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Energy and Poverty in the Context of Climate Change

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Abstract

Energy drives development, economic as well as human, with advanced technologies as means to achieve this. The deprivations in energy in terms of quantity as well as quality causes lack of development thereby poverty and human sufferings. This technical paper is an attempt at providing deeper insights into these aspects with a focus on the developing countries of the Asia and the Pacific region. The paper begins with emphasizing the issues of securing energy needs of poor and climate change mitigation emerging as conflicting challenges, and their significance in the Asia-Pacific region in the global context. These challenges are extremely critical in the region because it has the highest energy deprivation among the poor at present and it is fast moving towards emerging as the biggest emitter of CO_2 in the future. Further, the linkages between energy, poverty, sustainable development and climate change are analysed by developing different sets of indicators and the results suggested relatively strong association among these. Finally, the possibility of providing universal access to modern energy carriers for the households of the Asia-Pacific is explored by adopting a low-carbon pathway.

Key words: Energy Access, Energy Security, Climate Change, Poverty

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List of Acronyms

ADB	Asian Development Bank
AGECC	The Secretary-General's Advisory Group on Energy and Climate Change
ALRI	Acute lower respiratory infections
APEC	Asia–Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
APL	Above Poverty Line
ARI	Acute Respiratory Infections
ASEAN	Association of Southeast Asian Nations
BC	Black Carbon
BCM	Billion Cubic Meters
BoD	Burden of Disease
BPL	Below Poverty Line
BS	Baseline Scenario
CDI	Composite Development Index
CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CH_4	Methane
CIA	Central Intelligence Agency
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COPD	Chronic Obstructive Pulmonary Disease
CSD	Commission for Sustainable Development
CTI	Climate Technology Initiative
DALY	Disability-Adjusted Life Year
DC	Developing Country
DDG	Decentralized Distributed Generation
DMC	Developing Member Country
EAC	East African Community
EAP	East Asia and the Pacific
EDI	Economic Development Index
EIA	Energy Information Administration
ENDI	Energy Development Index
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Program
EVDI	Environmental Development Index
EVN	Electricity of Viet Nam
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Green House Gases
GII	Gender Inequality Index
GJ	Gigajoule
GNI	Gross National Income
GW	Giga watt
GWh	Giga watt hour
HDI	Human Development Index
HDR	Human Development Report

ICS	Improved Cooking Stove
IDA	International Development Association
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISF	Institute for Sustainable Futures (ISF)
ITDG	Intermediate Technology Development Group
KfW	Kreditanstalt für Wiederaufbau
kgoe	Kilogram of Oil Equivalent
KTOE	Thousand tonne of oil equivalent
kWh	Kilowatt-hour
LDC	Least Developed Countries
LDU	Local Distribution Utilities
LED	Light-emitting Diode
LLDC	Landlocked Developing Countries
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MDC	Major Developing Countries
MDG	Millennium Development Goals
MNRE	Ministry of New and Renewable Energy
MPI	Multidimensional Poverty Index
MTOE	Million tonne of oil equivalent
MW	Megawatt
N_2O	Nitrous Oxide
NCAER	National Council for Applied Economic Research
NGO	Non-governmental Organization
OCHA	Office for the Coordination of Humanitarian Affairs
OECD	Organization for Economic Co-operation and Development
PDS	Public Distribution System
PJ	Petajoule
PPP	Purchasing Power Parity
PRB	Population Reference Bureau
PV	Photovoltaic
R&D	Research and Development
REN21	Renewable Energy Policy Network for the 21st Century
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RIDF	Rural Infrastructure Development Fund
SIDS	Small Island Developing States
SSA	Sub-Saharan Africa
TJ	Terajoule
TOE	Tonne of oil equivalent
TWh	Terawatt-hour
UAS	Universal Energy Access Scenario
UEA	Universal Energy Access
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia-Pacific
UNICEF	United Nations Children's Fund

UNPD	United Nations Population Division
USAID	United States Agency for International Development
WDI	World Development Indicators
WEO	World Energy Outlook
WHO	World Health Organization

Definition of Technical Terms

Primary Energy – It is the energy form as found in nature and that has not been subjected to any conversion or transformation process

Final Energy – It is the form in which energy and fuel delivered to the final consumers

Commercial Energy – An energy which is traded in the market or for which money is paid

Non-commercial Energy or Traditional fuel or energy – Energy carriers which are produced and consumed locally and do not appear in local market.

