# Energy and Adaptation

## Exploring how energy access can enable climate change adaptation

June 2013

Prepared for PISCES by Practical Action Consulting

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Cover image: Woman cooking on upasi stove inside refugee tent after flooding in Gaibandh, Northern Bangladesh
Photo credit: Samaj Kallayan Sangstha (SKS)

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# Executive Summary

It is widely recognized that it is the poorest people who will be hit first and hardest by the impacts of climate change. Climate variability and change, as well as an increasing frequency and intensity of extreme events, will have substantial impacts on societies. In particular, developing countries are the most vulnerable to the impacts of climate variability and change because they have fewer social, technological and financial resources to support adaptation. This paper explores how improved access to energy can contribute to the challenge of adapting to climate change for people living in poverty.

Access to modern energy services is critical for social and economic development. The six case studies in this paper explore how energy is also important for adaptation. This working paper postulates that access to energy contributes to enabling climate change adaptation in the following ways:

### Improving general physical and economic well-being

Improving people's general physical and economic well-being provides the pre-requisites for resilience and adaptation. Access to energy enables broad social and economic development; if people are healthy, wealthy and wiser they have greater capacity to adapt.

### Building resilience

Modern energy and technology enables a whole host of productive use activities; diversification of livelihoods away from vulnerable activities is a key factor in building resilience to adverse events, including the impacts of climate change

### Enabling innovation and adaptation through ICTs

Access to knowledge and information powers innovation; it enables experimentation and testing of different adaptation options. Electric-powered ICTs including mobile phones, TVs and radios can provide valuable information that can, for example, inform a farmer about new drought-resistant plant varieties, farming techniques or seasonal weather forecasts.

### Empowering communities

Energy technologies can be deployed in such a way that empowers communities. Approaches that strengthen community organisation and decision making, and build relationships with local stakeholders can empower communities to take independent action in the future in response to climate change.

It is important to note that energy is an enabler, but not the be-all and end-all. Additional, complementary activities beyond simply the supply of energy are necessary to fully realise the adaptation co-benefits of improved energy access. For example, diversified livelihoods through productive use of energy will not necessarily follow when a community is connected to an electricity grid; entrepreneurs need electrical equipment, finance and the knowledge and skills to run their enterprise.

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. Furthermore, proving that energy contributes to adaptation offers new possibilities of funding energy access initiatives through climate change funds.

Further research is required to strengthen the evidence for energy access as a contributor to adaptation and to explore approaches that can deliver the co-benefits in a sustainable and scalable manner.

# 1. Introduction

Climate change has been recognised as a global environmental threat and the impacts related to climate change are likely to worsen over the coming decades. While mitigation efforts to reduce greenhouse gas emissions and avert dangerous interference with the climate system are critically important, adaptation to the adverse impacts of climate variability and change is necessary now and will continue to be well into the future.

Energy is widely recognised as having an important role in mitigation through low carbon development. However, the connection between energy access and adaptation has so far not been sufficiently recognised or explored and there are very few methodological or policy frameworks that link the two. Furthermore, practitioners have often focussed on the incompatibilities that sometimes arise between the objectives of increasing access to energy (to promote socio-economic development) and those of climate change mitigation (where emission reductions are a priority) and adaptation (where improving adaptive capacity is a priority). Figure 1 illustrates the elements of the development, mitigation and adaptation strategies, and shows the potential synergy of climate-compatible development.

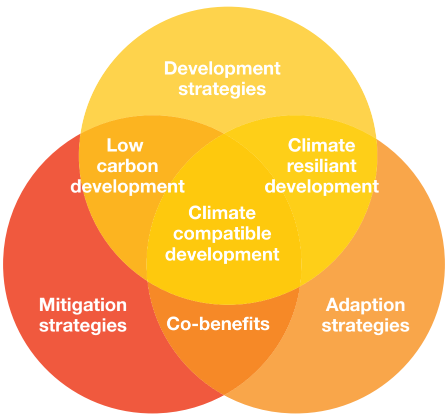



Figure 1: Climate compatible development (Adapted from Mitchell et al., 2010)

This paper argues that energy access is the golden thread that connects development, adaptation and mitigation. It posits 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.

