ENERGY, ECOSYSTEMS and LIVELIHOODS:

Understanding linkages in the face of climate change impacts

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This paper has been prepared by HELIO International in cooperation with IUCN.

HELIO is an independent network of leading energy analysts whose objective is to identify, assess, measure and publicise the contribution of energy systems and policies to sustainable and equitable development. This work has expanded recently to address the interface of the vulnerability and resilience of energy systems within the context of climate change.

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Summary

The document begins with a short overview on the impacts of degrading eco-systems on human well-being. How current energy consumption is contributing to this degradation is also addressed. The affect of climate change on ecosystem services and the energy services they provide is then briefly examined. The document concludes with suggestions for how IUCN could bring its expertise to the energy, ecosystem, climate change nexus.

Section I. Introduction – why this work?

> **IUCN's Energy, Ecosystems and Livelihoods Initiative**
>
> IUCN is working to accelerate the transition to energy systems that are ecologically sustainable, socially equitable, and economically efficient through its Energy, Ecosystems and Livelihoods Initiative. This Initiative is cross-cutting and multi-sector, coordinating work between relevant regions, thematic programmes, Commissions and Members.
>
> The Energy Initiative also works on building internal awareness of the energy agenda, the important implications of energy decisions and systems for the conservation agenda, and opportunities for leveraging IUCN's knowledge, expertise, and convening power.

Energy is a fundamental part of our lives. It is needed for heating, cooking, cooling and lighting in our homes. Modern life is also reliant on the provision of energy for communication, transport and industrial processes.

Most energy sources at some stage are dependent on ecosystem services, e.g. water flows used to power turbines to generate electricity or biomass which can be used for heating, cooking and electricity generation. How these forms of energy are harnessed and employed makes energy use a critical environmental issue as often its sourcing, production, transmission and consumption—particularly conventional fossil fuel-based sources, and even renewable energy options—impact ecosystems. Ecosystems are also key to helping meet the growing energy demand. Thus to sustainably increase future energy supplies, the quality and integrity of ecosystems need to be well-managed and enhanced.

Energy is also a critical development issue, underpinning each of the UN Millennium Development Goals (MDGs). Currently, 1.6 billion people in the world lack access to electricity and over 2.5 billion people depend on biomass fuels for cooking and heating (WEO 2006). These people have a legitimate right to, and need for increased energy services which are affordable, healthier, reliable, and sustainable. Energy issues are particularly challenging for developing countries where high energy costs exert tremendous pressure on fragile economies that have little capacity to adapt to change (IUCN 2007).

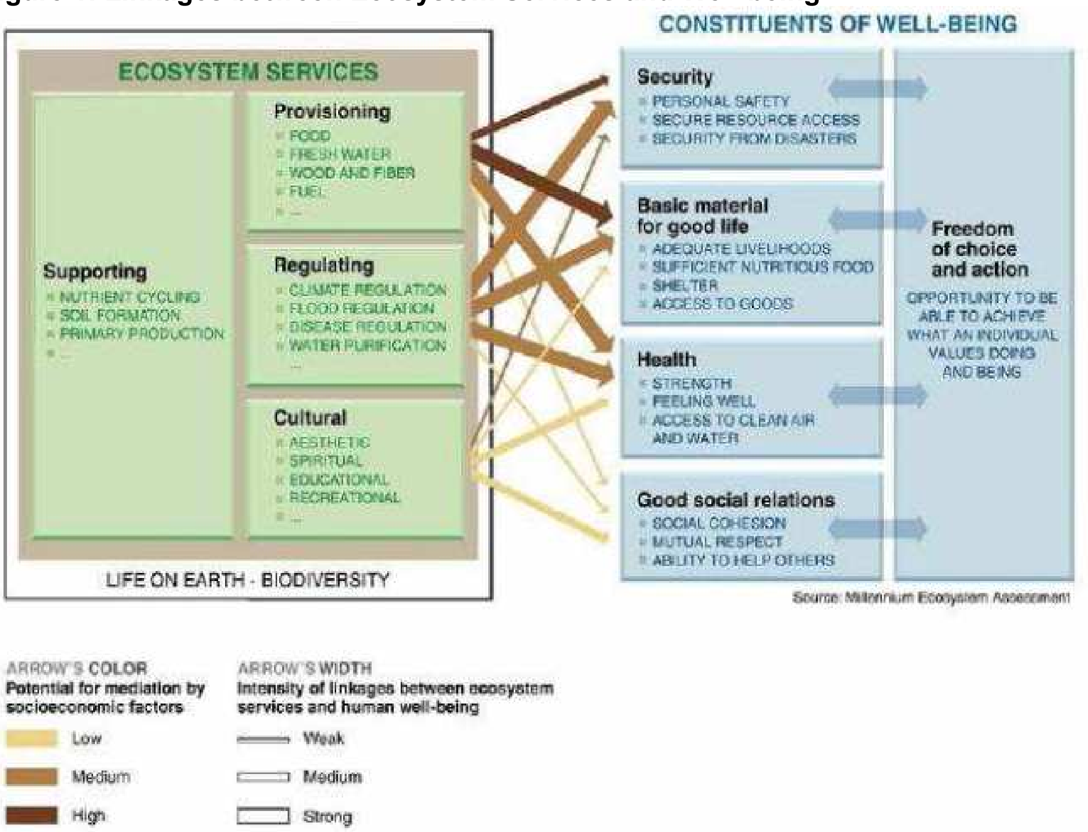
The effects of climate change, e.g. changes in water levels, temperatures, rainfall and wind patterns will challenge the resiliency of communities. Those who depend directly on ecosystems for their energy supply, e.g. biomass, will suffer the greatest consequences. Ensuring energy security, while maintaining ecosystem integrity in the face of anticipated climate change, must therefore be a top priority. However, despite its importance there is relatively little information on the inter-linkages—and the implication of these inter-linkages—between these three issues.