Modern Fuels – These refer to clean and convenient cooking fuels with minimum pollution and use modern end-use devices like LPG, kerosene, electricity, biogas.

Executive Summary

Energy, Poverty and Climate Change

Poverty and climate change are the two greatest challenges being faced by the humanity. Poverty is an ongoing crisis whereas climate change is an impending crisis. Climate change is expected to intensify the sufferings of the poor by impacting the meager resources and assets owned by them. Poor with limited access to income as well as to other resources, goods and services are typically vulnerable to unpredictable events and disasters. Climate change is likely to result in many such events. Energy is at the center of the two – extent of access influences the poverty levels and consumption contributes to climate change by emitting GHGs. Modern energy is the driver of technology, which facilitates improvement in living standards, promotion of efficient use of resources, adaptation to local conditions and needs, and integration with other existing technologies. Technology has emerged as the driving force behind: structure of domestic production, advantage in market competition, opportunities for cross border trade, and growth in standards of living of people. These are essential for eradication of poverty as well as for economic development. However, this technology-related development has increased the demand for energy and associated emissions of GHGs. The concern is more serious with developing countries because they are adopting various policies for speeding up the process of economic development in attempting to catch up with the developed countries.

The spectacular economic development measured in terms of GDP growth rates and technological advances is masking the human poverty prevailing in the world. The 2007 estimates suggest that out of a population of about 6.6 billion about 1.7 billion are living below an income of $1.25 a day and about 2.6 billion are living below an income of $2 a day. The number of energy poor is also equally significant at about 1.4 billion without access to electricity and about 3.1 billion without any access to modern fuels for cooking. From this, it could be easily hypothesized that income poor are also energy poor, and energy poverty spans beyond income poverty, if we define $2 a day as poverty line. About 860 million lack access to adequate water and about 2.5 billion do not have access to basic sanitation facilities. Thus, there is currently about 21% of the world population without access to electricity and on a more serious note, about 47% of the global population relies on solid fuels – coal, charcoal, wood, dung and agricultural residues – to meet their daily cooking needs. It appears that the majority of the deprived people live in Asia and the Pacific. The estimates for 2007 suggest that it is home to about 1.8 billion people who survive on less than $2.00 a day and 982 million people living below the poverty line of less than $1.25 a day. More than 406 million people in rural areas and 93 million people in urban areas lacks access to adequate water, while more than 1.9 billion people are living without basic sanitation facilities. About 800 million people in the Asia-Pacific do not have access to electricity and about 2 billion people rely on solid fuels for cooking. This situation has serious impacts on people's health and the condition of the natural environment. It also severely limits people's economic opportunities and ability to overcome poverty.

According to World Energy Outlook 2009 of the International Energy Agency (IEA), the energy sector contributes 84% of global CO_2 emissions and 64% of the world's greenhouse-gas emissions. If no action is initiated, the contributions will increase to about 91% of the global CO_2 emissions by 2030 and the share in GHG emissions is likely to reach 71%. In absolute sense, energy related emissions are expected to increase from 28.8 Gt in 2007 to 40.2 Gt in 2030. To limit the global average temperature increase of 2^oC, the concentration of greenhouse gases in the atmosphere would need to be stabilized at a level of around 450 ppm

CO_2e. According to IEA, in this scenario, the global energy related CO_2 emissions are expected to peak at 30.9 Gt by 2020 and decline thereafter to 26.4 Gt in 2030. To achieve these reductions, the energy demand has to reduce substantially. The strategy as proposed by IEA is to increase contributions from renewable energy and adoption of energy efficiency. Developing countries are worried about what these reductions imply for continuing economic development and efforts in eradication of poverty. It is postulated that these reductions can have very serious implications for economic growth as well as sustainable development. Unless approached strategically by opting for optimally chosen options it can lead to catastrophic consequences for human development.

