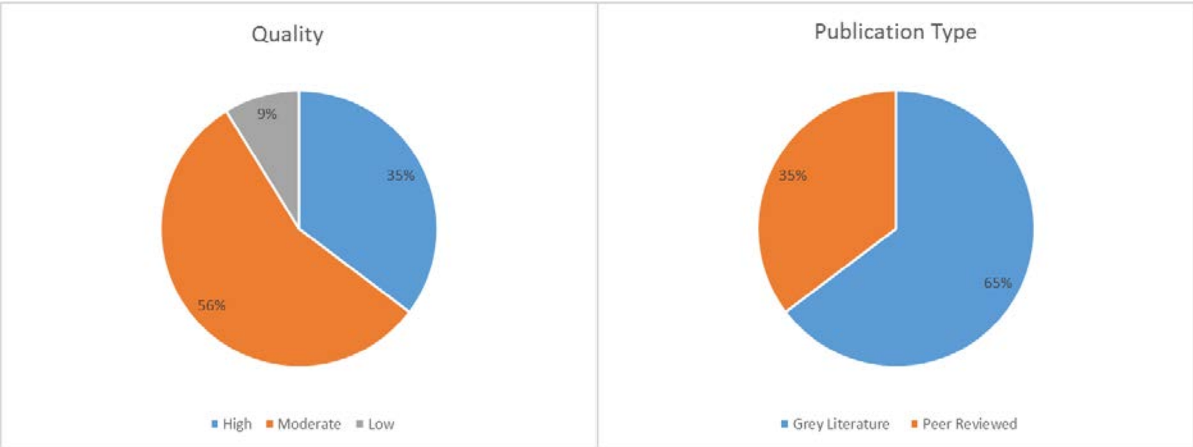
Evidence

4.1 Survey of the literature reviewed

Type of publication and quality of studies

The review covered studies across high, moderate and low quality literature as described in Section 3.3.3. The majority of literature (56%, 19 studies) was moderate quality using secondary non-systematic and conceptual methodologies. Very few project reports included primary research methods. Out of the 34 studies 35% (12 studies) were classified as high quality and the remaining 9% (3 studies) were of low quality. They more commonly used non-experimental or observational approaches to document evidence. A total number of 34 studies were included in the review.

Figure 3 Breakdown of studies based on their quality and publication type

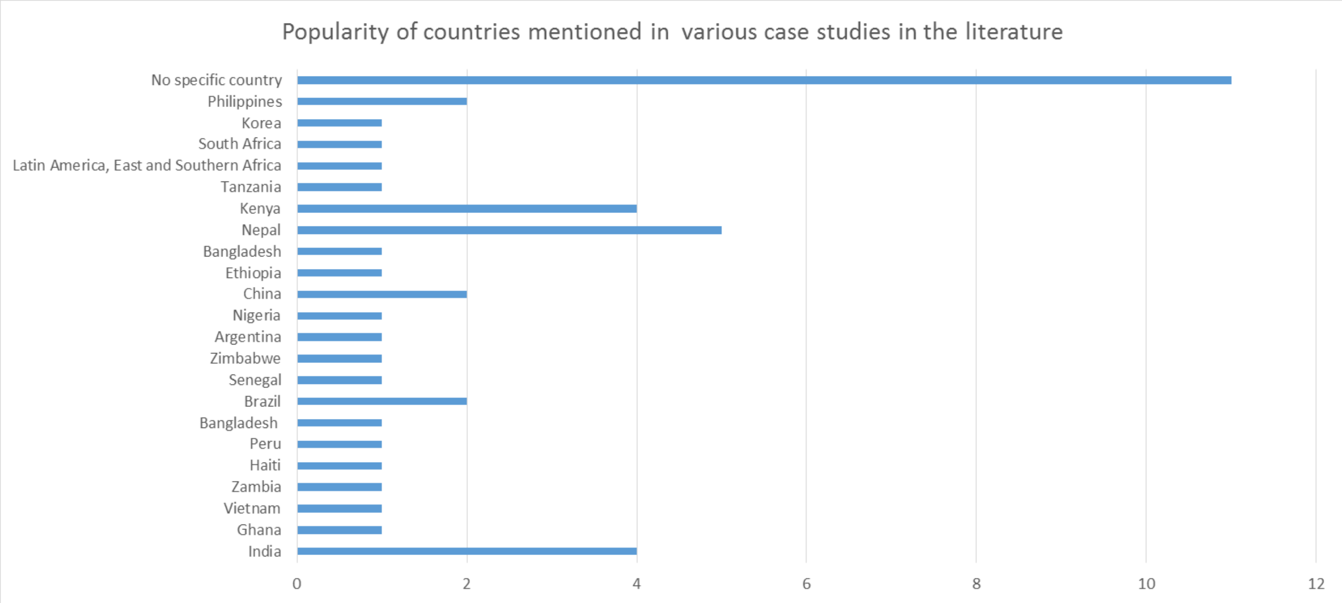


The review attempted to ensure as a broad a range of materials and literature were considered as was feasible in the timeframe. Literature included peer-reviewed academic journal articles (35%), including primary empirical research, and grey literature (65%), including observational anecdotal evidence as well as a review of some strategic policy and country strategy documents. Both primary and secondary research studies were considered for this review.

Geographical scope of the literature

The literature reviewed covered a wide range of developing countries from Asia, Africa and Latin America. Figure 4 shows the most widely researched countries. As several country case studies were discussed in some cases the results are not by number of studies, but give a general overview of which countries were discussed most commonly.

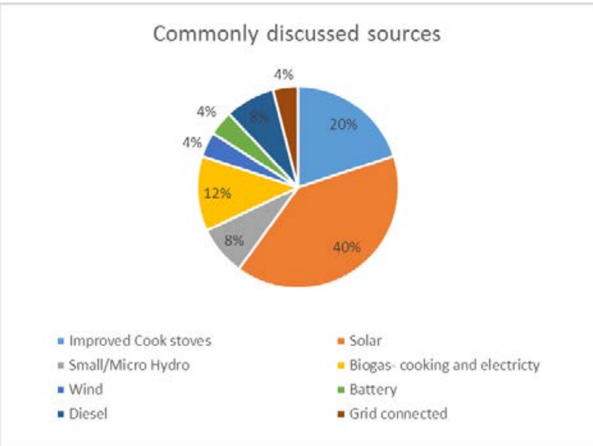
Figure 4 Popularity of countries mentioned in various case studies in the literature



Types of energy sources

The literature covered a range of energy sources, with the most frequent being decentralised small scale renewable energy technologies including solar PV, biogas and micro-hydro. Others considered options for replacing use of biomass (plant and animal materials) in traditional and conventional (more fuel efficient methods) by improved cook stoves (ICS) and modern cooking fuel options such as biogas. Non-renewable sources such as diesel and grid connected systems were only covered by 2 studies. The spread of the different energy sources included in the case studies is presented in the Figure 5.

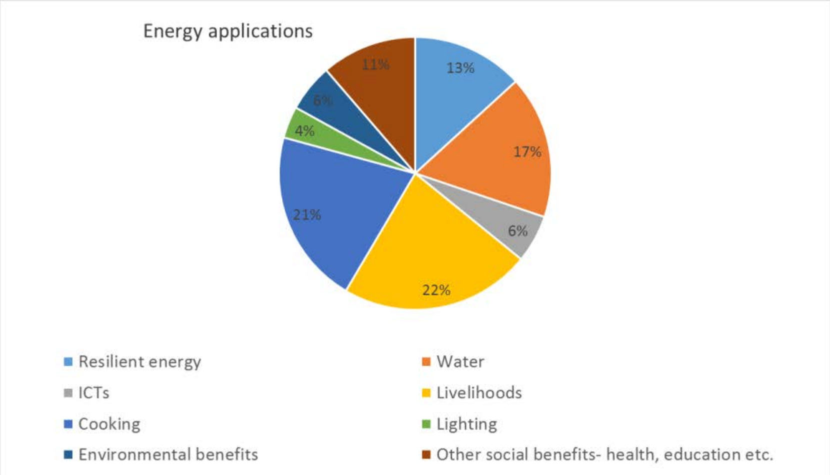
Figure 5 Commonly discussed energy sources



Type of energy application

The literature covered a range of different energy applications, including domestic use for cooking, water and space heating and lighting, technological uses including ICTs (mobile phone charging, radios), livelihoods which particularly included agriculture including food processing and storage. Figure 6 presents how often these applications were discussed within the literature.

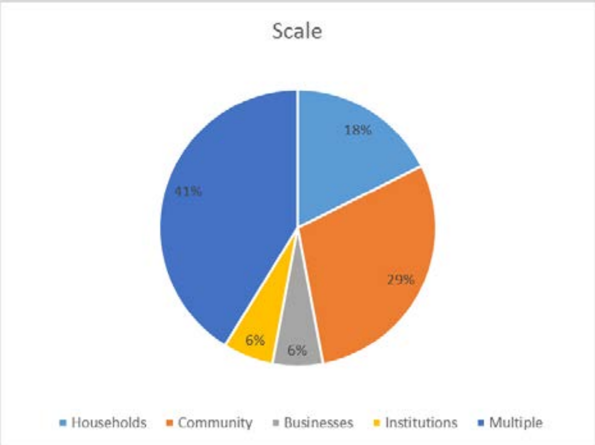
Figure 6 Commonly discussed energy applications



Scale of intervention

The scale of the interventions was not always clearly discussed within the literature. However based on information provided in various case studies the scale could be classified for 17 studies, in which most were focusing on multiple scales.

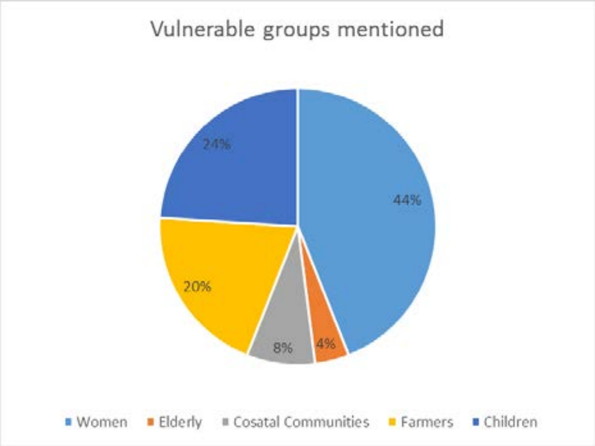
Figure 7 Scale of the interventions commonly discussed



Vulnerable groups highlighted in the literature

Women were the most commonly identified vulnerable group, followed by children. The literature also included studies that particularly focused on coastal communities who were highly vulnerable to disasters. Farmers were mainly considered as they were heavily dependent on natural resources (livestock and agriculture) for their income generation. Although 'urban' was included in the search string used for the literature search (Appendix 1), the literature review did not capture studies that identified conceptual or empirical evidence discussing the linkages between energy accesses in urban areas and how it contributes to building resilience to climate change among urban populations.

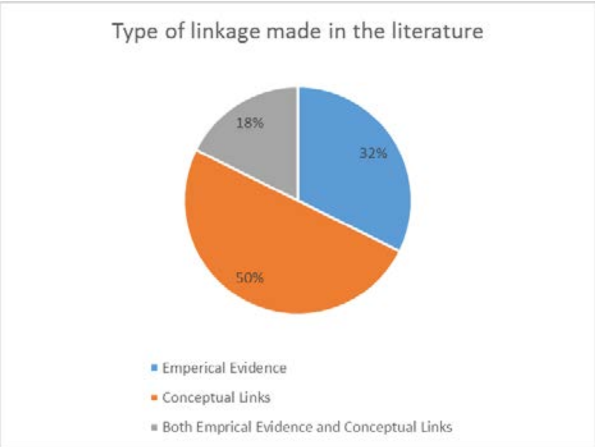
Figure 8 Commonly discussed vulnerable groups



Type of linkages

The studies were categorised based on the type of linkages made between access to energy and the dimensions of resilience: studies with conceptual linkages (without any empirical evidence), studies with empirical evidence and studies that presented both. The majority of the studies (50%) only presented conceptual links.

Figure 9 Type of Linkage made in the literature



4.2 Framing of energy access in the literature

As an initial step this review sought to answer the following question to illustrate what conceptual linkages have been identified in the literature:

How has energy access been framed in the context of adaptation and building resilience to climate change and climate variability?

This literature review identified 34 studies (both peer reviewed studies and grey literature), that link energy access (particularly via decentralised small scale energy solutions) to the 9 dimensions of resilience identified in Section 2 (See Box 2).

Dimensions of Resilience 1-5: Access to services, adaptive capacity, income and food access, social safety nets and livelihood viability (and the cross-cutting 9th dimension Assets)

Most literature identified that access to energy is critical for addressing the various dimensions of resilience and wider social and economic development. Literature on the conceptual linkages between energy access and the above 6 dimensions are often fragmented and at the same time overlapping. Examples of these links between energy access and adaptation and resilience to climate change include enabling communities to receive clean water, sanitation, healthcare, efficient lighting, heating, cooking, mechanical power, transport and telecommunications services, and enabling communities to build dimensions of resilience to climate change. The literature suggests that with affordable access to energy resources and services, communities are able to improve their quality of life, sustain livelihoods, increase income and also reduce pressures on ecosystems, thus improving adaptive capacity. The links that identify energy as a key enabler for enhancing people's livelihoods and wellbeing infers that limited access to energy can considerably limit the ability of communities to cope with the effects of climate change shocks and stressors and wider development pressures (Bogdanski, 2012) (South Centre, 2008).

Christensen et al., (2006) look at the role of decentralised renewable energy technologies and how they can result in various adaptation benefits. The authors seek to illustrate how small-scale renewable energy technologies can contribute to climate change adaptation. In addition, some of the social and economic development benefits (highlighted in Table 4) relate to some of the dimensions of resilience introduced in Box 2. Table 4 presents a list of energy technologies and how they may build adaptation and resilience to climate change.

Table 4 Adaptation benefits from different small-scale decentralised renewable energy technologies (adapted from Christensen et al., 2006, p28 and UNDP, 2013)

Type of energy technology	Application	Adaptation benefits	Social and economic development benefits	Link to resilience dimensions in the Conceptual Framework
Efficient use of biomass: Shells, peanuts, bagasse	Electricity generation Heat	Reduces the likelihood of deforestation and desertification	• Creation of jobs and livelihood opportunities. • Reduced drudgery therefore better quality of life. • Reduction of time spent on fuel collection. • Reduction of incidents related to indoor air pollution and respiratory infections prevalent with biomass	Adaptive capacity Income and food access Assets Natural context Personal circumstances
Wind pumps	Crop Processing Irrigation Water pumping	Greater resilience to climate related stresses through reduced vulnerability to water scarcity. More adaptation choices i.e. through irrigated agriculture and not relying solely on rain-fed agriculture	• Increased access to energy and energy consumption. • Greater prospects for income generation. • Improved quality of life. • Reduced risks of vector borne diseases. • Improved water supply that is beneficial for	Access to services Livelihood viability Income and food access Personal circumstances

Type of energy technology	Application	Adaptation benefits	Social and economic development benefits	Link to resilience dimensions in the Conceptual Framework
			agricultural productivity and livestock rearing. • Improved food security. • Reduced out migratory fluxes • Improved performance and attendance level of school children particularly girls	
Biogas plants	Production of sludge for fertilisers	Adapting to soil erosion, aridity and environmental degradation	• Environmental sustainability • Better prospects of agricultural productivity for greater chances to generate income	Income and food access Natural context
Solar Home Systems	Water heating Cooking Lighting	Illuminated studying and access to ICTs	• Improved quality of life as well as better health and sanitation through streetlights and boiled water	Access to services Personal circumstances
Solar panels, PVs	Lighting Water pumping Water desalination	Building resilience and coping strategies of communities especially during periods of drought, thus reducing vulnerability to water shortages	• Improved access to water Reduced drudgery for women responsible for water collection • Reduced risks of infected water therefore improved sanitation and health	Access to services Personal circumstances
Micro hydro	Lighting Access to information technology, agricultural processing	Improved social resilience	• Improved health (indoor air pollution and other respiratory illnesses) as kerosene lamps are no longer used • Greater school attendance with electrification in schools. • Access to internet facilities with electrification	Personal circumstances

Several studies present these conceptual linkages with a more in depth analysis. A recent study by Murphy and Corbyn (2013, p5) state that ''energy is a crucial feature of a resilient household, community or country, and that development programmes addressing adaptation should consider components relating to increasing and securing energy access services, alongside other vital resources such as water, land, food, shelter and biodiversity''. This study looks at six case studies to explore how energy is important for building climate change adaptation and identifies four main opportunities: improving general physical and economic well-being by providing opportunities for people to have improved health, incomes and knowledge; building resilience through productive use activities and diversification of livelihoods away from vulnerable activities; enabling innovation and adaptation through ICTs; and empowering communities through new income generation.