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. Furthermore, proving that energy contributes to adaptation offers new possibilities of funding energy access initiatives through climate change funds. For example, the Adaptation Fund that was established to finance concrete adaptation  HYPERLINK "http://www.adaptation-fund.org/funded_projects" projects and programmes in developing countries that are parties to the Kyoto Protocol and are particularly vulnerable to the adverse effects of climate change.

This paper begins by defining climate change adaptation and the importance of energy access in order to frame the case study analysis. Six case studies are presented from sub-Saharan Africa, South Asia and Latin America that explore how energy has contributed to building adaptation in specific projects. The case studies are then analysed to provide the summary of co-benefits. Analysis of the case studies is summarised into four co-benefits. The paper concludes with recommendations and outlining further research requirements.

## 2. Adapting to a changing world

Poor communities concentrated in the areas of high (climate-related) risk are particularly vulnerable to climate change (FAO, 2008); dependence is high on resources that are climate-sensitive such as water for human consumption and irrigation, wood for burning and building, biomass for heating and cooking. In addition to climate change impacts, poor communities face multiple stressors such as market fluctuations and lack of access to current information and technology. The vulnerability and resilience factors vary widely between geographic regions, rural and urban areas, community scenarios and many other factors – but they are in many cases worsened by the lack of access to modern energy services.

Fundamentally, all societies are adaptive to changes in climate; and in the past societies have adapted to climate change and similar risks. But some groups in the society are more sensitive and vulnerable to climate change-related risks than others (Adger et al., 2003). This is because different societies have different resources and coping mechanisms to deal with various threats (Adger, 1999). When the viability of ecosystems is threatened, it ultimately threatens people who directly rely on the natural resources for their livelihoods (Williamson et al., 2009).

When a change in climate is too sudden and does not have recent historical precedent, the familiarity or capacity to cope and adapt may not be present. One of the most common responses to environmental stresses has been migration to more hospitable regions on a seasonal or permanent basis. However, in a crowded world where there are no verging territories left to exploit, large population movements are known to cause stress and hostility within and between countries and have ceased to constitute an effective adjusting measure. The pastoralists who suffer repeated or multiple crises and have lost their livestock, or people displaced by conflict, would take actions simply to survive and become dependent on a limited number of marginal activities, such as firewood collection, brick making, casual labour etc. These coping strategies are the short-term responses to deal with shocks and are not necessarily 'adaptation' in a positive sense. (If environmentally damaging and therefore not sustainable, this is referred to as maladaptation). Positive adaptation involves long-term changes to the mix of activities required for subsistence.

The ability to minimise negative impacts and maximise any benefits from changes in climate is known as adaptive capacity. There are several aspects that contribute to this capacity: the asset base made of economic and infrastructural resources; the institutional environment that must ensure equitable access and entitlement to key resources; the ability of the system to collect, analyse and disseminate knowledge and information in support; ability to innovate and test niche solutions; and elements of flexibility and dynamics of the decision-making and governance to best respond to evolving circumstances (Jones et al., 2010)

On a practical level, economic capacity can for example refer to the extent to which households are able to diversify and incorporate non-agricultural components (which are less likely to be disrupted by natural disasters) into their income-generating strategies, or the ability to commute outside of drought-and flood-affected areas to pursue sources of income. The social capacity would be strengthened by education and community institutions, and weakened by existing patterns of vulnerability created by gender, income and social position. The structural capacity could relate to the ability of households to obtain secure sources of water for domestic uses, whether by exploiting local sources, distant water markets, or rural supply schemes (Workshop of NAPA 2009).

As well as changing, people should be able to withstand a threat if and when it strikes. The resilience can be defined as 'the capacity of a system to anticipate, prepare for, respond to and quickly recover from the changes in the system – be it climate shock and stresses or other drivers of change' (Badahur et al., 2010).

Clearly, to ensure resilience effectively, particularly because of the uncertainty of where and how climate change impacts will be felt, existing threats should also be addressed (Ensor 2011). This inextricably links the climate adaptation community to the mainstream development community, highlighting how human development projects that are not specifically focussed on climate change share a common ground with adaptation interventions (See Box 1).