Energy Access Status and Sources of Energy for Poor

As stated, the most important indicators of energy poverty are the extent of access the population has to electricity and modern fuels for cooking. The status in Asia-Pacific suggest that as a whole about 77% of the population had access to electricity as against the world average of about 78%. This compares favourably with 26% access level in the sub-Saharan Africa. However, the region has countries like Papua New Guinea, Myanmar, Afghanistan, Solomon Islands, Vanuatu, Timor-Leste, Cambodia and Korea, DPR where the electricity access levels are lower than that of sub-Saharan Africa. The urban region with electricity access levels of almost 94% is almost on the verge of achieving universal access whereas still 43% of the rural population does not have access to electricity and this compares favourably with the 89% of the rural population without access in sub-Saharan Africa. However, in terms of absolute numbers Asia-Pacific region with about 807 million people without access to electricity lags behind sub-Saharan Africa at about 591 million without access. Further, the south-Asian region consisting of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, has the highest number of electricity deprived population with about 605 million people without electricity compared to about 591 million in sub-Saharan Africa.

The status of access to modern fuels for cooking is worse than that for electricity access. About 44% of the population of the Asia-Pacific region had access to modern fuels like LPG, electricity, kerosene, natural gas, and biogas for cooking in 2007 compared to 53% globally and just 17% in sub-Saharan Africa. Out of the 34 countries in the region, 8 have access levels lower than that in sub-Saharan Africa and another 8 have access levels of more than 80%. Out of these 8 countries with more than 80% access to modern fuels, 6 belong to small island countries. Even China, which has achieved spectacular success in providing access to electricity, has failed to achieve similar progress with access to modern cooking fuels with only 52% of population having access. About 74% of the urban population in Asia-Pacific use modern fuels for cooking whereas it is only 19% in the case of rural population.

Except for few countries wood is the dominant fuel on which majority of the households depends for their cooking energy needs. Significant share of households in Mongolia and Cambodia rely on electricity for cooking. China and Mongolia depend on coal for meeting significant share of cooking energy needs. The pattern of cooking energy use suggests that it is quite varied and mostly relying on solid fuels. Among the population relying on solid fuels for cooking, about 30% use improved cookstoves and nearly 79% of them live in China. In total, the households of Asia-Pacific region consumed about 18,503 PJ of energy in 2005. Out of this, about 63% share is accounted by the solid fuels. Wood with about 42% share occupies the top position and electricity with nearly 14% share is a distant second. In poorer countries like Cambodia and Nepal, the solid fuels account for over 90% of the household energy consumption whereas it is around 85% in Mongolia and Solomon Islands. India is not far behind these countries with a solid fuel share of about 78%.

The total GHG emission from the household fuel use in the Asia-Pacific is in the range of 1,135 million tonne of CO_2e to 1,853 million tonne of CO_2e depending on how the wood is sourced either from sustainable or un-sustainable source. The share of wood fuel in the total emissions is in the range of 6.5%-42.7%. Emissions from coal account for about 14% of the total GHG emissions. With the sustainable wood assumption, China will be the major emitter with a share of nearly 47% and India coming second with a share of 18% in total GHG emissions. However, with un-sustainable wood, the respective shares for China and India would be 39% and 26%. The total emission of black carbon (BC) is about 1.05 million tonne in the region. Coal used in China contributes to about 68% of the BC emissions. Wood with a share of about 25% is the second most important contributor. China, because of its extensive dependency on coal, accounts for about 73% of the BC emissions in the Asia-Pacific. India with a share of nearly 16% is the second big emitter of BC. Emission of BC is mostly contributed by the poor who rely on solid fuels. Thus, expanding access to modern fuel for cooking has dual benefits – better life for the poor and high climate change mitigation potential.

Sources of Energy in the Industrial Sector

The Asia-Pacific region as a whole is a dominant industrial energy consumer with accounting for about 80% of the coal, 37% of the firewood, 47% of the bagasse, and 37% of the electricity consumed by the global industrial sector. This domination is mainly because of China, where the industries consume 70% of the coal and 82% of the electricity consumed by the industrial sector of the Asia-Pacific. The higher firewood share is because of high industrial consumption in Indonesia (45%) and India (43%) in the region. The industries of the Asia-Pacific region consumed about 31,700 PJ of energy in 2007 which works out to a share of about 40% of the world industrial energy consumption. Among the countries, China accounts for nearly 61% and India for 16% of the total industrial energy consumption in the Asia-Pacific. The two most dominant industrial energy carriers in the Asia-Pacific are coal with nearly 40% and electricity with 31% shares where as the dominant energy carriers in the world are electricity with a share of about 32% and natural gas with a share of about 27%. Solid fuels with about 48% share dominate the industrial energy scene in the Asia-Pacific whereas they account for only 26.6% in the world industrial energy consumption.