Stone (2013) provides ideas for how energy systems can contribute to increasing people's resilience to climate change: diversifying livelihoods and increasing income; provision of energy requirements for adaptation interventions; knowledge, information sharing and early warning systems; and indirect adaptation benefits such as sustaining ecological systems. Stone (2013, p22) also identifies the importance of considering the climate proofing of the energy systems being used, ''climate change can be extremely unpredictable, which is why climate proofing of energy systems needs to be addressed by component and energy system manufacturers. The systems themselves must be made more durable to extreme weather, including through water resistance and water proofing of components or development of mobile systems that can be moved or stored in the event of extreme weather''.

Supplying energy can also create new livelihood options and income generation opportunities, such as stove manufacturing, energy crops and supply chain for energy technologies. Practical Action (2012) highlights that ''the supply of energy is today a vital sector of employment for millions of poor people living in the developing world. The production of bioenergy continues to be an important source of income for poor people and often encompasses long and job-intensive rural value chains''. The study further highlights that while access to energy can create livelihood opportunities, it can also affect existing employment sectors such as the currently dominant fuelwood and charcoal markets. Addo et al. (2014) explore how biofuel (Jatropha curcas) can provide an income generation opportunity for poor farmers in northern Ghana where farming is only feasible for smallholder farmers during the rainy season. Addo et al. (2014) conclude that biofuel (Jatropha curcas) can provide an income generation opportunity for poor farmers, based on their findings from models for northern Ghana, where farming is only feasible for smallholder farmers during the rainy season. Addo et al. go on to suggest that peasant farmers who can't compete with the global market can consider energy crops (Jatropha curcas) to grow their incomes, and at a national level, biofuel projects will generate new industries, new technologies, new jobs and new markets. Similarly Ochieng et al. (2015) argue that charcoal production is a livelihood measure particularly for communities living in dry lands and if sustainably managed can increase the adaptive capacity of these communities while also addressing the challenge of energy access at the national level. Earlier research (for example, German et al., 2011; Schoneveld et al., 2011), that was beyond the scope of this literature review, conclude that the livelihoods benefits and income generating potential of biofuels to communities are not so clear cut, suggesting further research is needed, particularly to explore in more depth the links between biofuel production and energy access.

The literature also demonstrated linkages between energy access, food and water with direct links to adaptive capacity and building resilience to climate change. IRENA (2015) and IPCC (2014) find that surface and groundwater resources are projected to deplete due to climate change in most dry subtropical regions and that changing precipitation patterns are already affecting energy generation through hydropower reserves and thermoelectric power plants, agricultural yields and natural replenishment of freshwater reserves. IRENA (2015) and Platonova and Leone (2012) present a range of energy technologies that can bring water security to rural communities, particularly those facing extreme climate hazards such as droughts through water pumping (for irrigation and household use), desalination, purification and water heating. In addition to the integration between water and energy systems in the literature, several studies presented conceptual linkages relating to how adaptation benefits can be achieved from integrating food and energy systems, in particular how energy can provide access to technologies for irrigation and agro processing. For instance Bogdanski (2012, p2) highlights ''considering this important role of energy in food production and consumption, energy is a crucial prerequisite for resilient livelihoods, strongly contributing to the adaptive capacity of rural communities in light of climate change''. Bogdanski (2012, p2) highlights that integration of food and energy production can give smallholder farmers the opportunity to diversify farming systems and energy options that can ''substitute for costly, external inputs, saving on household expenditures – or even lead to the selling of some of the products, providing the farmer with extra income, leading to increased adaptive capacity''. Evidence in Section 4.2 under 'Access to water' provides examples where energy access support water for irrigation and under 'Natural context' on how biogas bi product can be used as a soil fertiliser.

Several studies look particularly at decentralised energy systems and the direct linkages between access to energy and adaptation (Platonova and Leone (2012), Christensen et al. (2006), Kumar (2011), South Centre (2008), Akkerman et al. (2014), Kumar (2011), Institute of Engineering (2013), Climate Change Knowledge Network (CCKN) and International Institute for Sustainable Development (IISD) (2004)). Platonova and Leone (2012) and Akkerman et al. (2014) highlight that in regions where natural disasters such as flooding lead to frequent power grid failures and where changing rainfall patterns and droughts impact the power generation of hydropower plants, decentralised energy systems may be more suitable options as they can be designed to be more resilient to local climate conditions and disasters. Akkerman et al. (2014) also highlight that impacts on energy systems from disasters cause problems not only for livelihoods but also other economic impacts such as the disruption of business, decreased income due to loss of work or higher production costs and increased expenses for alternative fuels. Impacts on livelihoods and income sources increase peoples' vulnerability to climate change impacts and reduce their adaptive capacity. Akkerman et al. (2014) show that the coastal city of Quy Nhon, Vietnam, despite being connected to an electricity grid, constantly faces disruptions of supply which are also exacerbated during times of water stress and natural disasters. Akkerman et al. (2014) suggest that disaster resilient energy supplies particularly off-grid renewable energy can help these communities reduce impacts on their working conditions and better adapt to climate change and climate variability. Thus other dimensions or resilience such as livelihood viability are also being addressed. Similarly Platonova and Leone (2012, p4) state, ''a decentralised energy production network is more resilient to local nodes/links failures due to a climate change dramatic event. There are indications that the water cycle involved in local energy production is likely to be less disrupted''. However there is no empirical evidence presented in the 34 studies reviewed to strengthen this argument.

Several studies also identify the importance of energy access in building resilience within the energy sector, ''renewable energy systems offer diversification, low carbon energy in energy supply, thus strengthening energy security and adaptive capacity of climate change by broadening national or regional energy generation portfolios'' (Fang and Wei, 2012, p2). Murphy and Corbyn (2013, p18) suggest that to build energy resilience it is necessary to invest in technological preparedness (renewables, efficiency, management) and expand the available energy options for communities by diversifying energy supply sources. They also note that ''decentralised energy systems can decrease vulnerability by both reducing the need for extensive transmission and distribution lines, and allow for local energy generation according to the best resource available; however their capital cost per installed Watt may be considerably higher than that of more conventional, larger-scale power generation''. In countries like Nigeria where 80% of households are dependent on wood for cooking and heating the transition to modern energy services such as improved cooking stoves, LPG and biogas is essential to build resilient livelihoods and reduce vulnerability (Eleri, 2007). Similarly Jarvie and Nicholson (2013) highlights that poor communities with very limited capacity to adapt to climate risks and recover from disasters can benefit through the introduction of disaster resilient renewable energy technologies.

While Christensen et al., (2006) cover most of the adaptation benefits, more recent studies suggest additional benefits, such as Murphy and Corbyn (2013), Giri and Malakar (2011), Cabana (2012) and Gippner et al. (2013) on evidence illustrating how energy access works as an enabler for knowledge and information sharing and early warning systems**.** These are presented under 'Access to information' and 'Social safety nets' in Section 4.3. Murphy and Corbyn (2013, p10) highlight that ''whilst communities rely on the established pathways of communication with a range of actors, meteorological information and potential solutions will typically be outside their regular network of interactions. The advances in communication technologies have considerably broadened the scope and increased the speed of communications in ways that can help deal with climate change impacts''. Murphy and Corbyn (2013, p.20) also illustrate how information can be used to deal with future climate uncertainty.

Table 5 Use of information to deal with future uncertainty (adapted from Murphy and Corbyn, 2013 and Pasteur 2011)

Information about trends and impacts	Information about adaptation options
Climate science, long range climate predictions and short range forecasts Implications of policy trends, for example what would the privatisation of intellectual property mean for farming communities Implication of processes such as desertification for crop production	Access to, and management of, traditional and new seed varieties Skills in management of emerging livestock pests and diseases Improved soil and water conservation strategies to help cope with drought Skills to pursue entirely new, possibly non-farm, livelihood options

Dimension of resilience 6: Natural context

The Food and Agriculture Organization (FAO) identifies that forests can play a crucial role in mitigating the impacts of disasters such as floods, landslides and storm surges. FAO specifies the benefits as being (FAO, n.d.):

- Floods: that forests restoring damaged forest ecosystems or re-establishing forest cover where it has been cleared will increase protection against future floods;
- Landslides: re-establishing or increasing forest cover on steep lands that have been affected by landslides will reduce the risk of future landslides;
- Storm surges: coastal forests (mangroves and other coastal forests) can help protect coastal inhabitants, infrastructure and productive land against storm surges.

The United Nations Development Programme (UNDP) (2014) highlight that the unsustainable use of forests is already causing deforestation in many developing countries. UNDP (2014) state that ''billions of individuals rely on biomass for cooking and heating, about 2 million tons of it is combusted every day. Where wood is scarce, or populations are dense, the growth of new trees is not enough to match demand for fuel, resulting in deforestation, desertification, and land degradation''. Thus the natural safety nets that exist for communities to reduce exposure and sensitivity to climate stresses and shocks such as floods, landslides and storm surges are also being degraded. Christensen et al. (2006) highlight that the efficient use of biomass can reduce the likelihood of deforestation. Alternative technologies such as biogas stoves, ICS and electricity that can replace conventional cooking and heating technologies can play a crucial role in reducing fuel wood consumption.

Dimension of resilience 7: Personal circumstance

Almost all of the literature reviewed provides some conceptual linkages for building resilience among vulnerable groups, particularly women and children.

Gupta and Velumeil (2007) highlight that access to sustainable energy leads to development of communities by: ''diversifying income opportunities, reducing dependence on climate sensitive resources, proliferation of micro enterprises, social welfare, poverty reduction and overall growth and development''. They further highlight that communities who are heavily dependent on natural resources may be forced to sell off their assets and migrate to informal settings in urban areas during periods of climatic stress. CCKN and IISD (2014), Gippner et al. (2013) and Wilcox et al. (2015) provides evidence related to reduced migration in Section 4.3.

Gippner et al. (2013) and Murphy and Corbyn (2013) present case studies where energy access has brought opportunities for empowering women thus providing the opportunity to build their adaptive capacity and knowledge on responding to climate impacts and disasters.

Gender specific benefits of access to energy are also highlighted in Table 6 below.

Table 6 Benefits of modern energy services for women (adapted from UNDP, 2013)

Energy Source	Practical Benefits	Productive Benefits	Strategic Benefits	Link to resilience dimensions in the Conceptual Framework
Electricity	Pumping water, reducing the need to haul and carry mills for grinding, improved conditions at home through lighting	Increased possibility of activities during evening hours, refrigeration for food production and sale, power for specialized enterprises and small businesses	Safer streets, participation in evening classes, access to radio, television, and the Internet	Access to services Adaptive capacity Personal circumstances Assets
Biomass (ICS)	Improved health, less time and effort gathering fuelwood, more time for childcare	More time for productive activities, lower cost of space and process heating	Improved management of natural forests	Natural context Personal circumstances
Mechanical	Milling and grinding, transport and portering of water and crops	Increased variety of enterprises	Access to commercial, social, and political opportunities	Adaptive capacity Income access

The conceptual linkages discussed above suggest that energy access can help communities reduce their vulnerability to climate change and climate variability, whilst also diversifying livelihoods and increasing their resilience to the effects of climate change. Thus social and economic benefits of energy access for women can improve factors that contribute to building resilience to climate change, diversified livelihoods in particular look at building adaptive capacity of individuals and communities.

Dimension of Resilience 8: Institutional and governance context

The potential synergies between development, adaptation and mitigation have emerged over the last few years, particularly with respect to developing national level polices in developing countries. A range of different terminology such as climate compatible development, green growth, low emission development strategies, and low carbon climate resilient development have been adopted by various organisations and governments to combine these policy ideas, with the assumption that there is potential to leverage 'triple wins' or 'co-benefits' in a more cost effective way (Fisher, 2013). However the theoretical basis and empirical evidence to understand the potential co-benefits and the trade-offs involved are very limited (Tompkins et al., 2013).

For many developing countries the primary approach to adapting to climate change is to strengthen the nation's economy and to increase the resilience of society. This means proactively reducing the vulnerability of individuals and communities to the impacts of climate change by:

- Decreasing poverty and inequality
- Creating employment
- Increasing levels of education and promoting skills development
- Improving health care
- Maintaining the integrity of ecosystems and the many services that they provide.

(National Planning Commission South Africa, 2012)

Adaptation can therefore be closely linked to development. While energy is a key enabler to achieve these goals, it is also recognised that increasing energy demand (through conventional methods) will have an impact on the level of greenhouse gas emissions being emitted.

The evidence on where these linkages have been highlighted in the literature is highlighted in Section 4.3.

4.3 Does energy access build resilience and does it contribute to maladaptation?

In order to gather evidence the literature review sought to answer the following question:

What does the literature say in terms of evidence that energy access builds resilience and contributes to adaptation to climate change? Is there evidence that it contributes to maladaptation?

This section provides some of the experimental and observational empirical evidence that was identified during this review. Using the framework presented in Section 2 (see Figure 2), this section seeks to understand what evidence there is to suggest that energy access actually leads to resilience (Element 4: Reaction to disturbance) and whether some of these changes are maladaptive, i.e. people don't recover, adapt, or transform but they are actually worse off. The emphasis of this literature review was to track the complete chain of evidence (see Figure 2) from access to energy to building dimensions of resilience to Element 3 'Building capacity to deal with disturbance' and on to Element 4 'Reaction to disturbance'.

Considering the availability of this complete chain of evidence we used in the conceptual framework of this literature review, the evidence can be categorised as below:

1. Complete evidence chain (Access to energy all the way to Element 4): Evidence showing how communities, groups and institutions that have access to energy increased resilience to climate variability and change.
2. Partial evidence chain that could be reliably inferred backwards to complete the evidence chain (Dimensions of Resilience to Element 4): Evidence showing how certain energy services (such as ICTs) have had an impact on building resilience to climate variability and change.
3. Evidence chain stopped short of making the link to adaptation and building climate resilience and could not be reliably inferred forwards (Access to energy to Dimensions of resilience): Evidence showing how energy access has contributed to dimensions of resilience without necessarily making a link to climate variability and/or climate change.

It is important to note that this literature review focuses primarily on the evidence related to categories 1 and 2 above as the link between energy access and climate change adaptation were evident in the literature more clearly. An inferred link has been attempted in the evidence related to category 3 using the Conceptual Framework presented in Section 2 of this literature review.

While most authors agree that energy is an asset that enables adaptation and builds resilience to climate change, there is very little empirical evidence in the literature that clearly demonstrates the complete link between energy access building adaptation and resilience to climate change and climate variability. The studies that demonstrated empirical evidence of complete links include IRENA (2015), AdaptCap (2014), Rural Development Planning Tanzania (2014), (Platonova and Leone, 2012) Gippner et al. (2013), Jarvie and Nicholsan (2013) and CCKN and IISD (2014), and are discussed in more detail in the following sub-sections.

The evidence has been categorised under the dimensions presented in the Conceptual Framework (see Table 1 and Figure 2). These include:

1. Access to services
2. Adaptive Capacity (particularly new livelihood strategies)
3. Income and food access
4. Social safety nets
5. Livelihood viability
6. Natural context
7. Personal circumstances (including vulnerable groups)
8. Institutional and governance contexts

Evidence relating to the 9th dimension of resilience ('assets') is not presented separately in this section as it overlaps heavily with other dimensions (particularly dimensions 2 and 3 in the above list) and is presented under the other headings where relevant.