The aim of this document is to begin the process of identifying the central issues and connections. It is not meant to be comprehensive but rather to be used a starting point for discussion about what IUCN's contribution could be. This document was prepared as input for an interactive workshop at the Fourth World Conservation Congress (October 2008). The workshop—designed to stimulate discussion about ecosystem supporting energy services—allowed participants to have structured discussions about the inter-linkages between energy systems and ecosystems. Discussion groups focused on five key ecosystems: marine and coastal; islands; drylands; forests; and, freshwater. Information gathered from the discussions has been incorporated into this document.

Section II. Linking Ecosystems, Energy and Livelihoods

Ecosystems, through the goods and services they provide, support human well-being (see Figure 1). A key ecosystem service is energy provision, which directly and indirectly contributes to our collective well-being and livelihoods. However energy use also impacts ecosystems and can undermine the integrity of ecosystems. This section explores these inter-linkages and trade-offs.

Figure 1: Linkages between Ecosystem Services and Well-being



Source: MEA (2005)

Ecosystem Services for Energy

The goods and services provided by ecosystems—through their supporting, provisioning and regulating services—underpin most of the energy services we use daily. Biomass has traditionally been the most widely used energy source. Over 2.5 billion people still depend on traditional use of biomass for cooking and heating although more modern uses of bioenergy are also being promoted, for example, in the form of copra for combined heat and power generation and the production of biogas (see Box 1). In the case of biofuels and biomass-based energy, ecosystems provide both goods (biomass, feedstocks and enzyme digesters) as well as services (soil formation, climate and water regulation and pollination).

Box 1: Biomass for Energy Production

Rural Electrification from Copra
Many Pacific Island Countries (PICs) are dependent on imported petroleum for commercial energy. However fuel supplies are often erratic and costs rise as the distance between fuel source and use increases. High fuel costs relative to the small economies of these PICs limits socio-economic development.

Copra, the dried meat, or kernel, of the coconut is a potential fuel source. Once processed the efficiency and power output of copra oil is roughly equivalent to that of diesel. Moreover its impact on the fragile island ecosystem is less than that of imported diesel fuel (CIRAD 2000). Using copra as a local fuel source can lead to higher energy independence, a decrease in real costs and greater local value-added to the crop. The rehabilitation of coconut groves can contribute to adaptation strategies by stabilising erosion and providing local income through harvesting and processing. As coconut grows in coastal areas valuable land is not removed from agriculture. Ecosystem preservation can be encouraged through coconut grove management.

Biogas: Reducing impacts on ecosystems and biodiversity
Abattoir effluent, which frequently is not collected, has a significant impact on human health, agriculture, drinking water and aquatic species. However the effluent—if properly collected and converted—can be a source of domestic energy and reduce pollution and greenhouse gas emissions.

Collected effluent is treated in a biogas plant. By breaking down the organic matter in the absence of oxygen, biogas is produced and can be harnessed as an energy source. By upgrading the gas and compressing it, the gas can be used as a substitute for natural gas in household cooking and can (depending on demand) be used to generate electricity. The sludge from the reactor can then be used as organic fertiliser (Seed initiative, 2005).

Drylands—covering 40% of the world's land mass and inhabited by only one-third of the world's population—provide a prime energy service. Whereas land productivity decreases as aridity increases, the efficiency of solar power generation increases (within certain limits) due to solar radiation (UNCDD, 2005). Use of solar energy in drylands can reduce the overexploitation of natural vegetation for biofuel and its impact on soil productivity as well as support diversification of income. Dryland afforestation protects against soil erosion while the provision of firewood reduces the destruction of range vegetation.[1]

Water provision is a key ecosystem service and underpins numerous energy production options. In addition to supporting biomass production and its use in hydropower installations, water is also used in oil and gas production and for cooling in electricity generation.

The marine environment is increasingly being viewed as an energy source. Biomass-based (algae) energy options as well as electricity production through the harnessing of ocean currents are of particular interest (see Box 2). Marine systems are impacted

[1] Depending on local conditions, trees can either reduce local and regional water storage or they can augment it, and depending on tree species, they can promote indigenous biodiversity or become an invasive species.

by energy developments such as oil and gas exploration and energy installations such as wind turbines and the associated transmission systems needed to transport energy to the coast.

Box 2: Marine Flows for Energy Generation

As part of the effort to decrease the emissions of greenhouse gases and meet future energy demands, increasing attention is directed towards oceanic energy sources. Thermal-, current-, tidal-, wave- and wind-energy technologies are under development, of which offshore wind-, wave- and tidal-power are currently the most advanced. A number of wave and tidal energy projects have been implemented; in La Rance, France a 240 megawatt generating system has been harnessing tidal energy since the late 1960s. Significant expansion of these technologies is expected in the near future (IUCN, 2008).

While tidal energy is a renewable source of electricity that does not emit greenhouse gases or acid rain its environmental impacts are not clear. Many impacts are site specific e.g. effect of the barrier on local tides. Others such as disturbance effects from noise, shadows, electro-magnetic fields and changed hydrodynamic conditions and habitat structures on benthic communities, fish, mammals and birds have not yet been determined.

Island ecosystems are home to many of these ecosystem services and thus provide a range of energy options. Because of their relatively small size and isolation from large land masses islands are already demonstrating the impacts of climate change through changes in their flora and fauna and physical structures e.g. coral reefs, sand formation etc. Islands can therefore be a valuable "laboratory" for understanding the inter-linkages between ecosystems, energy systems and climate change.

Energy Supporting Well-being and Livelihoods

Eco-system services support our well-being,[2] the components of which are affected by changes in ecosystems services and by the supply and quality of contributing socio-economic factors such as technology or social capital.