The total GHG emission from industrial energy use in the Asia-Pacific region is estimated at 3,910 million tonne of CO_2e in 2007, which is about 41% of the world industrial emissions of 9,535 million tonne of CO_2e. In the Asia-Pacific region, GHG emissions from electricity consumption with 57% and coal with 29% shares account for the largest contribution to the total emissions. It is obvious that with highest share in industrial energy consumption, China accounts for nearly 70% of the GHG emissions contributed by the Asia-Pacific region. The total emission of black carbon is nearly 285,000 tonne in the region and it accounts for nearly 38% of the world BC emissions due to industrial energy use. Diesel with 43% and bagasse with 38% shares are the major contributors to BC emissions in the region. China, because of its extensive dependency on coal, accounts for nearly 38% of the BC emissions in the region.

Expanding Energy Access for Building Empowerment and Resilience

Access to modern energy carriers brings in development – enhanced income, opportunities for economic activities, access to better education and health facilities, connectivity to external world through TV, internet and other media, gender empowerment, clean environment, access to information facilitating knowledge gains, enhanced social status with ability to participate and interact, ability to take informed decisions, etc. All these could significantly enhance the adaptive capabilities of individuals as well as society as a whole.

Further, with the adoption of low-carbon pathways to expand energy access has significant environmental and ecological benefits. All these contribute to empowering the poor and build resilience to adversities. Thus, resilience could be built through economic, knowledge, human and social empowerments.

As discussed earlier, energy development through expanded access to modern energy carriers has implications for economic development. This could happen through employment generation, skill development through education and information dissemination, establishment of small enterprises, access to markets, expansion of economic activities, etc. Thus, GDP per capita measures the level of economic development of a country and the poverty counts indicates the extent of reach of the economic development to the larger section of the population. Even though the average GDP per capita of Asia-Pacific region is just one-third of that of the world its share of extremely poor population (below \$1.25 a day) of 23.5% is less than the global average of 26.2%. This is indicates the benefits of economic development, though low, is better distributed in Asia-Pacific. However, the share of poor population (below \$2 a day) in the Asia-Pacific is high at 51.8% compared to the world average of 40%, which is an indicator of lower economic development in the region.

The human development benefits associated with expanding energy access are related to better education facilities and opportunities, access to healthcare as well as better health conditions, access to information for knowledge empowerment, gender empowerment through reduced drudgery, productive endevours, enhanced security and clean working environment. In addition, the enhanced income levels and employment opportunities would significantly reduce the poverty levels thereby enhancing the living standards of the people. To make a comparison, indicators related to poverty, gender, human development, health, education and access to improved services are used. Asia-Pacific has a smaller poverty gap ratio compared to the world average indicating lesser depth in poverty. However, for countries like Nepal, Bangladesh, Cambodia and India there is a need for substantial efforts to bridge this gap. The high values associated with the multi-dimensional poverty index too points out to the deficiencies in these countries with respect to eradication of poverty and providing access to basic services. On an average, the human development is lower in Asia-Pacific compared to the world but far better than sub-Saharan Africa.

The gender inequalities are highest among poor countries and those are having low energy access levels. China has the least gender inequality index (GII) value indicating higher levels of gender empowerment. The non-income HDI scores indicating the level of achievements with respect to life expectancy and education are relatively high for Tonga, Malaysia and Sri Lanka. Sri Lanka though a poor country in terms of per capita GDP has done well with respect to other development indicators. This is true even with respect to providing access to better sanitation and potable water with more than 90% of the people having access. Cambodia, India and Nepal are the worst performers with respect to providing access to good sanitation facilities. Their performance is same as that of sub-Saharan Africa. Except for Papua New Guinea and Cambodia, all other countries in Asia-Pacific have done well with providing access to clean drinking water to the majority of the population. Most direct impact of using solid fuels for cooking is the indoor air pollution, which is considered as one of the most important causes of deaths in the world. Cambodia with 1,304 deaths per million people in 2004 and India with 954 deaths occupy the top two positions. Next two countries with highest deaths are the neighbouring countries of India, namely, Nepal and Bangladesh.