Access to energy can contribute to multiple dimensions of resilience. The case studies presented in the following sub-sections identify the multiple dimensions access to energy contributes to where possible. To reduce duplication these are placed under the dimension of resilience that best fits. Furthermore evidence where energy access interventions have contributed to maladaptation are also captured within this section.

Resilience Dimension 1: Access to services

Various technologies such as water supply and purification systems, and information and communication systems adopted for community needs can increase adaptation and resilience through economic, social and environmental benefits. Most technologies require a reliable source of energy to function. Several documents reviewed provide some interesting evidence from projects where energy access have provided communities with access to technologies that support adaptation and building resilience to climate change. However most of these reported projects have not been evaluated for their outcomes, thus limiting the ability to understand success and failure factors that can support scaling up. This is a limitation of the research available.

Access to water

With respect to energy supporting to access to water services specifically, IRENA (2015) presents how communities in Africa's Sahel region benefit from energy technologies to tap into ground water resources. Due to the widespread lack of energy access in the region it is estimated that around 68 million people have to find ways to transport water from as far as 10 kilometres every day. With the water tables at most 100 metres down (330 feet), without energy people cannot tap into those groundwater resources and face great difficulty coping with prolonged drought conditions. The Permanent Interstate Committee for Drought Control launched the Regional Solar Programme (RSP) in the Sahel in 1986 deploying 995 solar pumping stations and 649 community systems, providing improved access to water and electricity to 2 million people. IRENA (2015, p57) highlight that ‘’By the end of the second phase in 2009, the population without access to safe drinking water had dropped by 16% in the Sahel countries of West Africa’’.

Desalination technologies are also expected to play an increasing role providing access to clean water in many countries, particularly among coastal communities. In the Middle East and North Africa region the shortage of water is expected to be met using desalination by 2050 (IRENA, 2015). Increasing salination of groundwater aquifers and the resulting scarcity of fresh water sources leads to lack of drinking water for many poor communities living in coastal areas (AdaptCap, 2014). Strengthening Adaptation Capacities and Minimizing Risks of Vulnerable Coastal Communities in India project (AdaptCap) highlights that in Vengamukka Palem, India, these impacts are exacerbated by the changing rainfall patterns that are putting additional pressure on scarce water resources. The project presents an adaptation pilot project where solar power is used to provide a reliable and safe water supply to poor communities in Vengamukka Palem, India. The project illustrates that due to the lack of stable grid power supply there is insufficient desalination capacities in the existing local reverse osmosis plant, which is one of the few sources of drinking water in the community. It is reported that across the region the grid power is cut 6-8 hours every day, usually in the middle of the day affecting almost 1000 residents with a lack of water. The pilot project upgraded the existing desalination plant with photovoltaic panels ensuring continuous supply of energy thus providing a supply of clean drinking water without any interruptions in case of power blackouts in the local grid AdaptCap (2014).

The Adaptcap (2014) monitoring and evaluation report also presents an adaptation pilot project providing drinking water filtration and distribution system using solar pumps which makes a community’s water supply safe and reliable in the village of Dasaraju Palli, India. It is noted that piped water for Desaraju Palli comes irregularly (community estimates once every three days in the dry months) and is bacteriologically contaminated. Due to water scarcity over the past two years the villagers have begun to purchase water cans. In the dry months, villagers are forced to drink untreated and highly contaminated well water supplied from the canal-filled pond reservoir, resulting in water borne diseases in the community. The solar energy system ensures that the community can now access clean water for drinking and cooking needs, for all the villagers on a daily basis. The project in particular expects to reduce the rate of water borne diseases thus reducing the costs to villagers for medication and purchasing water. These ancillary benefits such as improved health and financial savings of gaining access to water services show potential contributions to other dimensions of resilience such as improved personal circumstances and increased savings.

Similarly the Institute of Rural Development Planning Tanzania (2014) presents a case from a climate change project called the Chololo Ecovillage in Dodoma region of central Tanzania. The project identified several key issues by carrying out discussions with residents and members of the village committee, triangulated by secondary research, climate change vulnerability reports and rainfall data. These include drought, deforestation, flooding and strong winds, human diseases (skin diseases, cholera and diarrhoea), livestock diseases and crop pests (Rift Valley Fever, army worm, calidea bugs, stink bugs etc.) and inadequate ground water recharge. Lack of ground water in particular has resulted in the lowering of the water table and increased salinity, leading to a shortage of drinking water for domestic use and livestock and crop production. The traditional dependency on rain-fed agriculture, use of poor farming technologies, unsustainable use of natural resources, lack of enforcement of natural resource by-laws, limited awareness of climate change issues and unsustainable coping strategies exacerbated the impacts on the community. Given these issues the Chololo Eco Village project was developed to work with the community to identify, introduce, test, evaluate and take up a holistic range of integrated innovations for agriculture, livestock, water, energy, and forestry to build a resilient community. In addressing the energy needs a solar powered village water supply, energy saving stoves and domestic biogas were installed in the village. The existing village water supply was a 40- year-old borehole pump and diesel engine which had broken down. Most often women and children walk 2 kms to the next village to fill their buckets and carry them home on their heads. In addition replacing the existing diesel powered system was calculated to cost the village Tanzanian Shillings (TZS) 560,000 (280 Euro) per month. The Chololo ecovillage project installed the solar powered electric pump, which can pump water to a 23,000 litre water tank allowing villagers access to water from six water distribution points. The solar water pump can pump around 40,000 litres supplying 6 hours of clean water daily. The system has reduced the amount of time villagers spent on water collection while providing a constant and reliable water supply. The price of water has been halved from 50 TZS to 25 TZS per bucket, enabling the poorer village community members to also access clean water. This low cost supply also allowed the village committee to provide water free to the more vulnerable communities such as the elderly. The money collected from the village committee is being used to support funding a survey to identify another borehole, and for repair and extension of the current piped water system**.** This change to modify existing practices and the opportunity to identify methods to respond to potential longer-term changes can also build the adaptive capacity of the community to cope and recover from future stresses and shocks. Thus there is evidence that it addresses other dimensions of resilience such as improved personal circumstances particularly of vulnerable groups and increased financial savings (assets).

In 2010 the International Development Research Centre (IDRC) launched a project called Clean Energy and Water: An Assessment of Services for Local Adaptation to Climate Change. The aim of the project was to assess the drivers and barriers to the use of decentralised renewable energy technologies for providing access ton water services to help communities better adapt to climate variability and climate change. Case studies presented secondary qualitative data from Argentina, Mexico, East Africa and Southern Africa. Table 7 illustrates the energy supplies and technologies used, and how they contributed to addressing water issues. These case studies highlight specific situations where various elements such as ‘’financial, political, local population capacity or expertise’’ of renewable energy technologies had allowed successful outcomes.

Table 7 Energy technologies used in each country (adapted from Platonova and Leone, 2012)

Country	Case study	Key findings	Link to resilience dimensions in the Conceptual Framework
Argentina	Photovoltaic (PV) pumping from deep wells in Catamarca Pumping with low power wind turbines in Neuquen Grid connected high-power turbines for irrigation in La Rioja	• The dry regions in the studies are particularly vulnerable to the climate variability, which will exacerbate existing water availability problems. • Renewable energy-based water pumping systems can be a cheaper and more reliable alternative to conventional systems.	• Access to services • Personal circumstances
Mexico	Solar water heating in Mexico City Solar-powered desalination in Sonora and Baja California	• Combining renewable energy and water systems can be used in both urban and rural environments for increasing water supply resilience.	• Access to services • Personal circumstances
Kenya/ Tanzania	Treadle pumps Wind pumps Ramp pumps	• Renewable energy technologies can play an important role in addressing challenges for water services in the region. Used for irrigation these technologies can be useful in improving food security among the poor. • Compared to other water pumping renewable energy technologies, treadle pumps are most disseminated. This is mostly because of the low cost of treadle pumps, where low income users can purchase the systems from savings or retirement benefits. However, the lifetime use of the treadle pumps is six years, while ram pumps – 40 years and wind pumps - 20 years.	• Access to services • Income and food access
Namibia	Off-grid solar systems for groundwater extraction Solar water heaters and solar water pumping Solar diesel hybrid energy supply system in Gobabeb and Tsumkwe	• The region faces critical resource constraint in water and energy. • Renewable energy technologies for water	• Access to services • Natural context

Country	Case study	Key findings	Link to resilience dimensions in the Conceptual Framework
Botswana	Solar energy for ground water extraction in Ngamiland	services can address these constraints in the most vulnerable areas.	• Access to services
Mozambique	Solar water pumps in Nampula and Zambezia Solar water pumps in Maputo and Guro		• Access to services

CCKN and IISD (2014) also present an example from Zimbabwe where wind powered systems are being used to access water in a community that faces problems due to lack of clean water. The study highlights that Zimbabwe is ‘’ increasingly a water stressed and deforested country with deforestation exacerbating water resource stresses that may worsen with climate change’’ *(Ibid,* p11). Small scale wind power systems are used to provide energy for water pumping in otherwise energy deprived areas.

Access to reliable, affordable and resilient energy services

Mercy Corps conducted 11 energy poverty surveys in six countries (Haiti, Uganda, Myanmar, Indonesia, Timor Leste and Somalia). The results of these surveys are presented by Jarvie and Nicholsan (2013) showing that the energy programmes put in place have shown positive climate resilience outcomes. For instance they highlight ‘’in countries like Haiti, slum dwellers can spend as much as 40% of their weekly income on energy. Lowering these costs through the introduction of renewable or energy efficient technologies can result in substantial household savings as well as opportunities for income generation and education’’ (*Ibid*, p19*)*. However the study does not present quantitative data on these savings or qualitative evidence on what these savings are used for. This case study is also relevant to the resilience dimension 3 (income).

Table 8 shows extracts from “Outcomes of Mercy Corps’ Energy Programmes presented by Jarvie and Nicholsan (2013) highlighting the multiple dimensions of resilience that are being addressed.

Table 8 Energy programmes and climate resilient outcomes (adapted from Jarvie and Nicholson, 2013)

Country	Problem	Energy intervention	Climate resilient outcomes (found via surveys)	Link to resilience dimensions in the Conceptual Framework
Haiti	Over 80% of Haiti's population relies on wood or charcoal (or a combination of both) for cooking fuel. The toll on Haiti's forests has been devastating, with an estimated 2% of natural forest remaining.	Raising the efficiency of charcoal / wood kilns from 10% to 35%. Creating two stove production centres that will manufacture fuel-efficient stoves that have been tested for optimal performance and cultural acceptance among local target groups. Planting 268,000 trees. Promoting alternative livelihoods for charcoal producers.	Promoting protection of agricultural landscapes contributing to food security; reducing household expenditure on fuel by > 40%.	• Access to services • Adaptive capacity • Income and food access • Assets • Natural Context
Uganda	98% of households in the Acholi region of Uganda rely on wood or charcoal for cooking, causing a rapid depletion of forest resources. An estimated 40% of household income is spent on cooking and lighting fuel.	Development of supply chains for solar products and Ugandan made fuel-efficient stoves, following a successful Mercy Corps pilot project demonstrating demand. Work with local distributors and community groups to provide education on benefits and ensure products match needs. Support for enabling environment including financial services, marketing and awareness building, and business services.	Reducing demand for wood, reducing pressure on household resources, and increasing livelihoods and entrepreneurial opportunity.	• Access to services • Adaptive capacity • Income and food access • Natural context • Social safety nets
Myanmar	100% of households in the Delta region rely on firewood, largely from mangroves for cooking fuel. Cyclone Nargis in 2008 destroyed	Development of a local fuel-efficient stove industry through creation of stove production hubs. Planting of 100,000 trees.	Increased capacity of community based organisations to react to challenges and manage and coordinate programmes. 8,000 locally made fuel-efficient stoves	• Access to services • Adaptive capacity • Income and food access • Natural context

Country	Problem	Energy intervention	Climate resilient outcomes (found via surveys)	Link to resilience dimensions in the Conceptual Framework
	large areas of mangroves, further increasing pressure on an ecosystem vital to the local economy and food security.		sold to vulnerable households, reducing fuel use by 40%.	

While it is highlighted under the conceptual findings in Section 4.2 that access to decentralised energy solutions can be more resilient in disasters, only one case provided evidence that was relevant. Symons (2013, p13) presents one case in her study on using household bioethanol to cope with flooding in Nyallenda, Kenya: ''The participants reported that since the stoves are highly portable, they can simply be moved when areas become too waterlogged for traditional cooking methods. In addition, the bioethanol is stored in bottles which are not affected by water, as opposed to charcoal, wood or gathered debris which can become too wet to burn'' . This also addresses the resilience dimension 3 that relates to access to food.

Access to early warning systems

Murphy and Corbyn (2013) present several cases where energy projects have successfully disseminated ICTs. These include solar lamps and radios that provide households with the ability to charge and use mobile phones in addition to a radio and a light; hydro powered community focused radio stations which can broadcast valuable information to farmers and other community members; and early warning systems. A case study shows how early warning systems have been disseminated with an improved and reliable connectivity through solar PV in Nepal. The extended hours of load shedding and unreliability of power supply in Nepal sometimes hinders the communication from upstream gauge station to downstream community, and then within communities. As a result the Department of Hydrology and Meteorology (DHM) introduced a project with solar PV systems with back up batteries at upstream gauge stations to ensure an uninterrupted power supply. Practical Action worked jointly with the DHM and distributed hand operated sirens and megaphones to disseminate information within the vulnerable communities. While the aim of the project is to ensure that the communities can plan for and cope with future stresses and shocks, there is no empirical evidence given in the study to confirm how the communities reacted to disturbances.

Access to information

Access to knowledge and information via ICTs has helped communities access social safety nets. Giri and Malakar (2011) presents a case study which uses mobile phones to reduce the adversities of climate change in rural Nepal. The project provides the farmers with phone contacts which they can use to get advice on ''treating crops and livestock, general advice on seed varieties, planting times and methods with the aim of raising incomes and thus reducing vulnerabilities'' (*ibid,* p1). It also gives them the opportunity to contact agricultural traders so that they are better informed about reasonable market price levels for their outputs. The project also provided a list of phone contacts in both upstream and downstream communities: ''When there is continuous heavy rain, those in the upstream areas phone and warn those in the downstream communities, who are then able to prepare and evacuate livestock, property, family, etc. They also warn about landslides that may block planned transport routes'' (*Ibid,* p2).

A similar case study is presented by Cabana (2012) on the contribution that battery operated radios can have on sustainable mountain livelihoods in the Peruvian Andes, where the livelihoods are affected by climate variability. The radio broadcasting helped communities improve their livestock practices and gain better access to markets. This case study also highlighted that the cost of batteries is a constraint to the uptake of the radio. Cases presented by Gippner et al. (2013) and Murphy and Corbyn (2013) show that decentralised small scale energy solutions have been successful in providing access to ICTs. Gippner et al. (2013) in his study shows how significant reductions (3.5 battery pairs per month in 1996 to 2.2 battery pairs per month in 2005) can be seen in battery usage when the community was connected to the micro hydro scheme also resulting in significant cost savings.

These studies also illustrate that ICTs can contribute to building livelihood viability.

Resilience Dimension 2: Adaptive capacity

The conceptual linkages found in this study highlight that social and economic benefits of energy access can improve adaptive capacity. While the social and economic benefits are captured throughout the evidence presented, this section on adaptive capacity will particularly focus on ''factors that specifically enable people to anticipate, plan for and respond to longer-term changes, (for example by modifying or changing current practices and investing in new livelihood strategies), that are not represented by the other dimensions'' (Brooks et al., 2014).