Disproportionately, the communities most affected by climate change are often marginalised, remote and receive limited services or support from their governments. An effective way to operate interventions within this context is through community-based adaptation which recognises that the environmental knowledge and resilience to climate impacts lies within societies and cultures. The focus is therefore on empowering communities to take action on vulnerability to climate change, based on their own decision-making processes; involving the community in the planning, design and construction of projects, as well as linking with actors that provide support to build the necessary capacity to deal with a range of threats into the future. The goal of community-based adaptation projects is to increase the climate resilience of communities by enhancing their capacity to cope with less predictable rainfall patterns, more frequent droughts, stronger heat waves, different diseases and weather hazards of unprecedented intensity (Ensor et al., 2008).

**Box 1** **Adaptive Capacity and Human Development (Swedish Commission on Climate Change and Development, 2009)**

Wealth, or access to assets, provides the buffers and backup that takes people through crises and enables them to recover. Assets may be financial or material, directly accessible or through insurance, and come from the social networks of family and kin or through government social protection schemes for those with few means of their own.

Health safeguards the productive capacity of the individual and the integrity of families. This comes through clean water and effective sanitation, safe childbirth, and food of the right kind and amount so that children grow to their full potential.

Education gives people access to information, knowledge of their options, and the ability to make informed choices.

Governance, or rather the fullness of the institutional environment, provides the means through which people, working with others, have access to resources, articulate needs, and exercise their rights.

## 3. The Importance of Energy Access

Access to energy is considered a prerequisite for human development, essential for meeting basic and productive needs in households, enterprises and community institutions. Yet a vast proportion of people in developing countries remain without access to modern energy: 1.3 billion people are without electricity, and almost 3 billion cook using solid fuels, largely on a three stone fire. These traditional energy sources are characterised by inefficiency, high cost, and health implications. Three stone fires, for example, require more fuel compared with an improved stove, thus demanding more time spent collecting wood, or a higher percentage of household income spent on fuel. Using traditional cooking methods indoors kills 2 million people a year, mostly women and children, through smoke pollution (UNDP/WHO, 2009).

It is the services derived from energy - including lighting, cooking and water heating, space heating, cooling, and access to information and communications - that are essential to meeting people's basic needs and enabling development. Economic activities either rely on these services or are substantially improved in their productivity, profitability, and efficiency, allowing more time and money to be devoted to livelihoods than would otherwise be spent on the burdens of using traditional energy. Access to energy for community institutions, such as schools, health centres, meeting places, and local government buildings, help attract greater provision and efficiency of support, adding to the quality of life and livelihoods.

Energy access includes a wide range of technologies and uses. One definition of Total Energy Access is given as "Households, enterprises and community services have sufficient access to the full range of energy supplies and services that are required to support human social and economic development" (PPEO, 2013).

# 4. Case studies

## 4.1 Energy and Resilience: Bio-Oil Fuels Livelihoods in Ghana

Efficient production of shea butter requires a mechanical grinding machine; traditional manual techniques are labour and time intensive and produce low-quality butter. With the intention of encouraging sustainable rural industries and the economic empowerment of rural women, UNIFEM and the UNDP-GEF Small Grant Programme supported a local women's group in Gbimsi, Ghana, to initiate mechanised production of shea butter. The new extraction technology requires a shorter time and less effort, and avoids the use of excessive firewood and water. The Jatropha oil was identified as a source of energy to power the extraction equipment and was locally produced as part of the project.

The training programmes were introduced to reinforce women's entrepreneurial skills and help build their confidence; from learning to operate and maintain the oil extraction machines, to bookkeeping and basic accounting. Once the commercial production commenced, production levels went up sharply, securing higher level of income and pushing the group to seek new external marketing avenues. Moreover, much of the drudgery involved in the shea butter processing was eliminated, freeing time for other income generating activities.

The impact of this project has multiple dimensions which address different aspects of adaptation. At the national level, it provides an independent facility for energy generation which contributes to national preparedness toward hazards, making the whole system resilient to shocks. Also, it reduces the local use of biomass and water, helping to conserve the country's precious environmental resources.