The implications for environmental development are analysed keeping in mind the possibilities of mitigating the negative effects of climate change and building climate change resilience. In this regard, lack of modern energy access and over dependency on solid fuels has significant negative implications for climate change. In addition, the indicators of environmental/ecological development and degradation are used for assessing environmental development. The analysis suggests that all the developing countries of the Asia-Pacific together accounted for about 31% of the global energy related CO_2 emissions with China accounting for almost 67% of this amount. In terms of per capita emissions only Malaysia and China have higher emissions compared to the global average. As a whole, Asia-Pacific appears to be a low carbon intensive region both in terms of per capita emissions as well as carbon intensity of GDP. The countries with highly inadequate energy development such as Bangladesh, Cambodia and Nepal have very low per capita emission levels. These low per capita emissions in these countries are an outcome of poverty and dependency on traditional biomass fuels. Ecological footprint is a measure of human demand on the Earth's ecosystems. The data for the Asia-Pacific suggest that on an average it has a better ecological footprint at 1.5 hectares per capita compared to the global average of 1.8 hectares per capita. The smaller Pacific Island countries exert higher pressure on the earth's resources with ecological footprint ranging from a high of 3.7 hectares per capita in the case of Fiji to 1.7 hectares per capita for Solomon Islands and Papua New Guinea. Countries like Cambodia, Sri Lanka and Thailand with high share of protected areas could be less vulnerable to natural disasters. People living on the degraded land would be the most vulnerable to climate change related impacts. Cambodia, Mongolia and Sri Lanka with high share of population living on the degraded land expected to suffer more during disasters.

Energy Access Policies and Programmes

The status of modern energy access in the Asia-Pacific as in 2007 suggests that about 77% of the population had access to electricity and about 44% had access to modern fuels for cooking. Relatively high access level in electricity was the outcome many successful programmes implemented across Asia-Pacific. For example, in the early 90s China was electrifying villages at the rate of 30 per day and Viet Nam gave almost 400 people access to electricity per hour for 15 years. Though not as successful as in the case of electricity there were programmes targeting expansion of cooking fuel access. The biogas for cooking programmes implemented in China and India were reasonably successful. Broadly, the policies and programmes for expanding could be classified into – large-scale government initiated focused programmes, price controls to enhance affordability through energy subsidies and tax incentives, promoting technology dissemination and small-scale NGO and private sector initiated programmes with donor funding and government support.

China's national electrification rate in 2009 was 99.4% as with rural electrification of 99% and 100% in urban areas, which is an outcome of government's focused rural electrification programme providing electricity to over 900 million people during the period 1950-2004. Key factors in China's success were the government's ability to mobilize contributions at the local level, creation of local enterprises and the domestic production of low-cost components. Viet Nam achieved extremely rapid electrification, expanding coverage from about 10% in 1986 to 96.6% in 2009. Access to low-cost finance, funding from multiple sources and insistence on cost recovery, through tariffs or from government budget, were important for this success.

Many governments initiated large-scale programmes to support dissemination of renewable energy and energy efficient technologies. Most of these programmes had provision of access to modern energy carriers to the people, especially in rural areas, as one of the objectives in addition to promoting technology dissemination. Biogas plants, advanced biomass cookstoves, micro-hydro power plants, biomass power generation systems, solar water heaters, solar PV and home lighting systems are some prioritized technologies chosen for dissemination. Most of these projects are implemented by the local NGOs, government agencies and private sector entities with funding from international donor agencies. Funding has been largely restricted to renewable energy technology-based energy access programmes with twin objectives of climate change mitigation and energy access.

Low Carbon Energy Development in Asia and the Pacific – The Way Forward

The earlier discussions established the fact that universalizing access to modern energy carriers for the large majority of the poor in the Asia-Pacific has multiple benefits. Keeping this in mind, a proposal to achieve universal energy access in the Asia-Pacific is presented. It targets at 100% access to modern energy carriers/technologies for cooking, lighting and other basic electricity-based uses by 2030, i.e., in another 20 years starting from 2010. To ascertain the implications of 100% access to energy requirements, investments, operating and capital costs, GHGs and black carbon emissions, two scenarios are developed:

Baseline Scenario (BS) tracking the expansion of modern energy access in 2015 and 2030 with a base year status as on 2009. This scenario is similar to the Current Policies Scenario of the World Energy Outlook 2010.