The CCKN and IISD (2014) uses several case studies to highlight how energy access may address the various dimensions of resilience and in particular building adaptive capacity. The study notes that "decentralised renewable energy is not always a direct climate adaptation strategy, but the livelihood and social opportunities that electrification allows are extremely important in building adaptive capacity''. In addressing this, a case study highlights how energy access through diesel, solar and hydro generation systems brought lasting social and economic benefits to people in an isolated settlement in the province of Jujury in Argentina. These communities as a result of being heavily reliant on impoverished natural resources had become vulnerable to the intensified ecological stresses from climate change, such as increasingly frequent floods and droughts. The project provided electricity to individual households, schools, health centres, community centres and community street lighting. The study states that the project went beyond ''a merely sectoral and technical intervention program and included community development programs to create livelihood and cultural opportunities that complemented electrification. In doing so, the project increased the people's adaptive capacity to cope with social, economic and environmental stress including, but not limited to, climate change'' (*Ibid,* p40*).* However specific empirical evidence on how improved livelihoods and social circumstances led to building resilience to climate change (for instance, a comparative analysis of before and after shocks) to climate change have not been presented in the study. Project findings also highlight that with the use of an effective subsidy scheme there has been significant economic benefits to the community, ''although the full electrification cost is about $25 per household per month, people pay only $3 per month. Compared to pre-electrification costs ($9 to $21), this is a significant benefit'' (*Ibid*, p40). The study does not provide concrete suggestions for what this means to the sustainability of the scheme in the long-run.

A second case study by CCKN and IISD (2014) shows how rural solar electrification projects in Senegal have brought adaptation benefits to the communities to cope with the adverse effects of climate change and climate variability. These impacts are particularly faced by the agriculture sector where the majority of agricultural activities are heavily dependent on the exploitation of underground water supplies. Water supplies are heavily threatened by the reduced precipitation levels (recorded over the last few decades), which is having severe impacts on their livelihoods. One case study on a solar electrification project that implemented Solar Home Systems highlights several socio-economic and socio-ecological impacts that have contributed to improving living standards of the communities. The resulting impacts of the programme include:

- In a community where cattle-rearing is the main livelihood, improvement of water supply, following the introduction of the solar pumps, has helped them address the watering requirements of the Cattle herds. This has reduced the migration of farmers in search of water. Cattle dung is therefore available in greater quantities for use as fertilizer in agriculture. (This also addresses resilience dimensions related to access to services and natural context)
- The migration of youth has reduced with the improvements in agriculture productivity (also addresses resilience dimension related to improving personal circumstances)
- With access to electricity new markets and livelihoods have been created, these include tailoring, hairdressing, furniture making, welding, new restaurants etc.
- Increased efficiency of health centres and access to vaccine refrigeration facilities (also addresses resilience dimension related to improving personal circumstances)
- Greater access to information and knowledge, through the information media (television, radio, etc.) (also addresses resilience dimension related to improving personal circumstances, access to services and social safety nets)
- Refrigeration and preservation options for food (also addresses resilience dimension related to assets)
- Safer environments
- Electrification of homes has enabled students to study for longer periods. This has improved the quality of education (also addresses resilience dimension related to improving personal circumstances)
- Reduced dependence on firewood (also addresses resilience dimension related to natural context)

Gippner et al. (2013) explore the climate change adaptation benefits of micro hydro plants being promoted under the Renewable Energy Development Project (REDP) in Nepal. The study presents four key climate vulnerabilities that can be addressed through the project: i) changing climate patterns that impact agricultural productivity, which is a key livelihood for most poor communities in Nepal; ii) power deficit due to impact on large-scale hydro power generation capacity by unpredictable water flows; iii) impact on public health due to temperature rise and respiratory diseases due to open indoor fires; and iv) increased impact on women as they work more in climate sensitive sectors. The authors conducted a survey of REDP project sites which revealed how the micro hydro units have improved community income generation and employment, equalised gender roles, enhanced access to education and information, and reduced migration patterns. The projects have provided sufficient electricity to allow households to run several light bulbs, radio or TV, fulfil agro-processing needs, both manual and electric. New livelihoods have been created locally: "some have set up carpentry and tailor workshops, for instance using electric sewing machines. Restaurants and teahouses are now able to afford refrigerators mainly for cold drinks and to preserve food'' (*Ibid*, p8). In one of the villages the micro hydro scheme has also improved irrigation channels that were created when building the plant. Gippner et al. (2013) summarised findings on adaptation benefits with respect to the vulnerabilities identified and are shown in Table 9.

Table 9 Main climate change vulnerabilities addressed by micro-hydro electrification (adapted from Gippner et al., 2013, p17)

Vulnerabilities	Adaptation benefits of micro hydro	Link to resilience dimensions in the Conceptual Framework
Agricultural and food security	Avenues for income generation such as agricultural processing, shops, carpenters, and tailors, as well as long-term effects through schooling and information, as well as changed migratory patterns	• Adaptive capacity • Income and food access • Personal circumstances
Water resources and energy	Power supply independent of the national grid, attached irrigation systems, education and training in efficient water usage. In addition, replacement of expensive fossil fuels	• Access to services • Personal circumstances
Public health	More access to health services through information and income generation, and reduction of indoor pollution	• Personal circumstances • Income and food access
Gender	Women empowerment through community organization, women education, and affirmative action	• Personal circumstances

A recent study by Willcox et al. (2015) presents findings by considering whether improving the level of energy access has an impact on enterprise creation and new productive activities. The synthesis of findings by Willcox et al. (2015) show that their own literature review findings and in-country research findings differ. Their literature review findings support the view that access to electricity enables enterprise creation, while the findings from in-country research highlighted ''research in India appeared to support this finding, with three times as many enterprises being created in those communities which had benefitted from improved electricity access. (Only half of the new enterprises in the beneficiary communities were themselves receivers of improved electricity access suggesting that any relationship may be indirect rather than direct.) In Kenya, however, no difference in the level of enterprise creation between beneficiary and non-beneficiary communities was apparent'' (*Ibid*, 90). Thus the study highlights that there is no apparent pattern that can be derived to see whether electricity access had an impact on enterprise creation.

The case studies discussed above address factors that can enable people to anticipate, plan for and respond to longer-term changes through improved income and personal circumstances and diversified livelihoods. Thus building their adaptive capacity to climate related shocks and stresses. However it is important to note that the link to adaptive capacity has been inferred in this literature review based on the potential outcomes highlighted in the projects. The studies discussed above do not highlight to what extent the people involved in the project have actually adapted to climate change.

Resilience Dimension 3: Income and food access

Gippner et al. (2013) highlight that communities were able to cultivate more land and have additional crops during the dry season as a result of an improved irrigation channel built with the micro hydro schemes. They also highlighted reduced drudgery and conflicts with access to a reliable energy supply, for example one respondent reported that ''During the Monsoon months, the river swells such that the trip and crossing the bridge becomes more difficult. I had to walk 2 days each time to husk paddy. Our villages also fought perpetually over irrigation and water rights. Now we share. Now I can spend more time on the field and with my family and milling takes away only 1 h of my day'' (*Ibid,* p8). Increased livelihood options and better income generation activities has also had an impact on community resilience and migration. The community surveys confirmed that gaining access to electricity has made communities more attractive to reside in and the number of young people moving to Kathmandu and other cities in the search of work has reduced, “the average income had increased by a factor of twenty after the construction of the plant. Farmers now have excess produce to sell in nearby Dhulikel and to Kathmandu. Village sizes in two of our three visited locations actually increased after the construction of a micro hydro plant. Mahadevsthan’s community grew by 35 households to 300 households, in Lukla 90 new households moved in the plant’s vicinity, raising the overall number of households to 193’’ (*Ibid*, p15).

Willcox et al. (2015) finds that improved access to electricity for productive use has actually increased enterprise revenue and profit. The research findings from both Kenya and India highlight that ‘’ beneficiary enterprise average profits are 20 – 25% higher than those of non-beneficiary enterprises, but there is no consistent pattern in the increases in profits since programme implementation between those enterprises who had received electricity access and those who had not’’ (*Ibid,* p92*)*. However their field research did not show a clear and consistent set of impacts among all communities and there were only loose positive relationships between increased access to electricity and increased revenue and profits of enterprises that benefited by improved access.

Willcox et al. also provides an analysis on how various energy access programmes may have had an impact on household income. They highlight that out of the eight programmes reviewed across India and Kenya only one program showed a correlation between access to energy and income levels. The strongest correlation between enterprise access and financial impacts was found among the data from the Lighting a Billion Lives Solar Lanterns programme. “The strong relationship between household access and income indicates that the impact on poverty occurs through households’ access to electric lighting, but this does not mean that it cannot also occur through the increased productive activity enabled through enterprises’ access to electric lighting’’. Access to lighting at the household level for these fishing communities allowed them to mend fishing nets by night so that they could go fishing for more hours during the day. The community surveys have highlighted that the increased economic opportunities from fishing have reduced migration of villagers. The surveys have presented cases where four youths from the beneficiary community that earlier migrated to Andhra and Karnataka to work at brick kilns and in other industries are now back in their own village doing fish net mending business under the light of the lantern.

While there is evidence on cases where access to energy has increased income there is no evidence in the studies reviewed to show that access to energy has increased food security in comparison to how it was prior to occurrence of a climate related shocks or stresses. Similarly some evidence is presented showing how energy access contributes to increasing income at household level and in enterprises, but it is not clear how the increased income has been used and if the new livelihoods created have impacted existing ones. The evidence found in the 34 documents reviewed supports a link between access to energy and increased incomes, but falls short of providing the evidence to demonstrate the link from increased income to adaptation or increased resilience. This link is inferred in the literature rather than demonstrated by evidence.

Resilience Dimension 4: Social safety nets

Evidence illustrates that in regions that are most vulnerable to climate impacts energy access through decentralised solutions can significantly impact recovery processes. When the Typhoon Haiyan hit coastal villages in the Philippines in 2012, much of the disaster zone was left without power due to damage caused on the grid transmission systems. The UN Refugee Agency provided Solar-powered lanterns to people affected by the typhoon. The lanterns played a key role in helping them to carry out their recovery activities and continue with their lives. Fishermen had started to use these lanterns when fishing. The author notes ‘’the solar lantern, which provides illumination from six to eight hours, also allows the charging of cell phones – used by affected people to look for day jobs and find the best markets for the fish catch’’ (Del Mundo, 2013). The recovery process of Typhoon Haiyan has also included a radio broadcasting system which aimed “to be the voice from the government and the relief community to the affected people and also to provide two-way communication with the community'' (IRIN, 2013). With the power systems being damaged for over 5 months after the typhoon people had very little access to news and information from the government and the aid agencies. As a first step the project ensured that the evacuation centres and local government offices received solar powered and wind up radios so that the broadcasts can be amplified by loudspeaker to reach larger audiences (*Ibid. Blog post*).

Auth (2012) presents Haiti's focus on energy access as a route for disaster recovery, ''according to the Haiti Regeneration Initiative, Haiti currently faces four major challenges: post-earthquake recovery and reconstruction; economic and social development; environmental stabilization and restoration; and increasing resilience against future hurricanes, floods and earthquakes, and economic shocks. A crucial element for achieving all four of these goals is the extension of affordable, reliable, and sustainable electricity services'' (*Ibid,* Blog post). In January 2012, the Haitian Government launched the "Ban m limyè, Ban m lavi" ("Give me light, give me life") program with the aim of giving energy access to 200,000 rural households over the next two years. Onsite power generation using decentralised renewable energy is becoming more and more popular in Haiti providing opportunities to speed up the recovery process particularly through access to health services. However empirical evidence with regards to how the program had an impact on the communities has not been recorded.

These examples provide some evidence that access to energy provides communities the opportunity to connect with networks that connect with formal and informal support to stakeholders (governments, aid agencies etc.) as part of disaster response that can help recovery from the impacts.

Resilience Dimension 5: Livelihood viability

Several studies presented how adaptation benefits can be achieved from integrating food and energy systems. Many authors highlight how energy can provide new technologies for irrigation and agro-processing. There are a number of proposed conceptual ideas relating to this, however it has been difficult to find literature that makes the link to empirical evidence. IRENA (2015) presents a case study from Indonesia, where biogas has been used for tofu and tempeh processing. Tofu and tempeh are fundamental staples of the Indonesian diet and an important source of protein and other critical nutrients, especially for low income households. Approximately 85,000 informal micro, small, and medium enterprises are involved in the industry. Tofu and tempeh are traditionally produced using firewood to heat soybeans. With the increasing scarcity of firewood many people are finding difficulties to collect adequate supplies. In order to support these enterprises a Mercy Corps project is promoting biogas reactors in the tofu industry in peri-urban areas. The benefits include avoided fuel costs in the long term, avoided risk of price fluctuations for LPG and firewood, avoided risk of firewood scarcity, avoided community opposition due to reduction of smoke and water pollution, time savings and improved health conditions, and the option to produce electricity from biogas.

This study does not clearly make the link to climate change. However it provides evidence that by integrating food and energy systems there is potential that livelihood viability would be increased, particularly among communities who are heavily dependent on natural resources facing increasing stresses on their livelihoods due to firewood scarcity.

Resilience Dimension 6: Natural contexts

In the Chololo Ecovillage project in Tanzania (Institute of Rural Development Planning Tanzania, 2014) one of the key climate change impacts identified by the residents was deforestation, which is resulting in loss of vegetation, increased desertification, reduced animal forage and pasture, shortage of fuel wood and timber, increased women's workload, and increased land pressure due to poor natural resource management. In order to address these issues the project introduced alternative energy technologies for cooking which included energy saving cooking stoves and low cost domestic biogas plants. The energy-saving stoves halved the amount of wood needed to cook, reducing pressure on forest resources, saving women time and effort, and reducing harmful smoke in their homes. A survey of 50 households carried out by the project revealed that ''using an improved stove cuts down fuel wood use by 57%, reduces household CO2 emissions by 1.4 tons per year, saves 85,000 Tsh or up to 17 days per year collecting firewood, and reduces the risks associated with firewood collection''. The domestic biogas digesters which uses cattle dung was introduced as a suitable option mainly for farmers with 2-3 cows as it allows them to generate sufficient gas to meet their daily cooking and lighting needs. Upon using these biogas digesters one of the villagers highlights that "I advise livestock keepers to use biogas because it conserves the environment. Continuous cutting of firewood will result in more land degradation". In addition the bio-slurry left over from this process is easily collected used as a soil fertiliser to reduce soil degradation and erosion.

Dhakal (2012) presents project outcomes from a forest conservation and ICS project in Nepal. One of the key climate hazards faced in the Middle Mountains of Nepal is increased land slides resulting from changing weather patterns which have recently included both prolonged droughts and shorter, heavier, periods of precipitation. Forests are seen as the main barrier to the occurrence of landslides. However, in Nepal almost all rural household fuel requirements for cooking are met by firewood collected from forests. Thus reducing the demand for fuel wood plays a key role in forest conservation. He highlights ''these forests have vital roles in Nepal's agricultural terraced field agricultural system, biodiversity, climate amelioration and as carbon sinks. Their importance in preventing the land sliding of terraced slopes cannot be overstated''. In order to address this the Glacier Trust worked in partnership with Eco Himal Nepal to produce a programme to reduce the dependence of Nepali subsistence hill-farming communities on forest timber as a fuel source. The project introduced two types of improved stoves. An indicative survey undertaken by project shows that the use of these stoves appear to be saving 342 tonnes of fuelwood per year. The project predicts that reducing firewood use can bring beneficial consequences for the ecological health of the catchment. However empirical evidence to support actual outcomes have not been assessed.

CCKN and IISD (2014) state that in Bangladesh rural communities will face several climate change vulnerabilities:

- Land degradation from loss of soil organic content, erosion aggravated by deforestation and increased flooding and decreased rainfall in the dry winter months
- Food security – decreased crop yield resulting from loss of soil organic content, excessive flooding and increased droughts.

The study presents two case studies from Bangladesh that attempts to address these issues. The case study on social forestry shows how sustainably managed roadside tree plantations for biofuels can reduce the deforestation pressure on common-property forests while reducing land degradation. The poultry biofuel case study shows that the shift from poultry based protein from fish in Bangladesh (majority of the population in Bangladesh depend on fish as their main protein intake) could be a strategy to adapt to declining fish stocks, which are expected to worsen with climate change. In addition poultry waste produced by the biofuel can be used as a soil conditioner to potentially reduce soil degradation.