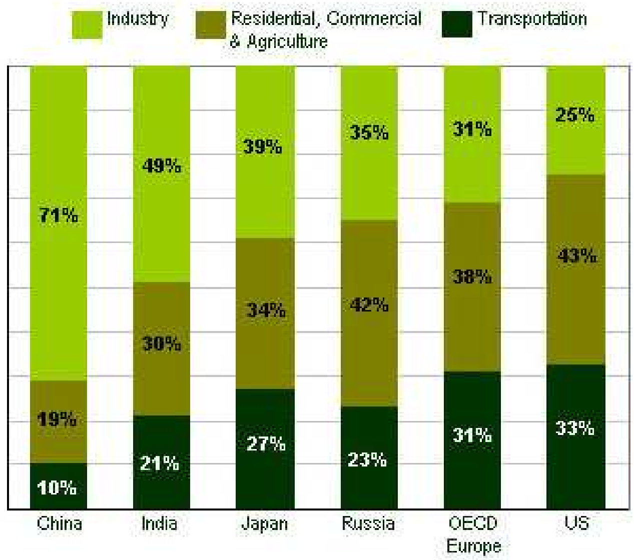
Energy is an ecosystem service that is central to people's level of well-being. It provides the basic materials for a good life in the form of heating (for cooking and warmth), cooling and lighting. Energy supports people's health through the refrigeration of vaccines and medicines. Alternative energy sources for cooking reduce air particulates and associated respiratory problems. Social relations are enhanced through the provision of lighting and access to alternative forms of communication such as radio, television and Internet. Lighting for personal safety improves personal security. Energy can also improve overall financial security through its application in income generating activities such as producing goods or providing services, e.g. hairdressing, telecommunications, charging batteries etc. Freedom of choice and action is facilitated through lighting for evening studying, meeting and socializing and fuel for transportation.

Energy is also crucial for development, supporting industry, transportation, agriculture and meeting the demands of modern life which span from providing

[2] Human well-being depends on material welfare, e.g. the basic material needs for a good life, health, good social relations, security, and freedom of choice and action (MEA, 2005).

electricity to run a refrigerator in a local store to powering servers that support computer networks (see Figure 2).

Figure 2: Energy Demand by Sector (2005)



Source: EarthTrends (2008)

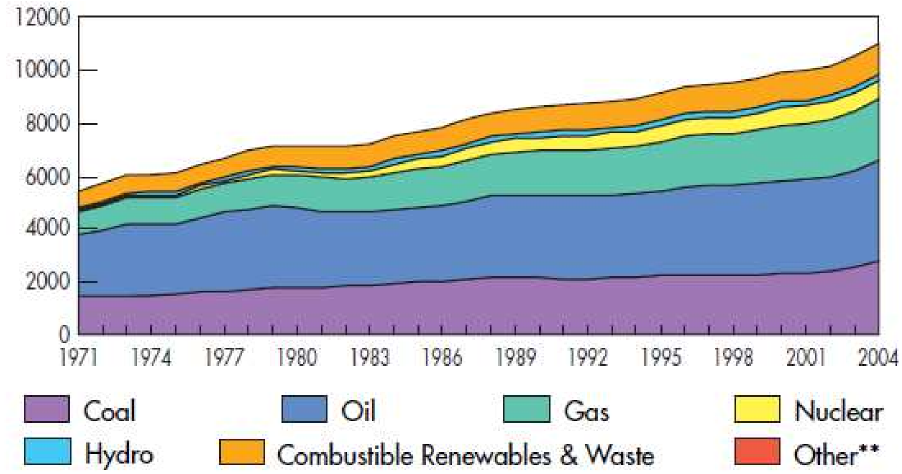
The International Energy Agency predicts a 50% growth in demand for energy by 2030 with 83% of that increase being met by fossil fuels (WEO 2006). Energy-related CO_2 emissions are also expected to climb by 55% by 2030 (WEO 2006), with growth mainly coming from industry and transport.

Impact of Energy Options on Ecosystems and Livelihoods

However, our dependence on, and growing requirements for energy causes significant changes in those same species and ecosystems that we depend on for our livelihood and well-being (UNEP 2007). The search for diversified energy sources and current energy use patterns further compounds these impacts. Moreover, the end of cheap oil and implementation of climate change policies will shift energy use—in source and amount—with consequent impacts on biodiversity and the services it provides.

As the world adjusts to these increasing demands, all types of energy will be called in to play especially biomass, the use of which is predicted to increase by 1.3% per annum with almost half of that coming from traditional biomass sources (see Figure 3). Energy efficiency and conservation are critical strategies for managing the growth in energy demand, but population growth rates and legitimate needs for expanded access to energy for development mean that global demand is likely to grow. The challenge will be meeting this growing demand in a way that does not undermine ecosystems. Improving energy efficiency, energy intensity as well as conservation must be central to any approach as will be managing the overall impacts of energy use on biodiversity.

Figure 3: Evolution from 1971 to 2005 of World Total Primary Energy Supply Fuel (Mtoe)



Source: IEA (2007)

The impacts of energy use are both local and global (see Annex 1 for detailed breakdown by energy source). Pollution from burning fossil fuels and the associated effects of acid rain has been a particular problem for both European and Asian forests and soils, which are continuing to deteriorate as a result. Air pollutants also cause lung disease and asthma, impair visibility and generate foul odours. Production of nuclear-generated electricity results in waste disposal problems and ecosystem degradation from upstream mining operations. Heavy metals produced during the fabrication of solar cells can contaminate soils. Desertification in the Sahel and elsewhere in sub-Saharan Africa has been linked to fuel demand from biomass (IUCN 2007). The increased demand for biofuels also affects food security as land and water resources are diverted from food crops to crops for fuel production. Indirect effects of energy use include both overexploitation of natural resources and the spread of invasive alien species facilitated through global trade, both made possible through cheap and easily-available energy for transport.

Energy use also impacts men and women differently. Seventy percent of the 1.2 billion people living on the equivalent of one dollar a day are women. Traditional responsibilities for collecting fuel and water mean time and physical effort are expended by women and girls in gathering fuel and carrying water rather than attending school or generating income. They also suffer disproportionally from health problems related to the collection and use of traditional fuels. Exposure to smoke from poorly-ventilated, indoor fires causes respiratory infections, cancers, and eye diseases; it is responsible for close to two million premature deaths per year. Replacing low quality fuels such as traditional biomass with more efficient fuels can significantly reduce the health impacts from smoke and physical exertion (UNDP 2004). Involving women in energy decisions can help ensure that solutions meet women's practical, productive and strategic needs.[3]

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[3] Examples of practical needs are electricity for pumping water and grinding grain. Productive needs include refrigeration for food production and sale and the possibility of activities during night hours. Strategic needs refer to broader issues such as making streets safer, providing access to radio, TV etc. (UNDP, 2004).