At the household level, it has improved several components of livelihood resilience. "A livelihood comprises the resources (including skills, technologies and organisations) and activities required to make a living, and have a good quality of life" (Pasteur, 2011). In this case, each aspect mentioned by Pasteur (skills, technologies and organisations) of the resources needed to support the business enterprise have been strengthened. The capacity building programme has resulted in increasing the women's economic and negotiating skills, self-esteem, and preparedness to make choices. The introduction of more efficient technology has provided a readily available, affordable and renewable fuel that protects the business activity from national increases in price or shortages of diesel. The third aspect, organisation, has been strengthened with the engagement of the women's group in a wider network of external actors, broadening their outlook and enabling the creation of partnerships and the access to new markets and appropriate technologies.

Another way in which livelihoods have become more resilient is through the poverty reduction effect that the project has had through the women's activity as entrepreneurs, and the diversification of income avenues which decreases exposure to potential shocks. Further, substantial indirect benefits in terms of household health have been obtained from the use of Jatropha oil as a kerosene substitute in local lanterns. Finally, gender equality gains have been achieved by accompanying the empowerment of women with work carried out at the family level.

However, the scaling up of the project would require a rigorous scrutiny of the energy production system to establish current strengths and weaknesses and what impact climatic change might have on it. For example, it would be useful to determine yield levels on marginal and arable land and how these vary with the precipitation and temperature; to assess the productive life span of the plant locally and what variations occur in different climatic zones; to ascertain the plant's resistance to parasites and diseases in the area of interest and how these vary elsewhere. This analysis is described as "climate proofing" of energy systems, and should become a mandatory part of every energy project.

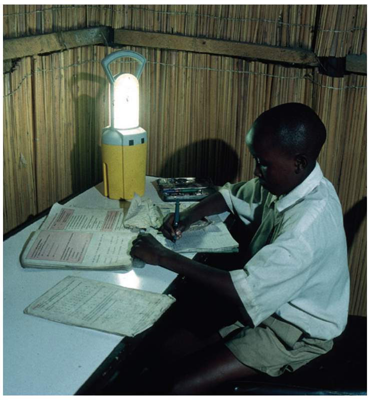
## 4.2 Energy and Communication: Radios, Meteo-Stations, Warning Systems

If people are to adapt to new circumstances, they need to know the types of changes and threats that are likely to occur, what solutions are possible, and where support can be accessed. 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. Information and Communication Technologies (ICTs) programmes are disseminating information that helps farmers to 'take timely decisions, especially on which crop to cultivate, what preventive measures to take when facing disease or pest attacks, when to harvest and what prices to demand' (Grimshaw et al., 2011). The vast majority of these technologies require electrical power and may be promoted through energy projects. However, as some of the following examples show, it is crucial that the technology is introduced in energy projects alongside the analysis of social and local conditions, opportunities and constraints, and that successful project design must always take into account every aspect of planning of which technology is just a small part. For example, in the case of early warning system in Nepal, powered sirens play an important but limited role in the overall alert structure, which is primarily made up of existing, traditional communication channels.

**Table 1: Use of information to deal with future uncertainty (Pasteur, 2011)**

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

### 4.2.1 Solar Lamp and Radio



Young boy using Solar lantern to do his homework in the evening, Kenya
Photo Credit: Practical Action

The off-grid lighting market in Africa is thriving; nearly 7 million people are now using solar lights and the market is growing at about 100% every year (Lighting Africa, 2013). Providing access to lighting allows longer working and studying hours in the day, impacting on education and increasing opportunities for better livelihoods. The possibility to charge a mobile phone opens to connectivity and a vast range of opportunities. Listening to the radio also offers substantial benefits - and particularly in a disaster situation to receive and act upon important information.