Garg et al. (2007) presents a case study from China where a programme called Replacing Firewood with Small Hydro (RFSH) was implemented. The study highlights that multiple benefits are expected from the programme: protecting local forests, better water conservation and flood control, and cheaper and cleaner electricity, as well as higher income and a more prosperous local economy. In China the consumption of large quantities of firewood by poor rural households has been a major barrier to improvement of its ecological environment. It is estimated that "annually, 420–560 million m3 of hay, straw and firewood were burnt by about 112 million rural people who had no other source of fuel for cooking and heating, decimating

23 million hectares of forests every year''(*Ibid,* p 85). A survey conducted by the Chinese Ministry of Water Resources indicates that in the areas covered by the RFSH programme, each household, on average, consumes 5 tons of firewood. It is predicted that after all the 28.3 million households shift to electricity for cooking and heating, the consumption of 141.5 million tons of firewood, equivalent to around 189 million m^3 of wood consumption, can be avoided. Further analysis by West China Development Office of the Chinese State Council show that offering non-wood energy to satisfy a 4-person household's daily needs can prevent the logging of 0.2–0.3 hectare of forest. Assuming a 4-year rotation logging interval, 0.8– 1.2 hectares of forest can be protected, which means, upon full-scale implementation, the programme can protect at least 23 million hectares of forest. While these estimates were given in the study for predictable outcomes, empirical evidence on the programme outcome was not found.

The conceptual linkages presented in the literature highlight that healthy ecosystem services can reduce impacts during disasters, control soil erosion and land degradation. However it is beyond the scope of this literature review to identify evidence on the role of forest and eco systems in reducing impacts of disasters. The evidence presented above shows that there is clear potential for reducing fuel wood by introducing alternative energy sources for cooking and heating, thus resulting in reduced deforestation locally and nationally. However there is no empirical evidence to determine whether deforestation has actually been reduced as a result of these programmes directly.

Resilience Dimension 7: Personal circumstances- particularly on vulnerable groups

The evidence presented in the previous sections highlight key findings related to how access to energy has acted as an enabler to improve personal circumstances or addressed the needs of those who are most vulnerable to climate change.

These include improved access to health services (for example Gippner et al. (2013) presents improved health services through Micro hydro electrification), access to knowledge (for example via access to ICTs), enhanced access to better quality education (for example the case study from Senegal by CCKN and IISD (2014) acknowledges access to high quality education), improved health of women and children through improved cooking solutions, time saving and women's empowerment.

The Chololo Ecovillage project in Tanzania highlights the benefits domestic biogas users identified ''it not only saves fuel costs, but also reduces the workload of women and children involved in fuel wood collection. The indoor air pollution associated with cooking on inefficient wood stoves is virtually eliminated with biogas'' (Institute of Rural Development Planning Tanzania, 2014, p26). In addition the solar powered village water system that was introduced allowed the village committee to provide water free to the more vulnerable communities such as the elderly.

Dhakal (2012, p17) highlights that the use of ICS has contributed to smoke reduction in the households, ''visiting a kitchen without an ICS very rapidly reminds you of the extraordinary benefits to health from a ventilated stove. The impact on chest and eye infections seems to be immediately beneficial. A traditional medicine practitioner (who is now involved as a stove technician) reported a dramatic improvement in health. We frequently met people who, within months, had reduced or eliminated their doctors' bills (NRs 2–5000) twice a year''.

Gippner et al. (2013) show that gender equity is one of the key aspects addressed through the Rural Energy Development Program (REDP) programme. The study highlights that women operate the majority of agro processing facilities and poultry farms connected to the microhydro plants, providing women with the opportunity for livelihoods. In addition, access to electricity has reduced the time spent collecting fuelwood allowing women to pursue their own studies and engage in income generating activities: "Women's participation in small-scale enterprises increased by 75% between 1996 and 2005 according to a REDP survey. The main improvements took place in the industries of basket-making, knitting or cutting'' (*Ibid,* p11). The REDP programme also brought improved health care facilities which mostly benefited women: ''In Lukla, micro-hydroelectricity also powered a hospital with five dedicated beds for women and an actual operating theatre for the maternity ward. Electricity there is used not only for lighting and space heating, but also for sterilization and sanitation, a television for the sick guests, an x-ray machine, laboratory instruments, and a portable heater for a guard house to keep sick (or pregnant) women safe and warm'' (*Ibid,* p11).

Under the AdaptCap (2014) programme, a project was implemented that provide climate-smart lighting for a fishing village in Tamil Nadu. In 2004, the Tsunami had destroyed almost all structures in the village. The community currently has an insecure power supply with frequent power outages mainly caused by storms. The projected increase in extreme weather conditions due to climate change will put additional pressure on the unstable energy supply. The frequent power shortages are currently having severe impacts on people's public and work life at night, women are particularly facing safety issues when using latrines in public facilities at night without light. Installation of solar street lights have improved the lives of these communities by providing children with the opportunity to study at night and adults can conduct their livelihood activities in the evenings.

A country analysis in Nepal by Sapkota (2014) highlights findings from secondary research that demonstrates renewable energy technologies such as micro hydro, solar PV, biogas, and ICS have had positive socio-economic and environmental benefits in rural Nepal (see Table 10).

Table 10 Analysis of social benefits of renewable energy technologies in rural Nepal (adapted from Sapkota et al., 2014)

Social benefits	Specific benefits
Time saving and women empowerment	• The use of electrical mills, instead of manual agro-processing, saves 155 h per year for women and 85 h for men. • The installation of a biogas plant can save a household approximately 3 h of labour per day, which is equivalent to a total saving of over 1000 h a year. This time saving primarily comes from the reduction in labour required for gathering fuel for cooking. • The time spent cooking using ICSs is reduced by 15-20% compared with traditional stoves, which is a total of at least 2 h per week. As firewood requirements are also reduced by around 50%, family members spend much less time gathering fuel, and less physical labour is required to cut trees and collect firewood.
Improved access to better quality education	• Electricity can improve rural education by enabling the use of advanced equipment in schools, which attracts skilled teachers to rural communities. As electricity extends study time at home, it also contributes to better grades. • The number of children/youth between the ages of 6 and 14 without primary level education has decreased from 25% to 7%. • Children from households with electricity spend 50 min on evening study, while children from households with no electricity spend only 34 min on evening study each day. • Boys and girls from households with electricity complete an average of 0.4 and 0.21 more years of schooling, respectively, compared with boys and girls from households with no electricity
Improved health	• In areas with electricity, there is an average of 11 health workers per 10,000 people, compared to 2 health workers per 10,000 people in non-electrified areas.

Social benefits	Specific benefits
	• The use of micro hydro reduces suffering from respiratory diseases by 6 h per month for girls and by 1.6 h per month for boys. • The risk of fire (from the use of kerosene lamps, butter lamps, and candles) has also been significantly reduced by the use of renewable energy technologies.

The case study presented by Willcox et al. (2015) on the Lighting a Billion Lives solar lanterns programme in India, highlights that access to lighting at the household level not only increased income and economic benefits, but it also provided the following social benefits contributing to their general wellbeing:

- Reduced household labour for women as her chores don't have to be postponed until morning
- Villagers have stated that the education of high school students has been positively influenced by the availability of lanterns
- Better sanitation and hygiene as the villagers can use the lanterns while going to the lavatory or in the forest to relieve themselves.

While the case studies highlight the various opportunities for vulnerable groups such as women and children, there is very little empirical evidence showing whether they actually used these opportunities to cope and adapt to climate change and climate variability. For instance, whether the time savings that were used for income generation by women actually contributed to building their resilience or whether the increased rate of schooling has provided opportunities to build resilient communities is still unclear.

Resilience Dimension 8: Institutions and policy contexts

Fang and Wei (2012) present a case from Qinghai–Tibetan Plateau (QTP) that demonstrates solar energy utilisation can act as a climate change adaptation measure to increase resilience in the energy sector at both large scale and household levels to be resilient to future climate change and variability. Fang and Wei (2012, p7) highlight "as China moves towards the identification of climate change mitigation and adaptation strategies, China's adaptation strategy of climate change remains centred on energy development. Thus, the exploitation and utilization of renewable energy, especially solar energy, is a clear domain for climate change adaptation. From a social science perspective, it becomes very critical to understand the conditions under which policies and institutions can stimulate the adaptive capacity of society to deal with the potentially serious and irreversible impacts of climate change''. China has been implementing solar related regulations for many years at various scales. A list of these policies are presented in Table 11.

Table 11: Solar related policy and regulatory instruments (adapted from Fang and Wei, 2012, p8)

Scales	Policies and actions
International	• The Millennium Development Goals (MDGs) (2000) • China Rural Energy Enterprise Development Initiative (CREED) (2004–2006) • China Renewable Energy Scale-up Programme (CRESP) (2005) • Solar Energy Training and Service Project in Tibet (2004–2006) • Asia Solar Energy Initiative (ASEI) (2010)
National	• Brightness Programme (1999–2002) • Chinese Township Electrification Programme (SDDX) (2002–2005) • The Renewable Energy Law of the People's Republic of China (2005) • The 11th Five Year Plan for the Solar Industry Development (2006–2010) • China's National Climate Change Program (2007)

Scales	Policies and actions
Regional	• Med- and long-term development plan for renewable energy in China (2007) • China National Plan for Coping with Climate Change (2007) • Chinese Village Electrification Programme (2006–2010) • Golden Sun Programme (2009–2011) • The 12th Five Year Plan for the Solar Industry Development (2011–2015) • Sunlight Plan in Tibet (1990–) • Light of Science Plan in Tibet Autonomous Region (1999–2001) • Autonomous Region (1999–2001) • Industrial Development in Qinghai Province and Promote the Use of Solar Energy Plan (2009–2015) • The 12th Five-Year Plan for Economic and Social Development of Tibet Autonomous Region (2011–2015) • The 12th Five-Year Plan for Economic and Social Development of Qinghai Province (2011–2015)
Enterprise	• 10 MW solar PV project in Shigatze and 50MW PV project in Nagqu (2010) • The development of Qaidam Basin-based solar photovoltaic industry (2010-)

Although there are no specific outcomes being presented for each policy and action based on the expansion of solar PV in China, Fang and Wei (2012, p9) highlight that "from the early planning phase, the solar energy project was designed to expand into vast rural areas of the QTP; these initiatives and activities were instrumental in enhancing the adaptive capacity not only from regional scale but from enterprise or individual scale". In what way these policy instruments contributed to building adaptive capacity is not highlighted in this study. Fang and Wei (2012, p9) further highlight that to speed up the development of solar energy there is still a need for robust policies from the government, particularly focusing on ''financial subsidies, tax concessions, favourable price policy, technical innovation policy, industrialized support policy, and effective globe cooperation and collaboration framework''.

Approaches that combined mitigating greenhouse gas emissions, adapting to climate change and achieving economic and social development which is a 'low-carbon resilient development approach' has already been considered in several least developed countries (Fisher, 2013). Fisher (2013) also identifies several options for bringing adaptation, mitigation and development into one policy agenda. One option is bringing forward one single policy, for instance "a national campaign to distribute solar lanterns as a decentralised renewable energy solution. This type of campaign could offer benefits in all three areas: mitigation through renewable technology; adaptation through addressing the underlying causes of vulnerability; and development through better educational outcomes and income diversification by being able to work in the evenings" (*Ibid,* p8).

Fisher (2013) looked at a selection of country policies/strategy documents and national level approaches to considering low-carbon, climate resilient development. The Bangladesh Climate Change Strategy and Action Plan (BCCSAP) treats mitigation and adaptation as separate policy issues. In the BCCSAP "although mitigation is only a small component of the plan (with 3.2% of total resource), it was retained to support funding and address concerns around energy access and security" (*Ibid,* p23). Ethiopia focuses on building a Climate-Resilient Green Economy by combining green growth and climate resilience strategies and is implementing some flagship programmes such as the national cook stove and biogas programmes, with the aim of bringing these policies together. However there is very little evidence on how and if co-benefits can be leveraged (*Ibid*). Given the broader context of the study by Fisher (2013), energy is linked to the mitigation efforts or low-carbon development pathways rather than clearly identifying the linkages across the two areas and how improved access to energy can have an impact on adaptation or climate resilience at national, community/local or household level.

From the conceptual and empirical evidence taken in this literature review it is evident that energy access projects can have strong adaptation components. Thus ''demonstrating the link between improved access to energy and climate change adaptation offers the opportunity to enhance development programmes by maximising the co-benefits of energy and adaptation'' (Murphy and Corbyn, 2013, p2).

Furthermore Jarvie and Nicholson (2013) highlight that focusing in on strategic approaches, such as community based energy access that offers strong links to climate resilience, will help to break down the silos often put up between the adaptation/resilience vs. mitigation/development thinking, enabling transformation and holistic frameworks to be established.

Evidence where energy access interventions have contributed to maladaptation

There is very little empirical evidence available on how energy access contributes to maladaptation.

IRENA (2015) states that in India and China, where a substantial number of solar PV-based pumping systems have been deployed, evidence has been emerging with risks of over pumping. The study states that "although groundwater represents an invaluable source of irrigation water, it has proven to be difficult to regulate. Locally intensive and continuous groundwater withdrawals could exceed rates of natural replenishment, which would have negative consequences for local and global food production and therefore need to be managed adequately'' (*Ibid,* p57). The study does not elaborate on the details of how to "adequately" manage this.

Atteridge (2013) in his study presents the importance of transforming household energy practices using charcoal to reduce climate risk, and Ochieng et al. (2015) identifies the role of charcoal production in climate change adaptation of the Arid and Semi-Arid Lands (ASALs) of Kenya. Atteridge (2013) presents a case study from urban Lusaka, Zambia where charcoal dominates the household energy market as it is being used for cooking and heating fuel by most low and middle income households. His study states that charcoal is particularly popular in urban areas due to its benefits over fuelwood such as less smoke and easier to transport and handle. Atteridge (2013, p8) highlights that "charcoal production and use directly reduces the availability of mature trees as shade against higher temperatures, which in turn increases surface runoff of precious fresh water resources. Concurrently, climate change is predicted to affect the growth of woodlands that currently supply most of the charcoal, so the fuel itself may become harder to access. Finding ways to reduce charcoal use can therefore reduce the probable impacts of climate change for poor communities''. However Ochieng et al. (2015) demonstrates how charcoal production can be an adaptation measure for communities living in ASALs and that banning charcoal production as a measure for good environmental management can impact on the communities' livelihoods. Ochieng et al (2015) compares the community's drought coping measures used by the community where charcoal production was identified as a primary coping measure. The study highlights that ''Charcoal production, thus, as a coping measure can support and sometimes substitute vital livelihood measures and thus enable those engaged in it to generate additional income'' (ibid, p7). Charcoal, a commonly used source of household energy, livelihood and a coping strategy for drought by poor communities, if reduced can lead to wider economic challenges reducing people's adaptive capacity, thus increasing vulnerability to climate change, resulting in maladaptation. It is however important to ensure that exploring the potential as an adaptation measure of the charcoal sector should be regulated with proper controls of production measures to ensure environmental impacts leading to deforestation can be controlled.

Some research shows that women use the time spent collecting firewood and water as an opportunity to discuss the problems they face among others in the community (Matinga, 2012).

This could be a precious way of sharing information and supporting each other, and taking that away through access to improved technologies may potentially reduce resilience and have wider social impacts. Thus whether access to modern energy acts as a barrier as well as a mechanism to improve or intervene in the societal coping mechanisms used by most poor communities are important areas for future research.

While there is no clear evidence found in the literature reviewed that energy access can result in maladaptation with respect to food security and the environment, IRENA (2015) highlight some energy technologies, particularly large scale technologies that have the potential to result in maladaptation. Examples of these impacts include: "impacts of thermal power generation using cooling water from a river can affect the river's ecosystem (e.g., increasing the temperature of the water), altering fish availability and potentially affecting local food supply. Hydropower also can impose burdens on fish (e.g., on migratory species, which represent a large share of commercial fish), as has been observed in the Mekong Basin in Southeast Asia and in the Columbia River Basin in western North America'' (*Ibid,* p48). Similarly while biofuel production can be an income generation opportunity that could also enhance access to energy, in some countries promotion of biofuel needs further experimental research to ensure it does not have unintended impacts on food prices and food production locally (IRENA, 2015), (Addo et al., 2014). In addition, the promotion of biofuels needs to be carefully evaluated to understand fully the potential impacts on natural ecosystems.