Challenges

The 2005 Millennium Ecosystem Assessment reports that 60% of the world's ecosystem services are degraded to the point where they no longer provide sufficient benefits to people. Moreover, the ongoing degradation of ecosystem services is increasing the likelihood of serious damage to human well-being.[4] As rural and urban low-income households do not have access to alternative energy sources, degradation of local, energy-providing, ecosystem services—such as biomass—makes these populations more vulnerable to poverty and disease. Adverse environmental conditions also have a greater negative impact on women, especially in areas where the population is directly dependent on natural resources for their livelihood. Women's traditional roles and responsibilities, as well as gender inequality, means that they have limited control over, and access to environmental and energy resources in comparison to men (UNDP 2007).

Biodiversity, and the ecosystem services provided by them, is being impacted by our increasing demand for energy. Future energy choices should be made that incorporate biodiversity concerns in order to ensure that ecosystem services vital to our livelihoods are maintained (GEO 4 2007).

Industrial regions and wealthy populations are not immune to the effects of ecosystem deterioration on energy services. Ultimately the degradation of ecosystem services represents a loss of capital assets. Deforestation, for example, results in a loss of goods such as new trees, habitat, biodiversity, carbon sequestration, and erosion control, the latter which is important for the efficient functioning of hydro systems. It can mean an increase in air and water pollution, and land degradation. Regional conflict can also destabilise access to energy supplies particularly if the energy source and/or parts of the distribution infrastructure are located in the conflict area, e.g. rivers that feed a hydroelectric system, terminals and storage facilities, transmission lines, pipelines etc.

Because traditional biomass energy is relatively inexpensive—and more accessible—than other energy sources, it plays a vital role in supporting economically poor populations. If these resources are threatened, as is the case in some countries with extreme deforestation, poverty reduction will be an even greater challenge. Therefore, supporting development activities that raise incomes and diversify energy sources is a key way for increasing community resilience from both energy and ecosystem perspectives.

However, the energy sector's ecological footprint as a result of exploration, extraction and infrastructure development for higher efficiency fuels is significant. Exploration for hydrocarbons, pipeline construction, uranium and coal mining, hydroelectric dam construction, fuelwood extraction and increasingly, biofuel plantations can all lead to significant habitat degradation. Moreover, the end of easily available hydrocarbons, coupled with increasing oil and gas prices, is driving exploration and development into more environmentally sensitive areas. The result is two-fold: first, activities are occurring in areas where less is known about the local biodiversity and how to manage negative impacts; second, the methods used to extract and process these

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[4] Negative impacts include the emergence of new diseases, sudden changes in water quality, the collapse of fisheries, shifts in regional climate, and energy security, all which affect people's ability to live fruitful, productive lives.

hydrocarbons are often more energy, water and land intensive. Exploitation of tar sands is one such example (see Box 3).

Box 3: Mining Tar Sands

Tar sands consist of a mixture of approximately 85% sand, clay, and silt, 5% water and 10% crude bitumen. On average four tons of material (soil, rocks and clay) are removed to produce one barrel of bitumen. Once extracted, bitumen is mixed with hot water and solvents to remove particulates. The water is then spun off and the bitumen is heated to separate hydrocarbon vapours from the solid residue. The refined bitumen is then transported to refiners for final processing and distribution. The energy equivalent of one barrel of oil is need to produce three barrels of oil from tar sands; mining operations general withdraw 2 – 4.5 barrels of freshwater for every barrel of oil they produce. The production of one barrel of synthetic crude oil from the tar sands releases up to three times more greenhouse gas pollution than conventional oil (World Watch 2007).

One of the largest tar sands reserves is located in Alberta, Canada. These sands lie 30 to 90 metres below 362 million square kilometres of relatively pristine boreal forests. Mining operation depend on water from the Athabasca River that runs through the boreal forest. The river feeds Lake Athabasca Delta—the largest boreal delta in the world—which is one of the most important waterfowl nesting and staging areas in North America (World Watch 2007).

Large-scale, renewable energy options can also be problematic. The large expanses of open drylands are attractive for installing concentrated solar power (CSP) arrays. For example, parts of North Africa, with its relative proximity to Mediterranean and European countries, are being developed to support large CSP stations. However little attention is being paid to the biodiversity of the supporting desert and drylands and the impacts such installation and transmission infrastructure will have on other ecosystem services.

In short, virtually all of the factors leading to the accelerating loss of biodiversity are linked to the development and increasing use of energy by society. These links are both direct, e.g. fuel use, and indirect, e.g. support for food production and consumption. No one energy source is completely biodiversity-neutral and energy choices will need to be made with a full understanding of the trade-offs involved in any specific situation.

Identifying and Enhancing Opportunities

The first opportunity lies in applying environmental management and policy tools to reduce and manage the impacts of energy options. Positive synergies can also be achieved when there is conscious action to conserve or enhance a particular component of an ecosystem or its services so as to benefit other services or stakeholders (see Box 4). Identifying and understanding these trade-offs and developing positive synergies are key to establishing a balanced approach between energy security and ecosystem management, particularly in face of climate change.

Box 4: Enhancing Ecosystems and Improving Energy Supplies

Forest Restoration and Energy Services

Shinyanga is one of Tanzania's poorest regions; its low hills and plains are characterised by long, dry summers with an average rainfall of 700 mm. A government relocation scheme together with drought, over-grazing, cash crop cultivation, the destruction of forests to wipe out tsetse fly and increased demand for fuel wood began to reduce land productivity and increase deforestation and soil erosion. Women spent more time collecting formerly plentiful fuel wood; grasses to feed livestock became scarcer, as did traditionally harvested wild fruit and medicinal plants. Through a series of ecosystem projects, using traditional land management techniques, 350,000 hectares of forest enclosures in over 800 villages, supporting 2.8 million people have been restored. Products such as timber, fodder, fuelwood, medicinal herbs, wild fruits, honey and edible insects enhance livelihoods and provide a vital safety net during dry seasons and droughts. Villagers spent two to six hours **less** each day gathering fuelwood (WRI 2005).