### 4.2.2 Hydro Powered Community-Focussed Radio

CAMECO, a consultancy specialising in media and communications, provides a good overview of several projects in which renewable energy technologies were employed to power local radio stations in areas with no grid connection, enabling them to reach isolated groups with relevant information. An example is the radio station installed in a remote highland village in Indonesia, which broadcasts “crop prices for local subsistence farmers, advice on health and women’s rights, announcements from the local government and other news and information” to people with the highest poverty levels in the country. The station was set up after a famine in 2005 claimed the lives of 55 people, which could have been avoided if “the information about crop failures had been communicated quickly”. The radio is supplied with energy by a purpose built micro-hydro facility which also provides 7kW of power to local villages. The cost-benefit analysis based on the local natural and infrastructural conditions led to the identification of this energy solution over solar panels due to the lack of sun in the region, and over diesel generators because of the cost of fuel and the difficulty of transport.

This is another case in which decentralised solutions represent a better choice for the local situation: granting independence, isolation from grid interruptions, and an economic gain.

### 4.2.3 Early Warning Systems for Flooding

Improved flood watch towers

Photo Credit: Practical Action Nepal

In Nepal, downstream villages had experienced flooding for years. Despite measurement of the river from upstream gauge-reading stations that could have warned villagers, information was only sent to central agencies and academics. To address this problem, Practical Action’s Nepal programme coordinated and collaborated with the Department of Hydrology and Meteorology (DHM), the focal agency in the Government of Nepal, to monitor hydro-meteorological data. The practice was changed and permitted the data to be shared with vulnerable communities living at the risk of floods and with other stakeholders such as district disaster response committees, security forces (army, armed police, and general police) and media (especially local FM radios).

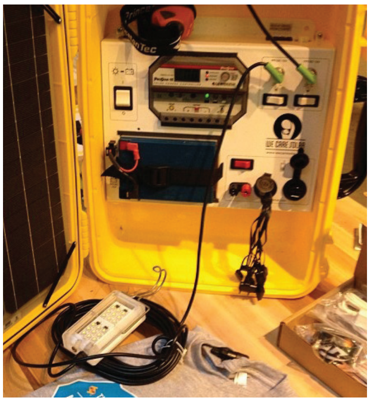
In addition, the programme has also focussed on strengthening the community capacity to predict and warn of floods themselves, respond to extreme events when they inevitably occur, and adopt mitigation measures such as building spurs and dykes.

In the initial stage, as a part of the early warning system, watch towers were constructed and equipped with electrical siren systems, despite some constraints such as reliance on batteries and unreliable power supply during periods of heavy rain. The system was based on ‘watch and warn’ in which communities monitored flood at local level and then informed communities of impending disaster due to floods. However, due to less lead time available on local watch and warn system, Practical Action jointly with DHM started linking flood vulnerable communities with gauging stations upstream. This has given an ample lead time of 3 to 7 hours depending on the location of community, which helps communities to be alert, prepare and respond when and as necessary. The major means of communication are telephones, mobiles and wireless used by security forces.

The extended hours of load shedding and unreliability of power supply sometimes hinders the communication from upstream gauge station to downstream community, and then within communities. The DHM has provided solar systems with back up batteries at upstream gauge stations to ensure an uninterrupted power supply. The Practical Action Nepal Programme has distributed hand operated sirens and megaphones to disseminate such information among vulnerable communities. The current system developed by Practical Action together with DHM and other partners is a milestone towards meeting the need for technologies to strengthen the capacity of the communities and stakeholders in responding to changes in climate.

While the technology input in this case has been important, it is useful to note that much of the project has focussed around developing the community’s own capacity to monitor the behaviour of the river and strengthening the traditional alert communication channels through training and improving organisation. This is a good example of how well-rounded projects are better able to tackle adaptation problems.

## 4.3 Energy and Health: Medical Equipment in a Solar Case



Solar Suitcase
Photo Credit: WE CARE Solar

An example from many of the energy services that can make an immense contribution to disaster interventions is the Solar Suitcase (by WE CARE Solar). Originally designed to support timely and efficient emergency obstetric care, it is a solar appliance that now provides energy for a range of emergency medical and humanitarian needs. It shows how available and appropriate technology, (high-efficiency LED light for medical task lighting, phone and battery chargers, contained in a rigid suitcase) can be suited to the needs of medical applications and disaster relief.