SECTION 5

Potential Challenges and Opportunities

5.1 Overview

This section presents key findings from the literature review in relation to the third research question:

What are potential challenges and opportunities for promoting energy access as a means of adaptation to climate change?

Conclusions about how to harness the opportunities and overcome the challenges identified in this section are presented in Section 6.

5.2 Opportunities

Section 4 discusses how access to energy can or has worked as an enabler to provide opportunities to poor communities, to deploy and use various technologies that help adaptation to climate change and increase economic and environmental benefits, thus addressing the key dimensions of building resilience.

Opportunities identified based on existing evidence

The greatest amount of evidence documented in the literature reviewed related to addressing the resilience dimension 'Access to services'.

Access to Services

The literature identified opportunities to promote energy access through decentralised sustainable options as part of ***addressing technology needs for adaptation***. These technologies include: water pumping systems, water purification systems, decentralised energy solutions that are more resilient to climate shocks and stresses, knowledge and information systems such as ICTs and early warning systems. Evidence from the literature shows that technologies such as Solar PV are increasingly being considered for adaptation options to access water and sanitation applications. The majority of these are community/village level interventions. Access to water using water pumps powered by various energy sources has taken place over the decades. With increasing climate change impacts such as reduced precipitation levels, increased salinity levels in water and unpredictable rain patterns, there is an increasing focus to view these technologies as an adaptation opportunity. Kenya's Technology Needs Assessment for Adaptation identified solar powered desalination as one of the priority technologies for Kenya in addressing impacts on water availability due to climate change and climate variability. IRENA (2015) highlights that the use of renewable energy solutions in addressing food and water issues at the community level can increase rural electrification. For instance, any excess energy available from a community energy system that is designed to pump water or process crops can be distributed to local communities.

The literature identified opportunities to promote more climate resilient energy solutions to ***reduce pressure on the environment and to support sustainable development***, particularly energy solutions that focus on community based energy security and ecosystem services. Williamson (2009, p47) suggests that "energy system diversification with decentralisation to increase and disseminate modern and improved energy solutions such as improved cook stoves will increase resilience to climate change in the energy sector, while decreasing the pressure on the environment''. For instance in countries like Nigeria where large hydropower plants represent about one-third of the country's total installed electricity generating capacity, increasing droughts have become one of the key issues affecting the current energy supply. Akkerman et al (2014) suggest that disaster resilient energy supplies, particularly off-grid renewable energy, can help these communities reduce impacts on their working conditions and better adapt to climate change and climate variability. Given the low energy access rates, diversifying energy solutions using decentralised solutions will not only increase resilience to climate change in the energy sector but will also increase a country's energy access rates while also contributing to a country's sustainable development. In addition resilient energy solutions such as portable cook stoves can help people cook, even during disasters such as floods ensuring they have access to food and cleaner water, which are key deprivations during natural disasters (Symons, 2013).

Social Safety Nets

The literature presented evidence on how energy access can address the resilience dimension of social safety nets (support networks). Access to knowledge and information via ICTs has helped communities to access social safety nets. Evidence shows that farmers can benefit from access to ICTs to build resilience to climate hazards that affect their crops and livestock and also be aware of market prices (Giri and Malakar, 2011), (Cabana, 2012). Specific programmes need to be developed to ***understand how ICTs can be used most successfully for information transfer and use in relation to climate variability and change***. Ensuring that ICTs are provided with an affordable source of energy can ensure that the ICT programme has a more successful uptake. Cabana (2012) highlight that the cost of batteries is a constraint to uptake of the radio introduced as a part of the ICT program to support sustainable mountain livelihoods in the Peruvian Andes, where the livelihoods are affected by climate variability. The radio broadcasting helped communities improve their livestock practices and gain better access to markets.

In regions that are most vulnerable to climate impacts, energy access through decentralised solutions can significantly impact the recovery process (Auth, 2012). This is particularly evident during large scale disasters when existing power systems and grid transmission lines are severely damaged, completely disconnecting power supplies. Energy is essential for functioning medical equipment for disaster relief through to economic and social recovery. ICTs can help raise awareness, open connectivity, access support from aid agencies and the government and keep people informed of future disasters allowing them to act fast and take timely decisions. Solar lanterns and small scale solar systems that can power radios provide lighting in shelters and electricity to clinics have been ***reliable energy solutions during disasters***.

Potential opportunities based on inferred links

Several examples have been detailed above from the literature reviewed that provided evidence for the two dimensions of resilience relating to access to services/access to social safety nets and how energy access has been applied in the context of climate change adaptation or how it has contributed to building resilience among individuals and communities to various shocks and stresses. For the remaining dimensions of resilience, the evidence stopped short of making the link, however the links were inferred in the literature. Opportunities exist to undertake further research to understand how and if access to energy helps communities, individuals or institutions react to stresses and shocks of climate change and climate variability within the following dimensions: Adaptive capacity; income and food access; livelihood viability; and personal circumstances (particularly for vulnerable groups).

Adaptive Capacity, Income and Food Access, Livelihood Viability and Personal Circumstances

Opportunities exist to ***pilot projects that help poor communities break through poverty traps and build adaptive capacity through provision of access to sustainable energy***.

Ewbank (2013) states the "lack of access to energy is both a major cause of poverty and a major constraint to increasing the resilience of the most vulnerable livelihoods'' (*Ibid,* p10). Energy access helps extremely poor communities increase their income, build resilient livelihoods, find alternative and new livelihoods with variations in climate conditions.

Energy contributes to addressing some of the combined challenges related to food security and climate change. Integrated food-energy systems (such as solar PV for agro processing and irrigation, use of bio-slurry from biogas as an organic fertiliser and bioenergy production) can be an opportunity for improving food security, increasing access to energy and building adaptive capacity to climate change. Bogdanski (2012, p2) highlight that ***the importance of energy for food security and adaptive capacity of smallholders has still not been recognized widely*** and most smallholder farmers tend to rely on costly farming options during climate variability. Energy is vital for food security and resilient livelihoods, but it is often dealt with as a separate issue.

Natural Context

The literature identified opportunities ***for enhancing the links between energy access interventions with community based ecosystem services and natural resource management that can have indirect adaptation benefits***. Providing access to clean cooking fuel and improved cook stoves can have impacts on saving local forests that can provide ecosystem services while also protecting communities from floods and landslides. Although this literature review did not present evidence directly linking access to energy and improved ecosystems services, the literature did provide evidence to support the following:

- In regions where communities rely on natural resources, such as forests, to fulfil their basic needs, access to energy can provide communities with the opportunity to rely less on these depleting natural resources (for example by providing access to improved cook stoves or biogas in the Chololo Eco Village project by Institute of Rural Development Planning Tanzania, 2014).
- Forests act as a natural barrier for climate related disasters. Unsustainable use of wood for fuel has been one of the key reasons for deforestation in some developing countries. Improved cooking solutions can reduce the use of firewood resulting in benefits for the ecological health of the local environment (Dhakal, 2012).
- Solutions such as biogas can provide soil fertilisers that can be used by communities who face issues due to soil fertility (Institute of Rural Development Planning Tanzania, 2014).
- Garg et al. (2007) presents a case study from China where a programme of Replacing Firewood with Small Hydro (RFSH) is being experimented. The study identify that there is a large potential for reducing deforestation through this programme.

Opportunities in the institutional and governance context

Various international drivers and national development priorities are presenting an urgent need for least developed countries to move forward with sustainable development and to identify linkages between development, adaptation and mitigation.

Expand opportunities for reducing vulnerability to climate change by mainstreaming adaptation into energy sector policies (Fang and Wei, 2012). According to the analysis by Fang and Wei (2012) many energy and development initiatives and activities were instrumental to enhancing the adaptive capacity in China. The most effective initiative to increase the uptake of solar services in China has been the various energy and climate change related policy instruments that have been implemented in China. With developing countries starting to focus more and more on a low-carbon climate resilient development path, renewable energy systems offer diversification of supply and a low carbon energy supply, thus strengthening energy security leading to national development (Fisher, 2013), Murphy and

Corbyn (2013). The adaptation benefits of these interventions are however not yet being clearly identified in both policy and scientific research.

Opportunity through strengthening local adaptation and development policies for identifying co-benefits. Poverty reduction and increasing household income can be key to building adaptive capacity and increasing resilience to climate change. Ochieng et al. (2015) highlight that there is a critical need to strengthen existing local strategies on adaptation and development in order to reach the most vulnerable. Energy is a critical enabler that can enhance the lives of poor and marginal people. Murphy and Corbyn (2013) in their recent study on energy access and adaptation offers a recommendation to undertake policy reform and institutional strengthening to ensure greater integration of policies related to energy access and adaptation.

Energy access initiatives can provide wider opportunities for adaptation. Murphy and Corbyn (2013) state in their recent working paper on energy and adaptation that a technology solution for increasing resilience can be an 'entry point' for ''integrated sustainable approaches for achieving adaptation''. The authors present an example where in addition to introducing cook stoves to communities living in the Char lands in Bangladesh, it also included awareness raising campaigns and provided training to local government officials on climate change threats.

Linking with international drivers which aim to link climate change mitigation priorities with climate change adaptation. The UNFCCC has brought forward an agenda to create a new international climate agreement by the conclusion of the Paris Climate Summit in December 2015, part of this will involve countries submitting their Intended Nationally Determined Contributions (INDCs) on reducing greenhouse gas emissions (Ecofys, 2014, World Resource Institute (WRI), n.d.). The INDCs will determine "whether the world achieves an ambitious 2015 agreement and is put on a path toward a low-carbon, climate-resilient future'' (World Resource Institute (WRI), n.d.). While the aim of the INDCs is to gain a collective commitment for reducing the global emissions, it can also identify how climate change can be integrated into national priorities, such as sustainable development and poverty reduction (World Resource Institute (WRI), n.d.). The inclusion of mitigation co-benefits of adaptation interventions are ongoing and are purely voluntary in addition to mitigation (Ecofys, 2014), but there is large potential for raising the profile of access to energy by identifying the co-benefits of adaptation arising from energy access projects here. This is particularly important given that small scale renewable energy technologies can play a key role in both adaptation and mitigation in developing countries.

Within the context of UNFCCC international climate change reporting, several developing countries are starting to develop measuring, reporting and verification (MRV) systems in order institutionalise the production of regular reports to the UNFCCC on mitigation and adaptation and also assist in the mainstreaming of climate change into development planning. Kenya has designed an ambitious system that aims to include the MRV of mitigation actions, monitoring and evaluation (M&E) of adaptation actions and consider the synergies between the two (Government of Kenya, 2013, Ricardo-AEA et al., 2012). This is called an MRV+ system, and if implemented well has the potential to gather evidence to assess the linkages between access to energy and adaptation.

The United Nation's SE4ALL initiative aims to ensure sustainable energy for all by 2030 through the achievement of three goals: Universal access to modern energy services; doubling the global rate of improvement of energy efficiency; and doubling the share of renewable energy in the global energy mix (UNDP,2013). A study by UNDP (2013) which focuses on achieving sustainable energy for all in the Asia Pacific provides conceptual findings that renewable energy technologies for household energy access can promote adaptation to climate change while also bringing other socio-economic benefits. However it was beyond the scope of this literature review to look further into whether adaptation has been linked to energy access within the SE4ALL initiative and how it may be framed within the ongoing dialogues of making energy a Sustainable Development Goal in the post-2015 development agenda.

5.3 Challenges

Only a few of the documents reviewed in detail identified challenges to promoting energy access as a means of adaptation. Most commonly literature identified challenges with respect to scaling up energy technologies in general. The challenges identified within the literature are presented below. Any further research undertaken should keep these challenges in mind and help to address them wherever possible.

Challenges in scaling up energy technologies:

- The case studies reviewed in the literature show positive impacts are achievable when renewable energy technologies are successfully adopted for water services. However, Platonova and Leone (2012) and Garg et al. (2007) highlighted a number of barriers that could prevent technology uptake. These barriers were mainly technical issues, physical factors, maintenance and servicing capacity, financial constraints due to low income levels of targeted communities, community involvement, social and cultural aspects and the political and institutional environment.
- Cost of implementing technologies hinders further development of technologies. For instance, the relatively high costs of solar pumping systems is a key barrier to expanding the technology (IRENA,2015). Similarly Fang and Wei, (2012) identified that in China lack of access and knowledge on technology and cost are two major barriers to the development of solar energy in rural areas of China. In addition the lack of technical knowledge for maintenance and management of solar energy installations among local people also appears as a barrier for scaling up.
- Need for technologies to be very context specific can hinder scaling up (Akkerman et al., 2014).
- Lack of resource data availability in developing countries can hinder investment in potential renewable energy sources (Williamson et al., 2009).
- Ensuring that there is a sufficient community and local authority participation and buy in throughout interventions (AdaptCap, 2014).
- The SE4ALL Initiative has produced a Global Tracking Framework which presents a new definition for energy access based on the performance of the energy supply ‘‘Access to energy is the ability to avail energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy and safe, for all required energy services across household, productive and community uses’’ (Angelou, 2014). These attributes can be seen as the drivers that enable the uptake of energy solutions by poor communities. Several studies also highlight that energy access itself is not sufficient for the successful uptake of energy services. There needs to be the necessary financing support, technical capacity, and market and regulatory support in place for their uptake (Willcox et al., 2015), (United Nations Development Programme (UNDP), 2013).

Challenges in linking energy interventions with climate change adaptation

- Murphy and Corbyn, (2013) highlight that there is a lack of policy frameworks linking energy access with adaptation to climate change Gathering the conceptual and empirical evidence from this literature review it is evident that energy access projects can have strong links to various dimensions of building adaptation and resilience to climate change. In order to break down the silos often put up between the adaptation/resilience vs. mitigation/development thinking, enabling transformation and holistic frameworks to be established is important to ensure that policies and frameworks at local, regional, national and global level should include energy access as an opportunity that offers strong links to climate resilience (Jarvie and Nicholson (2013).

- Fisher (2013) presented in her study that there is a lack of conceptual and empirical evidence to understand the potential co-benefits and the trade-offs involved in synergising development, adaptation and mitigation policies and interventions.
- Williamson et al., (2009) suggest that there is a lack of attention to policies focusing on energy system vulnerability to climate change. Murphy and Corbyn (2013) and Stone (2013) suggest that climate proofing of energy systems is essential to avoid maladaptation and climate related failures of energy systems.
- Studies by IRENA (2015) and Ochieng et al. (2015) highlight that the needs of local populations, existing coping mechanism and the local environmental conditions for interventions need to be understood for technologies to be successfully adapted by local communities and not result in maladaptation.

SECTION 6

Conclusions

This literature review is the first attempt at compiling the evidence base on how energy access contributes to adaptation and building resilience to climate change and climate variability. This literature review shows there is strong conceptualisation of the potential linkages of energy access and aspects of adaptation and building resilience to climate change and climate variability.

DFID's Resilience Framework presented in Brooks et al. (2014) is built on four key elements: Context ('Resilience of what?'), Disturbance ('Resilience to what?'), Capacity to deal with disturbance (exposure, sensitivity and adaptive capacity) and Reaction to disturbance. To identify the various dimensions that help communities, individuals, institutions and groups build resilience this literature review uses a conceptual framework (see Figure 2) which uses 9 key dimensions of resilience:

1. Access to services
2. Adaptive capacity
3. Income and food access
4. Social safety nets
5. Livelihood viability
6. Natural context
7. Personal circumstances
8. Institutional and policy contexts
9. Assets

The literature review found that access to energy can contribute to multiple dimensions of climate resilience at the same time, making it hard to separate evidence out under specific areas of resilience in Section 4.3 without becoming repetitive. The 9th dimension of resilience 'Assets' was presented under other dimensions (particularly 2 and 3 in the above list) as it overlapped with them considerably. Furthermore evidence where energy access interventions have contributed to maladaptation is also captured in this literature review.