Fresh Water for Energy and Biodiversity

The Penobscot River (Maine), with a length of 563 km and a drainage basin of 22,300 square kilometers, is the second longest river in the United States. Over the years a number of dams have been built on the river to harness its energy. The result has been the depletion of self-sustaining runs of American shad, river herring, sturgeon and other native species as well as one of the largest runs of Atlantic salmon in the United States.

A coalition of government agencies, private conservation groups and the Penobscot Indian Nation are working to restore historic fish runs to the Penobscot River. In an innovative agreement, this coalition—with the support of $25 million in private and public funds—will buy three dams on the river. Two will be completely removed and one will be decommissioned with a bypass installed for fish passage. The result will be to open nearly 1,600 kilometers of the river to Atlantic salmon and other migratory fishes. In return the power company has been granted permission to renovate and recommission its Orono, Maine, hydroelectric plant.

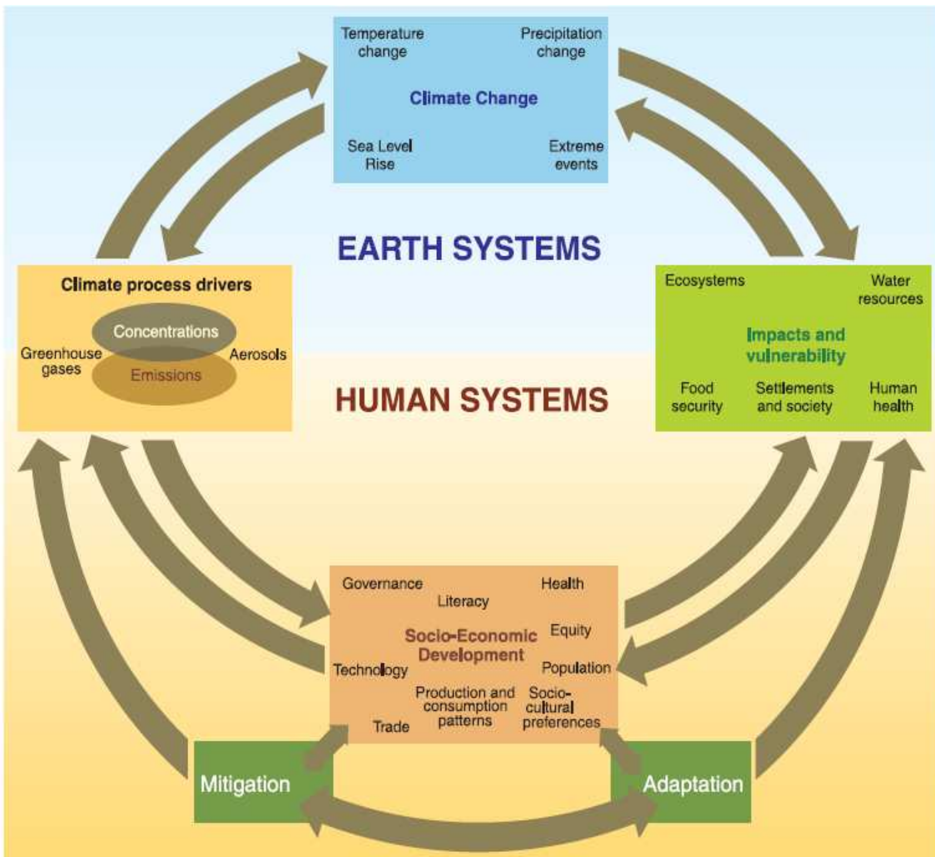
Return of healthy fish stocks will have multiple benefits, including food for fish-eating birds such as eagles, ospreys, and herons and for predatory fish in the Gulf of Maine such as cod and other commercially important species. Removing the dams will convert impoundments to free-flowing river, improving water quality and increasing the diversity and abundance of aquatic insects, which are ecologically important to fish and migratory songbirds. Riverfront communities will benefit from a restored river with healthy fisheries, improved community and economic opportunities, enhanced angling and paddling, revival of culture and tradition, and a renewed connection to the river. The recommissioned plant will add 20,000 megawatt-hours per year of clean, renewable electricity to the region's power supplies, enough to electricity to power 1,800 homes (Penobscot River Restoration Trust 2008).

Island ecosystems may provide an ideal environment for seeing how best to enhance ecosystem services to support energy provision. The size of most island states makes them heavily dependent on imported fuels. However given the ecological make-up of islands, there is high potential for diversifying the energy mix by tapping into the various, available ecosystem services: sun; wind; marine currents; biomass etc. An ecosystem approach to energy choices would help ensure a more diversified and sustainable energy mix and reduce fiscal instability by minimising dependence fossil fuel with its volatile prices and high transportation costs. How island states balance ecosystem management with energy provision could provide valuable information for identifying new opportunities for other communities.

Section III. Effects of Climate Change on Energy Security and Supporting Ecosystem Services

The challenge of meeting energy needs while protecting the ecosystem services that underpin the energy source is further compounded by the effects of climate change as is illustrated in Figure 4 below.

Figure 4: Interactions between anthropomorphic drivers and the impacts and responses of climate change



Source: IPCC (2008)

Climate change is a major global challenge; its impacts are already evident, and changes in water availability, food security and sea-level rise are projected to dramatically affect millions of people (UNEP 2007). Extreme weather events, floods and droughts are also likely to increase (IPCC 2008). Anthropogenic greenhouse gas (GHG) emissions (principally CO_2) are the main drivers of change and threaten to undermine ecosystems, human health and well-being as illustrated in Figure 5.