## 4.4 Resilient Energy Solutions: Portable Stoves in Bangladesh

The char lands of Bangladesh are precarious islands or embankments created as the major rivers shape their course through the plain, depositing silt and sand on one bank and eroding it on the other. Seven million people live at risk of flooding in these precarious locations, and are increasingly vulnerable as rainfall becomes more intense, and glacial run-off in Nepal and Bhutan contributes to higher volumes of water passing through the delta. Given the temporary nature of lands and the perennial threat of flooding, a survival strategy for inhabitants is relocation which, in some instances, needs to be enacted frequently.

Traditionally, households have used fixed stoves for cooking and could not move or use them during flooding (with some floods lasting up to two months). As part of a project to develop the adaptive capacity of people living on the chars, Practical Action facilitated a community-led process to identify more appropriate cooking technologies. A portable wood stove was chosen which can be moved to higher ground or taken to new places during relocation, enabling cooking to continue even during the floods.

The chosen technology meets immediate needs but also brings additional health and fuel efficiency benefits. Moreover, the stoves are affordable and serve well the usage requirement characteristic of the community. This makes the adoption of the stove suitable, avoiding risks of maladaptation, even in the unlikely event that flooding would become less frequent in the coming decades.

However, a stove alone does not address the wider needs of char inhabitants living with physical threat as well as with political, economic and social marginalisation. In addition to introducing improved cook  stoves, the project also launched an extensive climate change awareness raising campaign using formal and informal social networks and providing training for local government officials in recognising climate change threats that need to be taken into account during development planning. While these interventions partially tackle the charland population's exposure to disasters, further work needs to be conducted to fully understand and address

the underlying causes of vulnerability and the restrictions limiting the ability to adapt. This example shows how a technological solution is part of a wider response to increased resilience, and how it constitutes a good entry point to expand the work necessary to achieve adaptation.

## 4.5 Build Adaptive Capacity through Participatory Approaches

Practical Action worked in three very different communities to find ways that are accessible, acceptable and affordable that effectively addresses indoor air pollution due to cooking with biomass on open fires. The project adopted a participatory approach to engage with the target groups (an urban situation in Kisumu, Kenya, where fuel is scarce and often bought; a community of displaced people near Kassala, Sudan, suffering the effects of a conflict; and a community requiring space heating as well as energy for cooking in Gatlang, Nepal) to identify, install and monitor sustainable technologies to alleviate smoke pollution. This led to the choice of very different solutions in each country.

An important aspect of the project was the empowerment of women through the discussions around the energy technology with and between community members, particularly women, which prompted an on-going dialogue about improvements, ways of overcoming cost, and other further request for training.

It has also demonstrated the potential of energy projects to enable communities to organise and build relationships with external actors: other communities, other women's groups, and government and other agencies interested in health, natural resource management and gender.

The same methods of participation in decision-making processes can equally be applied to addressing a wider range of problems, including climate change.

Woman making improved stove, Sudan
Photo credit: Margaret Gardener

Following the steps for identifying and addressing energy problems, people's skills are enhanced and their support networks enlarged, thus building the capacity to make livelihood improvements. The platform established during this project could serve as a base to deal with the incremental challenges of climate change. Given the closeness of energy related issues to climate change themes, it is natural to move from one to the other. For example, the scarcity of biomass used as energy supply is strongly linked to unsustainable livelihood practices as well as to environmental change. The connection with perceived changes in weather and seasonal conditions leads to existing coping strategies including natural resources management techniques and access to meteorological and ecological information.

## 4.6 Small-Scale Irrigation in the Ethiopian Highlands

In Ethiopia, small-scale irrigation is a policy priority for rural poverty alleviation and growth, as well as for climate adaptation, since it is expected to contribute to income diversification and livelihood resilience. Only around 5% of Ethiopia's arable land is irrigated, and less than 5% of total water resources are withdrawn annually, leaving considerable scope for expansion.