All 34 documents included in the detailed review attempt to make the link between energy access and the 9 dimensions of resilience used in the conceptual framework. The majority of the studies (50%) only provided conceptual linkages which are highlighted in Section 4.2 detailing how energy access has been framed in the context of climate change and climate variability. These conceptual findings also fed into strengthening the conceptual framework presented in Figure 2.

The emphasis of this literature review was to track the complete chain of evidence (see Figure 2) from providing access to energy to building dimensions of resilience to Element 3 'Building capacity to deal with disturbance' and on to Element 4 'Reaction to disturbance' of the Resilience Framework. Only a few of the documents reviewed contain evidence demonstrating the link all the way through from access to energy to adaptation and building resilience to climate change (IRENA (2015), AdaptCap (2014), Rural Development Planning Tanzania (2014), (Platonova and Leone, 2012), Gippner et al. (2013), Jarvie and Nicholsan (2013) and CCKN and IISD (2014)). However, more commonly the remaining studies stop short of providing this evidence, and make links only as far as access to energy in building dimensions of resilience, leaving the reader to infer the link to climate change adaptation and building resilience. This lack of documented evidence to support the conceptual linkages between energy access and adaptation is mainly due to the fact that energy is commonly addressed under the banner of mitigation and in relation to energy security, rather than in relation to adaptation. Mitigation and adaptation policies and actions are typically dealt with quite separately and the synergies between the two are only recently starting to be explored. Hence to date, few energy related projects and programmes have documented evidence to support the link between access to energy and adaptation. Where this link has been documented, it is often in relation to the applications or services that energy provides (cooking, lighting, heating, mechanical power, water pumping, ICTs/information access, etc.), rather than access to the energy itself.

The evidence found related to the 9 dimensions of resilience has been grouped under 3 headings to indicate the completeness of the evidence chain from access to energy through to building capacity to deal with climate change and finally if energy access actually leads to resilience.

1. Complete evidence chain: Evidence showing how communities, groups and institutions that have access to energy increased resilience to climate variability and change. The link from energy access all the way through to adaptation or climate resilience was supported with evidence.

Evidence demonstrates how energy access can contribute to providing ‘Access to services’. The services mentioned most often in the literature that benefited from access to energy are water, electricity (in the context of energy security and resilient systems), early warning systems and knowledge and information. The literature covered a range of different energy applications that provided these services: water pumping and purification, lighting, clean cooking and space heating, ICTs (mobile phone charging, radios), energy for small scale enterprises, including food processing and storage. The literature considered a range of energy sources. Decentralised small scale renewable energy technologies were discussed most frequently, including micro hydro, solar, wind and biogas, of which Solar PV was most prominent (40% among the most commonly discussed energy sources). Non-renewable sources such as diesel powered systems and grid connected systems were only mentioned in climate resilient outcomes of Mercy Corps’ Energy Programmes presented by Jarvie and Nicholsan (2013) and the case study by CCKN and IISD (2014). Evidence was also found on improved cook stoves as a sustainable solution that contributed to multiple dimensions of resilience (e.g.: Dhakal (2012), Institute of Rural Development Planning Tanzania (2014) etc.). The literature identified that in areas where there are severe disruptions to grid electricity or no access to reliable gird electricity, or where communities have to depend on expensive options to access these services, off-grid, small-scale, decentralised and community based energy technologies were used for providing access to services. For instance communities who are vulnerable to disruptions in power supply such as the coastal communities in Vietnam, Haiti and India off grid renewable energy systems were identified as suitable solutions to access services such as clean water more reliably.

2. Partial evidence chain that could be reliably inferred backwards to complete the evidence chain: Evidence showing how technologies that require energy to function, have had an impact on building resilience to climate variability and change. The link back to energy access was not clearly mentioned in these case studies, but could reliably be inferred.

The evidence in this category was particularly found in relation to ‘’Access to social safety nets’’ and ‘’Access to information’’. Access to knowledge and information via ICTs has helped communities connect with formal and informal support networks (governments, aid agencies etc.) that can provide necessary support in time of disasters that can help recovery from the impacts. IRIN (2013) presents how solar lanterns and solar powered radios ICTs were used to help people access information from the Government and aid agencies during recovery from Typhoon Haiyan in the Philippines. Evidence also show that farmers can benefit from access to ICTs to build resilience to climate hazards that affect their crops and livestock while also keeping informed of market prices. Giri and Malakar (2011) presents evidence from rural Nepal and Cabana (2012) from Peruvian Andes. With such specific programmes that link poor communities to ICTs, it was also evident that an affordable source of energy could potentially contribute to better uptake of such ICT programmes. This was highlighted in the case study by Cabana (2012) where the price of batteries was a key barrier to the uptake of the radio programme.

3. Evidence chain stopped short of making the link to climate change or adaptation and building climate resilience, this link could not be reliably inferred forwards: Evidence showing how energy access has contributed to some of the dimensions of resilience without necessarily making the link to climate change or adaptation and building climate resilience. The link to climate change or adaptation and building resilience if it was mentioned in Section 4.3 was assumed or unreliably inferred forwards. The majority of this evidence was related to the following dimensions: Adaptive capacity; income and food access; livelihood viability; natural context; assets; and personal circumstances. The literature does present evidence that access to energy has contributed to diversifying livelihoods, increasing income, making livelihoods more viable and improving food security. CCKN and IISD (2014), Gippner et al. (2013) and Willcox et al. (2015) provide some of these key evidence links. However the evidence stops short of making the link to climate change or adaptation and whether access to energy has actually improved people's resilience to climate change. Similarly, while the conceptual findings identify the potential for access to energy to reduce impacts on the environment, particularly by reducing stresses on forest cover that can act as a natural safety system (e.g. by reducing land slides and flooding), actual evidence to support this conceptual link was not found in the 34 documents reviewed. The case studies highlight that there is great potential to reduce deforestation ((Institute of Rural Development Planning Tanzania, 2014), Dhakal (2012), CCKN and IISD (2014) and Garg et al. (2007)) by replacing fuel wood with sustainable energy sources such as bio gas, ICS, electric cooking powered by small hydro or solar PV, the studies reviewed do not provide empirical evidence supporting this.

In terms of improving personal circumstances, there is some evidence about how women and children can benefit from energy access to improve their personal circumstances, particularly through access to health care facilities, technologies that reduce negative health impacts, and reduce time spend on collecting fuel wood and water, leaving more time for education and income generating activities. These are presented by Gippner et al. (2013), CCKN and IISD (2014) (Institute of Rural Development Planning Tanzania (2014), Dhakal (2012), AdaptCap (2014), Sapkota (2014) and Willcox et al. (2015). However, the literature did not present evidence to support the link that these improved personal circumstances have resulted in building resilience to climate variability and change.

Strength of evidence

The strength of evidence (presented in Section 4.3) for each resilience dimension was assessed according to the four key characteristics presented in DFID's internal 'How to note' on assessing strength of evidence (DFID, 2014):

- **size** of the body of evidence
- **quality** of studies constituting the body of evidence
- **context** of the body of evidence
- **consistency** of the findings

In addition the analysis also assessed the strength of evidence on how complete the chain of evidence was (as mentioned in detail above):

1. Complete evidence chain
2. Partial evidence chain that could be reliably inferred backwards to complete the evidence chain

3. Evidence chain stopped short of making the link to climate change or adaptation and building climate resilience, and could not be reliably inferred forwards.

Table 12 Strength of evidence

Resilience dimension	Strength of evidence description	Overall Strength
1. Access to services	• The literature review found a relatively large body of evidence (8 studies focussed on this resilience dimension and 2 relevant crosscutting studies). The evidence found is equally moderate and high quality relating to how access to services through energy access can build resilience to climate change. The evidence is country or region specific (e.g.: Sahel, East Africa and Southern Africa or India, Tanzania, Nepal etc.). Evidence consistently shows that access to energy and the services it provides can build resilience to climate change. Evidence supporting the complete evidence chain or a partial evidence chain that could be reliably inferred backwards to complete the evidence chain is presented in the literature.	• Strong
2. Adaptive Capacity (particularly new livelihood strategies)	• The literature review found a relatively small body of evidence (3 studies focussed on this dimension of resilience and 2 relevant crosscutting studies). The quality of evidence is mixed. The evidence is specific to Argentina, Senegal, Nepal, Kenya and India. The evidence consistently suggests that energy access can result in building adaptive capacity particularly though new livelihood strategies. However the evidence chain stopped short of making the link to climate change and building resilience to climate change and climate variability, this link needed to be inferred.	• Limited
3. Income and food access	• The literature review found a relatively small body of evidence (2 studies focussed on this dimension of resilience and 2 relevant cross cutting studies). The quality of evidence is mixed. The evidence is specific to Nepal, Kenya and India. The evidence consistently suggests that energy access can result in providing access to income and food, however there is some inconsistency related to livelihoods with regards to biofuel. However the evidence chain stopped short of making the link to climate change and building resilience to climate change and climate variability, this link needed to be inferred.	• Limited
4. Social safety nets	• The literature review found a relatively small body of evidence (2 studies focussed on this dimension of resilience and 2 relevant cross cutting studies in). The quality of evidence is mixed. The evidence is specific to Haiti, Nepal and Philippines. The evidence consistently suggests that energy access provides access to networks that connect with formal and informal support to stakeholders (Government, aid agencies etc.) as part of disaster response that can help recovery from the impacts. A partial evidence chain that could be reliably	• Moderate

Resilience dimension	Strength of evidence description	Overall Strength
	inferred backwards to complete the evidence chain is shown. .	
5. Livelihood viability	• The literature review found a relatively small body of evidence (1 study focussed on this dimension of resilience and 1 relevant cross cutting study). The quality of evidence is mixed. The evidence is specific to Indonesia and Peru. The evidence consistently suggests that energy access can build resilient livelihoods - particularly by improving access to energy in food production, diversifying livelihoods for co-benefits for poor and marginal groups. However the evidence chain stopped short of making the link to climate change and building resilience to climate change and climate variability, this link needed to be inferred.	• Limited
6. Natural context	• The literature review found a medium sized body of evidence (4 studies focussed on this resilience dimension and 2 relevant cross cutting studies). The quality of evidence is mixed. The evidence is specific to Tanzania, Nepal, Bangladesh, China and East Asia. The evidence consistently suggests that energy access can contribute to reducing likelihoods of deforestation and pressures on ecosystems, and improving soil fertility. However the evidence chain stopped short of presenting results if energy access has actually build resilience to climate change and climate variability, this link needed to be inferred.	• Moderate
7. Personal circumstances (including vulnerable groups)	• The literature review found a medium sized body of evidence (6 studies focussed on this resilience dimension and 1 relevant cross cutting study). The quality of evidence is mixed. The evidence is specific to Tanzania, Argentina, India and Nepal. The evidence consistently suggests that energy access can improve personal circumstances of vulnerable groups to build resilience to climate change and variability. However the evidence chain stopped short of making the link to climate change and building resilience to climate change and climate variability, this link needed to be inferred.	• Moderate
8. Institutional and governance contexts	• The literature review found a relatively small body of evidence (2 studies focussed on this dimension of resilience). The studies are high quality. The evidence is specific to China and Ethiopia. There is a consistent body of evidence relating various policies that are driving the synergies between energy access and adaptation and building resilience to climate change. The evidence chain presented how policy contexts can potentially result in building resilience to climate change and climate variability, however the link had to be inferred as there was no empirical evidence showing the linkages.	• Limited

Key opportunities

Building on the evidence base the following key opportunities have been identified where donors, researchers and development practitioners can immediately strengthen the connection between energy access and adaptation while targeting better and more sustainable outcomes.

1. Promoting energy access through decentralised sustainable options as part of addressing the technology needs for adaptation. Solar PV is a key area that has had successful impacts and widespread uptake so far.
2. Promoting resilient energy solutions such as decentralised renewable energy systems and portable cook stoves for communities that face disruptions to their energy supply during disasters (for instance coastal communities who are highly vulnerable to disasters such as typhoons and face severe disruptions to grid electricity).
3. Promoting energy access for ICTs to help extremely poor communities, particularly those in very remote areas, to access social safety nets through providing access to knowledge and information using ICTs.
4. Including energy access as a component of disaster recovery interventions, which can support economic and social recovery. Solar lighting and ICTs for accessing social safety nets are proven to be successful in disaster recovery processes.
5. Expand opportunities for reducing vulnerability to climate change by mainstreaming adaptation into energy sector policies.
6. Breaking down the policy and research silos between adaptation and access to energy by identifying local adaptation, mitigation and development policies where energy access is a cross cutting element, and encouraging governments and research bodies to gather evidence to support the links and co-benefits between access to energy and adaptation. Relevant initiatives that would be well placed to gather evidence include the development of MRV/M&E systems to deal with international climate change reporting, intended nationally determined contributions (INDCs) and the development of national low carbon development strategies and adaptation strategies.

Gaps in evidence

The ultimate measure of the effects of energy access on building resilience will be the extent to which energy access can be associated with reducing sensitivity and exposure, and increasing adaptive capacity during adverse effects of shocks and stresses, leading to change in the reactions to disturbance beyond surviving. The challenge is that the success of energy access in building resilience to particular climate related shocks and stresses can be measured only if it is possible to measure what would have happened without the energy access under shocks and stresses. The link between energy access and adaptation/building resilience to climate change has largely been overlooked. There is a gap in high quality literature that can provide a strong evidence base that show how people have reacted to the stresses and shocks after an intervention has taken place which included an energy access element.

The following can be highlighted as some of the key gaps that future research programs and interventions should focus on to harness opportunities and overcome challenges. The gaps have been identified and framed under the first three elements of DFID’s Resilience Framework.

Element 1: Context

- While there are some inferred linkages in the literature reviewed that indicate how women, children and elderly can improve their personal circumstances to build their adaptive capacity to climate change, there is lack of empirical evidence whether the benefits gained from energy access have actually contributed to building resilience to climate change among these vulnerable groups. Thus empirical and theoretically informed work on the role of gender and other vulnerable groups in energy access and climate change adaptation is needed. The evidence reviewed in the literature is not sufficient to identify what the best and the most successful scale of interventions have been (community, household, institutional or national level), nor specifically what the opportunities and challenges are at different scales. More empirical research is needed related to scale to understand this better.

- Although included in the search string (in Appendix 1) used for the literature search, this literature review did not capture studies that identified conceptual or empirical evidence discussing the linkages between energy access in urban areas and building resilience to climate change among urban populations. Much of the literature review has been on rural and coastal areas, whereas urban areas (such as urban slums) appear to be understudied regarding both resilience and energy access.
- Lack of information on the context in studies limits the ability to understand what works for certain communities and what would not work. For example studies tend to focus on the technical or policy aspects of implementing access to energy but it is equally important to understand the physical and cultural context in order to successfully transfer technology and the associated adaptation/resilience outcomes to different communities or different countries and to scale-up. In addition, lack of understanding with respect to context specific information such as cultures, individual, community and institutional needs, local governance and support policies may result in maladaptation.
- Further work needs to be carried out to understand more clearly whether some energy technologies are better at supporting adaptation than others. This is partly due to the fact that a number of energy technologies could be used to provide the same service (e.g.: lighting, water pumping, heat for cooking, refrigeration, ICTs etc.) and it is the service that the energy enables that ultimately contributes to adaptation. Some energy technologies have featured more commonly in the literature reviewed (such as solar PV, ICS and biogas), but there was no comparative evidence in the literature to conclude one energy technology was better than another at providing particular services. The most suitable energy technology in any given situation will depend heavily on the local context and the service required.

Element 2: Disturbance

- Within the literature reviewed, there is lack of consideration of the shocks and stresses, particularly where the evidence chain stops short from linking to building adaptation and resilience to climate change and climate variability. The conceptual findings highlight that energy access interventions should consider future projections for climate change within a local environment. Furthermore for an energy solution to support climate adaptation it needs to also identify the level of impacts of climatic change and climate variability on the energy system itself. Although conceptual findings present the need for climate proofing energy systems there was very little empirical evidence in the literature reviewed to confirm the viability of doing so.
- Lack of understanding of the linkages between disturbance and response can lead to making unsuccessful development decisions, thus resulting in maladaptation.