Universal Energy Access Scenario (UAS) This assumes all will have access to modern energy carriers/technologies in 2030. Other inputs and assumptions are similar to that used for BS.

The implications are analysed based on following:

- The energy needs are to be met with a judicious mix of energy supply from both centralized energy systems (electricity grid and LPG) and decentralized energy systems (Mini-grid and Off-grid electricity systems, biogas from bioenergy systems, advanced biomass cookstoves).
- An annual electricity consumption norm of 500 kWh per urban and 250 kWh per rural households and an average annual LPG consumption 22 kg per capita.

The incremental electricity requirement for providing universal electricity access is about 74,000 GWh and the associated generation requirement is nearly 87,000 GWh. This estimate includes the electricity requirement of only those people who have been given access under the universal energy access programme. India accounts for nearly 54% of this requirement. The total incremental annual cost of providing universal electricity access is about US$ 12 billion by 2030 with India accounting for about US$ 6.5 billion. The total investment required over the period of 20 years is about US$ 40 billion with India accounting for more than 50% of it. The incremental CO_2 emissions due to universal electricity access are negligible at about 25 million tonne per year by 2030. With respect to universal access to modern fuels for cooking, about 4 billion people in the world need to be provided with access in the next 20 years. Nearly 2.8 billion of them would be from the Asia-Pacific with India accounting for 1 billion and China for about 750 million. Annual LPG requirement for this incremental population would be about 24 million tonne in the Asia-Pacific and nearly 36 million tonne globally. Most of the incremental energy needed for cooking would be met from biogas plants and advanced cookstoves. Total investment required over a period of 20 years in the Asia-Pacific is about US$ 72 billion.

Universal energy access needs a robust implementation mechanism to achieve the time-bound targets. We have made some specific recommendations for designing of regulatory policies, programmes, institutions, financing and local delivery mechanisms, which may function as useful inputs for developing country-specific universal energy access programmes.

Energy Access Policy: Enact energy access policies targeted at the poor who are vulnerable and have serious issues with affordability and it should – allow for lifeline energy consumption and affordable tariffs, enable establishment of institutions for programme implementation and delivery of energy services, enable creation of energy access funds to support implementation, provide for establishing distributed energy systems and flexible access to the grid, provide for tax incentives and support capacity development.

National and regional institutions for implementation: Dedicated national and regional institutions for implementing programmes are critical for the success. The role of national institution is to design implementable programmes, support its actual implementation along with regional/state level institutions and many other stakeholders, and monitor its progress.

Multi-stakeholder partnerships: These processes have to pass through a number of hurdles, which are created by various stakeholders of energy systems and their involvement is absolutely necessary to overcome them. Government/policy makers, energy organizations/utilities, technical institutions and R&D organizations, industries, entrepreneurs, financial institutions, donor agencies, NGOs and consumers need to join together to achieve the objective of universal energy access. The role of the stakeholders could be related to financing, advising, information dissemination, technology provision, capacity building and monitoring.

Dedicated energy access funds: Obtaining the required financial support for programme implementation is crucial. The proposal is to establish dedicated energy access funds at the national as well as regional or state levels. These could be made up of contributions from national budgets, government grants, redeployed energy subsidies, contributions from multilateral agencies and international donors.

Support from Carbon Markets: The climate change mitigation imperatives have created many market mechanisms established through international protocols which allow the avoided GHG emissions to be traded in the carbon market. The Clean Development Mechanism (CDM) is one such mechanism. The low-carbon pathway adopted for expanding energy access would have large potential for certified emission reductions (CERs) through avoided GHG emissions and these could be traded in the carbon markets under CDM or similar carbon trading mechanisms.

Institutions for local delivery of energy services: The success of these programmes depends mainly on the existence, effectiveness and efficiency of the local institution responsible for delivering energy carriers or services. This institution could be a small scale enterprise, an NGO or a community organization. These institutions need to be empowered with capacity to create and maintain the local energy infrastructure.