The Research-inspired Policy and Practice Learning in Ethiopia and the Nile region (RiPPLE) programme analysed three different spring-based community managed irrigation schemes in the highland communities. The programme showed that the increased water availability to irrigate crops enabled some of the households to generate more income by increased crop production, crops diversification and by growing higher value products. This strengthened their resilience and in some cases transformed their livelihoods. However, poorer and more vulnerable farmers are unwilling to pay higher costs for using more water or changing crops, due to high risks involved in the production and marketing.

The agriculture is already failing to sustain the livelihoods of millions in Ethiopia, with increasing populations, widespread land degradation and the expectation of future climate variability. The irrigation development has the potential to stimulate rural growth and generate new employment opportunities. However, this depends strongly upon the parallel development of the market infrastructure in terms of transport, communication links between rural areas and market centres, the number of people able to irrigate and the demand for labour and non-food products which irrigation creates. Again, most of these factors are related to energy access. Furthermore, the irrigation systems need to be proofed against climate variability. For example, boreholes and deep wells are likely to be less vulnerable than surface water sources or shallow wells.

# 5. Energy enabling Adaptation

The case studies in this paper explore how energy is also important for adaptation. It can be summarised that access to energy contributes to enabling climate change adaptation in the following ways:

**1. Improving general physical and economic well-being**
Improving people's general physical and economic well-being provides the pre-requisites for resilience and adaptation. Access to energy enables broad social and economic development; if people are healthy, wealthy and wiser they have greater capacity to adapt.

**2. Building resilience**
Modern energy and technology enables a whole host of productive use activities; diversification of livelihoods away from vulnerable activities is a key factor in building resilience to adverse events, including the impacts of climate change. The greatest benefits demonstrated were the reduction of time, increase in production, and greater number of livelihoods options available. However, extreme caution should be applied when developing livelihood options based on natural resource dependent energy supplies; thorough research into the sustainability of the source is needed.

**3. Enabling innovation and adaptation through ICTs**
Access to knowledge and information powers innovation; it enables experimentation and testing of different adaptation options. Electric-powered ICTs including mobile phones, TVs and radios can provide valuable information that can, for example, inform a farmer about new drought-resistant plant varieties, farming techniques or seasonal weather forecasts. Extending the reach of communication and relevance of information about threats and solutions is particularly important for agriculture and markets. Energy itself is not enough to trigger the supply of information that is not available or blocked from certain a group. Awareness-raising on the need for information and the creation of inter-personal relationships are required.

**4. Empowering communities**
Energy technologies can be deployed in such a way that empowers communities. Approaches that strengthen community organisation and decision making, and build relationships with local stakeholders can empower communities to take independent action in the future in response to climate change.

These are initial findings on the energy and adaptation nexus, and must be developed through further primary research and testing.

# 6. Climate Proofing of Energy Systems

It is also important to recognise that energy systems are vulnerable to a changing climate, and future climate-proofing considerations are necessary to avoid maladaptation.  Climate-related failures of energy systems (due to lack of water for hydro for example) risk setting back development gains.

Climate change directly impacts both the demand and the supply side of energy services (Williamson et al., 2009). For example, extreme events such as floods and storms might increase the risk of collapsing transmission lines, while heat waves are likely to increase the demand for electricity for cooling.

The changes in meteorological variables will have an impact on the infrastructure of power plants, energy transmission, and use, regardless of how the energy is produced, affecting fossil fuel based systems and renewables alike. The increased frequency and intensity of extreme events such as storms, cyclones, and floods are potentially disruptive, as is the rising sea level towards coastal buildings, structures and biomass.

However, there are also specific vulnerabilities which are characteristic of each system. The renewable forms of energy are particularly sensitive to changes in the meteorological conditions they depend upon. Table 2: Effects of meteorological changes on renewable energy production describes these effects in more detail.