Element 3: Capacity (Exposure, Sensitivity and Adaptive Capacity)

- More case studies are needed to provide empirical evidence on specific situations where energy access has resulted in adaptation and building resilience, particularly on those dimensions of resilience where the link has been inferred. For instance, empirical research on how energy access actually contributes to adaptive capacity to climate change, could build indicators that can be used in the evaluation of adaptive capacity in energy access programmes, and could help guide how context and shocks are factored into future energy access programmes and planning.

- Lack of understanding related to the links between access to energy and adaptation hinders recognising to what extent energy access actually leads to resilience and whether some of these changes are maladaptive, i.e. people/ communities don't recover or adapt, they are actually worse off. For instance, how new incomes generated through provision of energy access are being used and, are the new livelihoods created through provision of energy access impacting existing livelihoods and markets.
- Future case studies should identify the key elements (e.g.: financial, political, technical, local physical and cultural context, capacity building requirement etc.) that contribute to the success or failure of the particular intervention, to inform technology transfer and scale-up.
- This literature review identified cases where attributes such as affordability and reliability were recognised as important aspects of gaining access to services when faced by shocks and stressed. These include AdaptCap (2014), Gippner et al. (2013), Murphy and Corbyn (2013) and Institute of Rural Development Planning Tanzania (2014). However further conceptual and empirical research needs to be undertaken framing how the attributes highlighted in the SE4ALL Global Tracking Framework can be used in practice for measuring energy access and if these attributes contribute to building adaptation or resilience to climate change and climate variability.
- In the literature reviewed there is a lack of framing how energy access can result in maladaptation (Section 4.1). A clear conceptualisation of maladaptation with respect to energy access is needed to recognise how it can be assessed and captured within existing research that link energy access and building adaptation and climate resilience.

Furthering research

The above gaps have been identified from a comprehensive literature review. Researchers, policy makers and practitioners all have a role to play in helping to fill the gaps in evidence effectively and urgently, through more theoretical and empirical informed research.

Focusing in on strategic approaches, such as community based energy access that offers strong links to the various dimensions of resilience, will help break down the silos often put up between the adaptation/resilience vs. mitigation/development thinking, enabling transformational and holistic frameworks to be established. There is a large potential for raising the profile around improving access to energy by identifying the co-benefits of adaptation arising from energy access projects, particularly given that small scale renewable energy technologies can play a key role in both adaptation and mitigation in developing countries.

In order to strengthen and complement the findings of this literature review, as a next step it is recommended to conduct further research, building on stakeholder and expert interviews and discussions to gather evidence from existing projects. This should also include country focused field research including analysing policy and institutional contexts in selected least developed countries to identify if the link between energy access and climate change adaptation has been made or could be made in line with future development plans and goals. An option could be to focus particularly on those countries that are actively attempting to combine development, adaptation and mitigation through policy ideas such as low carbon resilient development, climate compatible development or green growth. In addition it could focus in countries where any MRV systems for international climate change reporting are aiming to gather evidence of the links or synergies between mitigation and adaptation. This research could also provide the opportunity to further investigate the linkages between energy access and climate change adaptation, to provide robust and strategic policy and programme recommendations that can also benefit ongoing planning and preparation around the post-2015 development agenda related to sustainable energy, climate change and development.

SECTION 7

References

7.1 Full bibliographic references of reviewed papers and quality rating

	Table header	Quality	Evidence linking to resilience dimensions (as presented in Section 4.3)
1.	AdaptCap, 2014. Strengthening Adaptation Capacities and Minimizing Risks of Vulnerable Coastal Communities in India (AdaptCap): Monitoring & Evaluation Report.	*High*	*Access to services; Personal circumstances*
2.	Addo, A., Bessah, E., Amponsah, S., 2014. Uncertainty of food security in Ghana by biofuel (jatropha curcas) production as an adaptation and mitigation capacity to climate change. English.	*Moderate*	*
3.	Akkerman, M., Binh, H.T., Phuong, D.T., 2014. Strengthening the resilience of vulnerable groups to disasters and climate change: sustainable energy solutions in Quy Nhon City, Asian Cities Climate Resilience. International Institute for Environment and Development (IIED).	*High*	*
4.	Atteridge, A., 2013. Transforming household energy practices to reduce climate risks: Charcoal use in Lusaka, Zambia. Boiling Point-Climate Change: Adaptation, Resilience and Energy Security.	*Moderate*	*
5.	Auth, K., 2012. In Haiti and Rwanda, Renewable Energy Helps Power National Recovery.	*Low*	*Social safety nets*
6.	Bogdanski, A., 2012. Integrated food–energy systems for climate-smart agriculture. Agriculture & Food Security 10.	*Moderate*	*
7.	Cabana, Y., 2012. Using Radio to Improve Local Responses to Climate Variability: The Case of Alpaca Farmers in the Peruvian Andes (Case Study), ICTs and Agricultural Adaptation to Climate Change.	*Moderate*	*Access to services; Social safety nets*
8.	Christensen, J., Denton, F., Garg, A., Kamel, S., Pacudan, R., 2006. Changing Climates The Role of Renewable Energy in a Carbon-Constrained World.	*Moderate*	*
9.	Climate Change Knowledge, International Institute for Sustainable Development, 2004. Seeing the Light: Adapting to climate change with decentralized renewable energy in developing countries. Climate Change Knowledge Network, International Institute for Sustainable Development.	*High*	*Adaptive capacity; Natural context; Personal circumstances; Assets*
10.	Dhakal, N., 2012. Forest Conservation and Improved Cooking Stoves (ICSs) Evolving a replicable project, implemented by Eco Himal, Nepal and focussing on the Village Development Committees (VDCs) of Lokhim1and Pawai (Lower Solu Khumbu district) and Bakachol (Khotang district). The Glacier Trust, Nepal.	*Moderate*	*Natural context; Personal circumstances*
11.	Eleri, E.O., 2007. Strengthening Energy and Ecosystem Resilience in Nigeria. Helio International.	*Low*	*
12.	Fang, Y., Wei, Y., 2012. Climate change adaptation on the Qinghai–Tibetan Plateau: The importance of solar energy	*High*	*Institutional and policy*

EVIDENCE ON DEMAND
CLIMATE & ENVIRONMENT
INFRASTRUCTURE | LIVELIHOODS

	Table header	Quality	Evidence linking to resilience dimensions (as presented in Section 4.3)
	utilization for rural household. Renewable and Sustainable Energy Reviews.		
13.	Federal Democratic Republic of Ethiopia, 2011. Ethiopia's Climate-Resilient Green Economy Green economy strategy.	***Moderate***	***
14.	Fisher, S., 2013. Low-carbon resilient development in the least developed countries: Emerging issues and areas of research.	***High***	***Institutional and policy***
15.	Garg, A., Halsnæs, K., Han, W., Hwang, J., Kim, J., 2007. From Vulnerability to Resilience: The Challenge of Adaptation to Climate Change Case Studies from Bangladesh, Brazil, China, India, South Africa and Korea. UNEP Risø Centre, Denmark and Korea Environmental Institute.	***High***	***Personal circumstances; Natural context***
16.	Gippner, O., Dhakal, S., Sovacool, B.K., 2013. Microhydro electrification and climate change adaptation in Nepal: socioeconomic lessons from the Rural Energy Development Program (REDP). Mitig Adapt Strateg Glob Change. doi:10.1007/s11027-012-9367-5	***High***	***Adaptive capacity; Income and food access; Personal circumstances; Access to services***
17.	Giri, S., Malakar, Y., 2011. Using Mobile Phones to Reduce the Adversities of Climate Change in Rural Nepal (Case Study), ICTs and Agricultural Adaptation to Climate Change. Practical Action Nepal Office.	***Moderate***	***Access to services; Social safety nets; Livelihood viability***
18.	Government of Kenya, 2013. Kenya Technology Needs Assessment- ADAPTATION.	***Moderate***	***
19.	Gupta, M., Velumail., T., 2011. Sustainable Energy Access for the Poor: A Means for Promoting Climate Change Adaptation of Communities.	***Moderate***	***
20.	Institute of Engineering, Center for Energy Studies (CES), 2013. Final Report on Study on Role of Renewable Energy Technologies in Climate Change Mitigation and Adaptation Options in Nepal.	***Moderate***	***
21.	Institute of Rural Development Planning Tanzania, 2014. Chololo Eco Village: a model of good practice in climate change adaptation and mitigation.	***Moderate***	***Access to services; Natural context; Personal circumstances; Adaptive capacity; Assets***
22.	International Renewable Energy Agency (IRENA), 2015. Renewable Energy in the Water, Energy and Food Nexus.	***High***	***Access to services; Livelihood viability***
23.	Jarvie, J., Nicholson, D., 2013. Building climate resilience through community based energy security. Boiling Point-Climate Change: Adaptation, Resilience and Energy Security.	***Moderate***	***Access to services; Adaptive capacity; Income and food access; Social safety nets; Natural context; Assets***
24.	Johnson, F.X., Lambe, F., 2009. Energy Access, Climate and Development. Stockholm Environment Institute (SEI).	***Moderate***	***

	Table header	Quality	Evidence linking to resilience dimensions (as presented in Section 4.3)
25.	Kumar, A., 2011. Energy access for climate change mitigation and adaptation : the "micro renewable" solution. Presented at the Micro Perspectives for Decentralized Energy Supply, Universitätsverlag der TU Berlin, Berlin, p. 7.	***High***	*
26.	Murphy, B., Corbyn, D., 2013. Energy and Adaptation: Exploring how energy access can enable climate change adaptation. Practical Action Consulting.	***Moderate***	*
27.	Ochieng, C., Juhola, S., Johnson, F.X., 2015. The Societal Role of Charcoal Production in Climate Change Adaptation of the Arid and Semi-Arid Lands (ASALs) of Kenya, in: Climate Change Adaptation and Development: Changing Paradigms and Practices. London.	***High***	*
28.	Platonova, I., Leone, M., 2012. The energy-water nexus in the context of climate change in developing countries: Experiences from Latin America, East and Southern Africa (Synthesis Report). IDRC, Canada.	***High***	***Access to services; Income and food access; Natural context***
29.	Sapkota, A., Lu, Z., Yang, H., Wang, J., 2014. Role of renewable energy technologies in rural communities' adaptation to climate change in Nepal. Renewable Energy 7.	***Moderate***	***Personal circumstances***
30.	South Centre, 2008. The role of decentralised renewable energy technologies in adaptation to climate change in developing countries. Geneva.	***Low***	*
31.	Stone, J., 2013. Climate Change: Adaptation, Resilience and Energy Security- Expert response by Jeremy Stone – Climate change and renewable energy consulant. Boiling Point- Climate Change: Adaptation, Resilience and Energy Security.	***Moderate***	*
32.	Symons, K., 2013. How Bioenergy Can Help Local Communities Adapt to Climate Change: Lessons from Nyanza Province, Kenya (Policy Paper), Policy Innovation Systems for Clean Energy Security (PISCES). University of Edinburgh.	***High***	***Access to services***
33.	Williamson, L.E., Connor, H., Moezzi, M., 2009. Climate-proofing Energy System. Helio International.	***Moderate***	*
34.	Willcox, M., Pueyo, A., Waters, L., Hanna, R., Wanjiru, H., Palit, D., Sharma, K.R., 2015. Utilising Electricity Access for Poverty Reduction. Practical Action Consulting (PAC), Institution of Development Studies (IDS), The Energy and Reseach Institute (TERI).	***Moderate***	***Adaptive capacity; Income and food access; Personal circumstances***

* These documents only provided information on conceptual links to answer question 1 "How has energy access been framed in the context of adaptation and building resilience to climate change and climate variability?"

7.2 Other references

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SECTION 8

Appendices

Appendix A: Search string

	Search 1- variations of sources of energy access and services with variations of Climate Risk for Individuals/Groups etc.	Search 2- variations of sources of energy access and services with substitutions for Risk, Resilience, Adaptation and Vulnerability
Level 1	energy electric*	Energy electricity
	PLUS ONE OF THE FOLLOWING	
Level 2	Access use cook* stove* heating off grid connection wood /fuel renewable* clean sustainable kerosene diesel irrigation health wood dung hydro solar biogas biomass waste	Access use cook* stove* heating off grid connection wood /fuel renewable* clean sustainable kerosene diesel irrigation health wood dung hydro solar biogas biomass waste

	wind on grid decentralis* mini grid productive pump ICT Radio TV mobile phone light* Heat* Cool* fan	wind on grid decentralis* mini grid productive pump ICT Radio tv mobile phone light* Heat* Cool* fan
	PLUS ONE OF THE FOLLOWING	
Level 3	Climate chang* Climate variabil* Climate extreme* resilien* vulnerab* sensitivity risk* adapt* maladapt* disaster* response*	anticipation networks* decision making* ecological system adaptive capacity* human social financial economic physicalinstitutions* poverty traps* project* poverty poor preparedness knowledge system* emergency events disaster mitigat* inform* sustain*

		disaster risk tool* livelihood interlinkages hazard manage* technolog* capacit* abilit* disaster response* skill* disaster recovery* recovery* financ* income employment air quality Awareness time saving education eco system productive use* enterprise Early warning system* Seasonal weather forecast* Forecast* Adverse event* Weather
	PLUS ONE OF THE FOLLOWING	
Level 4	group* poor* women* girls* gender disabled* people* minority*	Economic Development Well-being Social development Empower* Co-benefits Benefits

	marginal* discriminated* chronic*	
		PLUS ONE OF THE FOLLOWING
Level 5	isolated Local regional national community household productive users business cities rural developing countr* low income countr* Sub Saharan Africa Africa Asia South Asia Latin America Europe US	isolated Local regional national community household productive users business cities rural developing countr* low income countr*Sub Saharan Africa Africa Asia South Asia Latin America Europe US

Appendix B: Detailed reviews

The template used for assessing the detailed literature search is provided below.

For a full account of the literature search recorded, please see separate document attached.

Ref: 1 (Author, year)	
Title	
Full Bibliographic reference	
Type of document (Peer reviewed or grey literature)	
Research Type • Primary: Experimental/ Quasi experimental/ Observational • Secondary: Systematic Review/ Other Review • Theoretical/ Conceptual	
Method (Qualitative, Quantitative, Both)	
Overview	
Quality of the paper (High, Moderate, Low)	
Type of energy application (e.g.: cooking, heating, electricity used for lighting, productive use, irrigation, ICT etc.)	
Source of energy (Wind, Hydro, Biomass, Solar PV, Fossil fuels, Human/animal power)	
Attributes related to level of access to energy (Capacity, Duration/ Availability, Reliability, Quality, Legality, Affordability)	
The elements covered: adaptation or resilience or vulnerability	
Climate hazard (s) covered	
Climate risks or opportunities covered (e.g.: Evidence of institutional, social learning and actions on energy access following or relating to the events and responses in real actions- Livelihoods diversification, food security etc.)	
Vulnerable groups covered (e.g.: women, girls, extreme poor, tribal etc.)	
Scale (household, business, communities, national, regional, all)	
Geographical coverage	
Institutions and policy contexts with evidence emerging of these linkages	
Sectors covered (e.g.: Agriculture, Water, Energy, Urban Infrastructure, Health, Sanitation etc.)	
Question 1: How has energy access been framed in the context of adaptation and building resilience to climate change and climate variability?	
Response 1	

Ref: 1 (Author, year)
Question 2 a: What does the literature say in terms of evidence that access to energy increases resilience and contributes to adaptation to climate change?
Response 2a
Question 2 b: Is there any evidence that access to energy contributes to maladaptation?
Question 3: What are potential challenges and opportunities for promoting energy access as a means of adaptation to climate change?
Response 3
Any key areas/factors/questions the literature fails to address

Appendix C: Long list of literature captured

The table below presents 96 out of the 130 studies that were captured through the literature search and included as the long list. The remaining 34 studies were used in the detailed review of this literature review, these are presented in Section 7.1.

1. A.A. Refaat, 2008. Recommended Integrated Climate and Energy Policy for Africa: the Continent of many Contradictions. Presented at the 2nd WSEAS/IASME International Conference on Energy Planning, Energy Saving, Environmental Education (EPESE'08), Greece.
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