Figure 5: Climate Change Impacts on Well-being

	Impacts on Human Health and Well-being					
↕ GHG Emissions	**Environment/ ecosystem impacts**	**Human health**	**Food security**	**Physical security and safety**	**Socio-economic**	**Other impacts**
	↑ in temperature	↑ in deaths due to heat stress	↑ of hunger	↑ human vulnerability	↑ energy requirements for cooling	↑ threatened livelihood of communities
	↑extreme weather events, floods, droughts	↑ diseases e.g. diarrhoea and vector-borne diseases	↕ crop production		↑ loss of economic properties	↑ vulnerabilities of poor countries and amongst most vulnerable: women; children; aged; indigenous groups
	↑ sea surface temperature ↕ precipitation ↑ land and sea ice melting ↑ ocean acidification	↑ water scarcity ↓ sanitation			↓ overall capital e.g. natural, social	↑impacts on human rights and justice

Source: adapted from Table 2.2 UNEP (2007); IPCC (2008)

In terms of energy generation and supply, the impacts of climate change on the energy sector will be felt primarily through: storm damage to equipment; agricultural disruption; changes in the growth rates of biomass for fuel use; increased runoff and siltation from land degradation (affecting hydro-generation); and, losses or fluctuations in hydropower production due to increased stresses on water supply systems[5] and changing rainfall patterns.

Global climate policy will impact energy decisions particularly if a post-2012 regime mandates lower emissions thus necessitating different energy choices, but energy systems are also likely to be affected by climate change itself.

The effects of climate change already threaten the strained relationship between energy security and functioning ecosystems. The poor are particularly affected as they rely primarily on biomass, wood, waste, animal dung, and other natural resources whose quality and quantity is affected by climate change. With limited or no access to alternative energy sources they are the most vulnerable to climate-induced impacts and are the least able to adopt adaptation measures. Energy scarcity and increased threats due to climate change also hinder the provision of basic services such as water, health and education and thus a community's well-being (HELIO 2007).

Problems of inefficient energy production also increase people's vulnerability (see Box 5). Income-generating potential is undermined because of the time and/or

[5] Out of the 19 countries classified with water-stressed supply systems, more are in Africa than in any other region. This number is likely to increase—independent of climate change—due to rising demand from population growth, degradation of watersheds caused by land use changes and siltation of river basins.

financial resources spent securing the needed fuel source, which often has a low combustion efficiency.[6]

Box 5: Fuel Sources for SMEs

Studies show that small and medium enterprises (SMEs) in sub-Saharan Africa still depend on biomass for 84% of their energy needs. The increased threat of climate change on natural fuel resources reinforces the need for urgent action to provide alternative and sustainable energy generation and supply for this economic sector (HELIO 2007).

Anticipated Impacts

Hydropower generation is likely to be the most heavily impacted by climate change because it is sensitive to the amount, timing and geographical pattern of precipitation as well as temperature—rain or snow, timing and speed of melting, etc. Dam specifications designed for one climate may not be adaptable to function in another climate. As hydropower is the primary source of electricity in East and Central Africa and much of Asia, the impact on development will be significant.[7] This high dependence on water resources for energy generation further highlights the vulnerability of energy systems across these two continents. Moreover, large hydro (dams over 10 MWs) has significant impacts on the surrounding biodiversity. Dam reservoirs flood and fragment ecosystems. They increase the level of water borne diseases and amount of rotting vegetation, which releases greenhouse gases contributing to global warming. Water quality is also degraded. The dam structure itself blocks fish migration, disrupts water and sediment flows. Aging structures pose particular safety hazards. Reduced water flows have downstream impacts including disrupted water and sediment flows reduces biodiversity. Communities suffer from poor water quality, lower crop production and decreased fish populations (International Rivers).

Despite these negative impacts, dams can be modified to restore flows to support both the environment and those populations living downstream, particularly if they are small and constructed with by-pass systems to allow for fish migration.[8] For example, with increased water flows—either from increased precipitation or glacier melt—water storage infrastructure such a small, temporary reservoirs can help mitigate flooding. Moreover engineered infrastructure can be integrated with natural infrastructure such as peatlands and wetlands to store water and help buffer climate change impacts.

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[6] Combustion efficiency is the calculated measurement (in percent) of how well the heating equipment is converting a specific fuel into useable heat energy e.g. 100% of the energy minus % of heat lost due to incomplete combustion or loss through the system itself. For example, an open fire has a very low combustion efficiency in comparison to a boiler.

[7] Cameroon, the Democratic Republic of Congo (DRC), Ghana, Mozambique, Rwanda, Uganda and Zambia rely on hydroelectric power for more than 80% of their electricity needs. Over 60% of centralised grid-based systems in many African countries—such as Kenya and Zambia—are dependent on hydropower with dependency reaching over 90% in Cameroon and Uganda (HELIO 2007). About 93,000 MW of hydro capacity is under construction now in more than 30 Asian countries and more than 210,000 MW more is planned to be implemented in the next 10-20 years (ICOLD). International collaboration between many countries in the region is leading to rapid exploitation of this ecosystem service.

[8] Approximately 10% of the world's dams are used for hydropower. The majority are used for flood control, irrigation and multi-purpose (WBCSD, 2006).

The effects of climate change on biomass production still are unclear. However changing rainfall patterns, species migration, human migration, competition with food crops for arable land are already effecting the quality and quantity of the ecosystem service and thus energy security.

There is a real need to ensure sustainable energy supplies while also increasing access and affordable energy services for the world's poor—both rural and urban. In the face of projected climate impacts and their anticipated negative effects on ecosystem services, the need is even more pressing (HELIO 2007).

Dryland ecosystems may be able to provide opportunities for both adaptation and mitigation activities. For example, the use of solar energy would off-set CO_2 emissions by substituting the use of fossil fuels. The use of dryland afforestation offers firewood production and would help in carbon sequestration. The challenge will be in balancing adaptation and mitigation activities with land tenure and pastoral rights and maintaining ecosystem integrity.

Levels of atmospheric CO_2 and precipitation, the rate of melting ice caps and increased air and surface water temperatures are likely to affect ocean flows and those energy systems harnessing ocean currents as a power source. However the presence of marine energy infrastructure may help to protect coastal regions despite altering water flows.