*" A resilient energy sector is central to achieving greater community resilience. In order to properly assess how to increase the resilience of an energy system, the system must be examined from a broader sustainable development context."*

(Williamson et al., 2009)

**Table 2: Effects of meteorological changes on renewable energy production**

| | |
|---|---|
| Hydro Energy | Depends on river water flow |
| Average Precipitation | The river flow can change depending on precipitation levels and patterns in the watershed. River flow variability can be buffered to some extent but the change in power production is strongly dependent on the flow regime. |
| Glacier levels | If a river is glacial-fed, then flow is subject to glacial melting |
| Biomass Energy | Sourced from forests, agricultural residues or agricultural crops: depends on how vegetation grows |
| Temperature + | Increase provided that plants do not reach threshold of biological heat tolerance |
| Precipitation | Changing and unreliable precipitation patterns affecting crop calendars |
| Drought | Decrease or halt in production, Impacts of forest fires caused by sustained drought spells |
| Glacier melting | If biomass is under irrigation: Increase short- to medium-term but decrease over long-term |
| Wind Energy | Depends on wind pattern |
| Wind | Should the wind pattern be modified or change in intensity, it would affect energy production. The wind turbines work within a range of wind speeds that cannot be too low or too high (to prevent damage) |
| Solar Energy | Depends on sun radiation |
| Cloud | While the efficiency of solar PV and solar water heaters decrease with cloud cover, concentrated solar power needs full sunlight to function. |
| Temperature + | The efficiency of photovoltaic cells production decreases as ambient temperatures rises |

Energy systems are fundamentally important in the functioning of modern society and therefore must be adapted to withstand anticipated climate change and its impacts.

To achieve this objective, a number of measures can be employed that can be categorised as infrastructural/technical and behavioural/social:

— Technical adaptation tries to make infrastructures less vulnerable to long-term changes in meteorological variables and extreme events, by for example reinforcing technical equipment, siting it more appropriately or making it easier to transfer to another location or capable of operating at different production rates.

— Behavioural adaptation adjusts the operating conditions and the organisation of the service by for instance expanding linkages with other regions, planning disaster preparedness and managing demand.

To increase resilience, it is necessary to invest in technological preparedness (renewables, efficiency, management) by expanding the portfolio of options and diversifying the mix of energy supply sources, and ideally creating a safety net of numerous, relatively small units with a low individual cost of failure. Decentralised 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 captital cost per installed Watt may be considerably higher than that of more conventional, larger-scale power generation.

## Recommendations

The role of energy in enabling adaptation to climate change and the different mechanisms for this have been explored in this paper and illustrated through a range choice of case studies. Based on this analysis the following recommendations have been concluded:

### 1. Promote productive uses to encourage adaptation

Maximise the opportunities that energy access offers in improving livelihoods and diversifying income sources. Promote productive uses of energy through skills trainings, access to finance and business development. Sustainable livelihood frameworks and productive use manuals are available to support project developers.

### 2. Use energy to build resilience to cope with shocks

Introduce technological innovations and organisation models (irrigation systems, management structures of energy stations) that build the capacity of communities, are suited to new climatic conditions or that can respond to emergency events (early warning systems, solar medical or communication equipment). Extend access to information about threats, solutions and ways to innovate (radios, TV, mobile phones) and draw new connections and networks of communication channels that strengthen communities.

### 3. Capitalise on the participatory community adaptation approaches of energy projects

Household energy projects based upon participatory approaches constitute an ideal and natural background to introduce capacity building programmes on climate change. The skills, capacities and networks that have been built in the community, and the themes around energy and natural resources that the household energy project introduces, facilitate new dialogue on climate change and the environment.

### 4. Ensure climate-proofing of energy systems

Energy systems are vulnerable to a changing climate, and future climate-proofing of systems is necessary to avoid maladaptation. Climate-related failures of energy systems (due to lack of water for hydro for example) risk setting back development gains.

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## Policy Innovation Systems for Clean Energy Security (PISCES)

PISCES is a six-year research project funded by the Department for International Development of the United Kingdom (UK). Project implementation started in July 2007. Through action research the project is increasing available knowledge and understanding of policy relevant trade-offs between energy, food and water security for livelihoods in relation to bioenergy. PISCES is a Research Programme Consortium whose members include African Centre for Technology Studies (ACTS, lead) Kenya; Practical Action Consulting UK, Eastern Africa, and Sri Lanka; the University of Dar es Salaam, Tanzania; M.S. Swaminathan Research Foundation (MSSRF), India; and the University of Edinburgh, UK. **www.pisces.or.ke**

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