A secondary effect of warming waters is already being seen in the increased reproductive capacity of certain species, many of which are alien invasives, i.e. not native to the ecosystem. With the rise in temperature of North American in-land waters, Zebra mussels—a species introduced from the Caspian Sea—have become prolific in the Great Lakes ecosystem. Their ability to adhere to most surfaces has impacted the physical infrastructure of US power plants and treatment plants by blocking or damaging water intake structures etc. Likewise, increasing jellyfish populations, due to warmer ocean waters, is already impacting coastal ecology, commercial fishing and tourism in Japan, Australia, New Zealand and North America.

Given that energy is a fundamental requirement for supporting development and economic growth in all economies, how then can we sustainably provide energy services without driving further loss of species and ecosystems? Moreover, how do we mitigate the impacts of climate change which is both caused by energy production and consumption and has the most significant indirect impact on ecosystems services and biodiversity?

Approach

Solutions to these interlinked problems lie in parallel, mutually-reinforcing approaches: 1) restoring and sustainably managing ecosystems; 2) ensuring a diversified and distributed sustainable energy mix combined with increased energy efficiency and conservation; and, 3) adopting adaptation measures. Carried out in tandem these actions can increase ecosystem resiliency thereby helping people to adapt to climate change. A range of actions are possible. For example:

- **Improving ecosystem management** that promotes more moderate harvest levels of forest products or other vegetation so that the ecosystem can retain its overall integrity. Managing forest resources in a sustainable manner also increases resilience and adaptive capacity to climate change by providing a resource base as well as a physical buffer against flooding.

- **Ensuring diversified energy supply choices**, e.g. fuel efficient cookstoves and access to alternative energy sources to reduce pressure on local resources.

- **Implementing integrated water management that assesses river basin resources from a broad perspective and includes planning and multiple stakeholder involvement.** An integrated approach can help protect water flows and the ecosystem service over the long run by providing a life-supporting resource and an energy source for small hydropower systems,[9] thereby increasing resilience and adaptive capacity of the community.

- **Using air and sun ecosystem services to provide renewable energy solutions even in the face of anticipated climate change.** Production of solar panels and wind turbines can have negative environmental impacts, e.g. water use and generation of toxic by-products during manufacturing and disposal, presence of large installations on biodiversity. However given its very low carbon emissions and relatively low impact on ecosystem services—in comparison to the refinement of other energy sources such as tar sands, fossil fuels—solar and wind present good energy options.

Ecosystems are resilient and can be sustained through practices that accommodate their inherent biological limits, recognizing that ecosystems are not simple production factories but living systems built on complex relationships among species and physical factors such as water, temperature, and nutrient availability. Practices that respect and preserve how ecosystems function are [vital to…] the sustainable and equitable use of ecosystems (WRI 2005).

- **Protecting shores**, e.g., dikes, bulkheads, beach nourishment to prevent sea level rise from inundating low-lying coastal property, eroding beaches, or worsen flooding. Planting and preservation of mangroves and use of salt-resistant corps can also increase resilience and provide a fuel source.

- **Constructing riparian buffer strips** to manage pollution loadings from agricultural lands into rivers today and establishing protective barriers against increases in both pollution and sediment loadings due to future climatic change (SAP 2008). Protection of agricultural lands preserves or increases income generating ability allowing the purchase of goods, including fuel, and services such as electricity, to increase well-being.

[9] Small hydro is defined as an installation with generating capacity of 10 MWs or less and whose structure permits water flows necessary to maintain key functions such as sediment flow, fish runs and minimises the physical impact on the local ecosystem.

Section IV. Way Forward

While there is a lot of on-going work around the issue of energy security, e.g. promoting the role of renewables, developing policies that support diversified and sustainable energy sources, advocating for equitable distribution mechanisms etc., there is very little (if any) information on how to ensure energy security while preserving ecosystem integrity in the face of climate change impacts.

As outlined in this document, ecosystem services are central to energy provision and human well-being yet the very foundation upon which energy provision depends is being eroded by unsustainable practices. The situation is compounded by the impacts of climate change which are changing rainfall patterns, ocean currents and temperatures. How climate change will effect energy provision in the long-term is still uncertain.

How then do we define the trade-offs between ecosystem preservation, energy provision and adaptation in the face of climate change? Given IUCN's work on ecosystem management and restoration and its extensive networks, the organisation is well-placed to examine this question.

Below are a series of suggestions about how IUCN could shape its approach. Rather than being prescriptive these suggestions are meant to stimulate discussion and further thinking on this issue. Central to any decision is identifying how the work would build on the efforts being carried out by other IUCN programmes on specific ecosystem issues.

- Promote a world-wide programme to replace fossil fuel with energy efficiency and clean and sustainable renewable energy.

- Establish links between ecosystem services, energy provision, gender and climate change by looking at:
    - current status of ecosystems that directly provide energy services
    - anticipated demand for energy (production, distribution, consumption)
    - key elements that impact the management of ecosystem services and related energy systems
    - how climate change impacts may change/shift energy demand
    - adaptation measures to be adopted

- Examine the concept of ecosystem-supporting energy services, particularly the role of water

- Monitor effects of climate change on ecosystem services and energy security
    - develop a simple set of indicators to measure how climate change is affecting ecosystem services and the resultant effects on energy services
    - select key ecosystem services and vulnerable regions and report every three years on current status and changes relative to base year (1990).
    - use indicator results to inform policy and/or programmatic decisions

- Work with other programmes to prepare an informational manual that looks at:
    - key ecosystem services and the energy services each one provides
    - how climate change may impact the quality and quantity of each service
    - how ecosystem goods and services can be used to adapt to changes in land and water availability due to climate change impacts
    - proposed policies and measures to support identified actions

- Cooperate with efforts that are working to improve opportunities for the most vulnerable (particularly women) to have a voice in energy issues, e.g., in designing new energy systems, to ensure that ecosystem issues are incorporated into the process.

- Support gender-sensitive, sustainable energy technology innovation and production in cooperation with vulnerable communities, as a way to create jobs, increase coping capacity, provide energy security and manage ecosystem services.

Section V. Conclusion

Biodiversity plays a critical role in providing livelihood security for people.

Reducing the rate of loss of biodiversity, and ensuring that decisions made incorporate the full values of goods-and-services provided by biodiversity will contribute substantially towards achieving sustainable development (WCED 1987).

Energy affects everything that we do and many forms of energy are the result of ecosystem services. Ironically our growing requirement for energy is significantly impacting that same biodiversity, thereby undermining the quality of our well-being.

These impacts occur all along the energy chain from exploration, to production, distribution and use. Ecosystems negatively affected by shifts in energy systems, e.g. towards more intensive cropping for bio-fuels, may not be able to provide the range of goods and services which they currently provide or potentially could provide. Changes in ecosystem services will effect the provisioning of goods and services further impacting people—particularly those who rely directly on nature for their livelihoods.

No one energy source is completely biodiversity-neutral and energy choices will need to be made with a full understanding of the trade-offs involved in any specific situation. Addressing the future challenges of meeting increasing energy demands, while supporting biodiversity conservation, will require an integrated multi-sector approach.

Given the large scope for synergies among policies related to ecosystem management, energy security, health and air pollution and climate change there are numerous opportunities to reduce the vulnerability of people and their communities. IUCN with its conservation mandate and extensive networks is well placed to examine this climate change—energy—ecosystem nexus.

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Annex 1: Energy Sources and Impacts

Energy Source – % of world energy use	Impact on biodiversity	Subsequent impact on livelihoods
Fossil fuels Oil – 35% Coal – 25.3% Natural Gas – 20.7%	• **Global climate change and associated disturbance events**, particularly when coupled with human population growth and accelerating rates of resource use, will bring losses in biological diversity. • **Air pollution** (including acid rain), has led to damage to forests in southern China amounting to US$14 billion per year. Losses from air pollution on agriculture are also substantial, amounting to $4.7 billion in Germany, $2.7 billion in Poland, and $1.5 billion in Sweden (Myers and Kent 2001). • The direct impact of **oil spills on aquatic and marine ecosystems** are widely reported. The most infamous case is the Exxon Valdez, which ran aground on 24 March 1989, spilling 42 million cubic meters of crude oil into Alaska's Prince William Sound. • Indirect impacts also come through the development of oil fields and their associated infrastructure and human activities in remote areas (such as Alaska's Arctic Wildlife Refuge) that are valuable for conserving biodiversity.	• Changes in distribution of and loss of natural resources that support livelihoods. • Respiratory disease due to poor air quality. • Gastrointestinal diseases due to compromised water quality.
Biomass Combustibles, renewables & waste – 10%	• Decreased amount of land available for food crops or other needs due to greatly **expanded use of land** to produce biofuel crops such as sugarcane or fast-growing trees resulting in possible natural habitat conversion to agriculture, and intensification of formerly extensive or fallow land. • Can contribute **chemical pollutants** into the atmosphere which affect biodiversity (Pimentel *et al.,* 1994). • Burning crop residues as a fuel also **removes essential soil nutrients**, reducing soil organic matter and water-holding capacity of the soil. • Intensively managing a biofuel plantation may require **additional inputs of fossil fuel** for machinery, fertilisers, and pesticides, with subsequent fossil fuel related impacts. • Monoculture of biomass fuel plants can **increase soil and water pollution from fertiliser and pesticide use**, soil erosion and water runoff, with subsequent loss of biodiversity.	• Respiratory disease from reduced indoor air quality due to wood burning stoves, creating high incidences of illness and death among poor women. • Decreased food availability.

Energy Source – world energy use	Impact on biodiversity	Subsequent impact on livelihoods
Hydroelectricity ~2.2% of energy use	• Building large dams leads **to loss of forests, wildlife habitat, and species populations**, disruption of natural river cycles and the degradation of upstream catchment areas due to inundation of the reservoir area (WCD, 2000). • Dam reservoirs also emit **greenhouse gases** due to the rotting of vegetation and carbon inflows from the basin. • Some dam reservoirs provide **productive fringing wetland ecosystems** with fish and waterfowl habitat opportunities.	• Alterations in availability of freshwater resources (both improved and declining depending on situation) for human use. • Population displacement.
Nuclear energy ~ 6.3 %	• A nuclear accident would **have grave implications for biodiversity survival** generally and not just humans. • Water used to cool reactors is released to environment at significantly above ambient temperatures and accentuates **ecological impact on riverine fauna** of climatic accidents such as heat waves. • Produces relatively **small amounts of greenhouse gasses** (during construction of the infrastructure required). • Because of the potential risks posed by nuclear energy, some nuclear plants are surrounded by **protected areas**. For example, the Hanford Site occupies 145,000 ha in south-eastern Washington State: it encompasses several protected areas and sites of long-term research (Gray and Rickard, 1989) and provides an important sanctuary for plant and animal populations.	• Radiation-related diseases if a nuclear accident occurs. • Decreased productivity of ecosystems impacted by high temperature water. • Possible population displacement.
Alternative energy sources *Wind power* *Solar energy* *Tidal power* *Geothermal energy* ~0.5%	• **Ecosystem disruption** in terms of desiccation, habitat loss at large wind farm sites; undersea noise pollution. • Tidal power plants may **disrupt migratory patterns** of fish, reduce feeding areas for waterfowl, disrupt flows of suspended sediments, and result in various other changes at the ecosystem level. • Large photovoltaic farms **compete for land** with agriculture, forestry, and protected areas. • Use of **toxic chemicals** in the manufacture of solar energy cells presents a problem both during use and disposal (Pimentel et al., 1994). • Disposal of water and wastewater from geothermal plants may cause significant **pollution** of surface waters and ground water supplies. • Rotors for wind power can cause some **mortality** for migratory species, terrestrial and marine (Dolman et al., 2002).	• Decreased species populations to provide basic materials of life. • Unknown impacts from noise, shadows, electro-magnetic fields affecting fish and mammal populations (food source). • Toxins released to the environment may cause public health problems. • Decreased economic value of the landscape near wind farms due to visual impacts.

Source: Energy use statistics, IEA (2007); Table, IUCN (2006)