Capacity Development: As proposed, multiple stakeholders at different levels are involved in implementation of this universal energy access programme. The awareness and knowledge levels, experiences and commitment levels are varied across the strata of individuals associated with these stakeholders. Successful implementation to a large extent depends on empowerment of these individuals through effective capacity development programmes.

Energy Outlook for the Industrial Sector

The industrial sector in the Asia-Pacific is expected to continue to have a dominant share in the final energy demand even in future. As per the estimates, the industrial sector accounted for about 35% of the total final energy demand in 2006, which is expected remain same in 2015 and marginally reduce to 33% in 2030. The energy related CO_2 emissions is forecast to grow from 10,749 million tonne to 17,763 million tonne an increase of 65%. With majority of the developing countries in the region striving hard to attain high economic growths and sustain them in the long run these increases are bound to happen. However, with the climate change threats looming large and need for urgent actions towards mitigating these threats, these countries cannot escape from the responsibilities. According to IEA's reference energy scenario, the industrial sector energy demand is likely to be 1,793 MTOE in 2030. However, the 450 ppm climate change stabilization scenario requires this demand to reduce to 1,526 MTOE, a reduction of 267 MTOE. This reduction is to be achieved mainly through implementation of energy efficiency measures across industries.

The expectations are that the large reductions in energy consumptions and associated GHG emission reductions will result partly from a shift to low-carbon economic structure. Most of the critical measures in the industrial sector are expected to be initiated in the region are in China and India. Some of the measures proposed are rebalancing of the economy, efficiency improvements in industries, increasing use of CCS. Globally, the incremental investment required to achieve these objectives is estimated at US$ 18 trillion over a period of 2010 to 2035.Out this, the industrial sector needs an investment of US$ 2 trillion.

Conclusion

The technical paper begins with emphasizing the issues of securing energy needs of poor and climate change mitigation emerging as conflicting challenges and their significance in the developing countries of the Asia-Pacific region in the global context. These challenges are extremely critical in the region because it has the highest energy deprivation among the poor at present and it is fast moving towards emerging as the biggest emitter of CO_2 in the future. Energy deprivations measured in terms of lack of access to electricity and modern fuels/technologies for cooking are found to be critical in the region. The poor in the region mostly rely on solid fuels like wood, coal, cattle dung and agro-waste for most of their energy needs. Solid fuels accounts for about 63% of the total household energy consumption with significant contributions to both CO_2e as well as BC emissions. Further, the linkages between energy, poverty, sustainable development and climate change are analysed by developing different sets of indicators and the results suggested relatively strong association among these. A composite development index is developed integrating the indicators of economic, energy, environmental and human developments and the selected developing countries of the region are compared against this index for empowerment and resilience. Finally, the possibility of providing universal access to modern energy carriers for the households of the Asia-Pacific is explored by adopting a low-carbon pathway. The proposal entails a total incremental investment of US$ 113 billion over the next 20 years for providing electricity access to about 734 million people and access to modern fuels to about 2,779 million people. This is equal to a per capita investment of US$55 for providing access to electricity and US$26 for access to modern fuels. The GHG emissions due to universal energy access is minimal, a total incremental CO_2 emission of 101 million tonne per year in 2030. This is equal to a per capita annual emission of 35 kgCO_2 for electricity access and 27kgCO_2 for modern fuel access. This is negligible compared to the current (2007) average per capita CO_2 emissions of 2.7 tonne in the Asia-Pacific region. Overall, it appears a win-win proposition for all the stakeholders.

Energy and Poverty in the Context of Climate Change

1. Introduction

Poverty and climate change are the two greatest challenges being faced by the humanity. Poverty is an ongoing crisis whereas climate change is an impending crisis. Climate change related impacts are expected to intensify the sufferings of the poor by impacting the meager resources and assets owned by them. Poor with limited access to income as well as to other resources, goods and services are typically vulnerable to unpredictable events and disasters. Climate change is likely to result in many such events. Energy is at the center of the two – extent of its access determines the poverty levels and it contributes to climate change by emitting green house gases (GHGs). Energy, more specifically the modern energy, is the driver of technology and in general, technology is viewed as a mechanism, which transforms the natural resources into goods and services useful for the survival of human life. The technologies are expected to facilitate improvement in living standards, promotion of efficient use of resources, adaptation to local conditions and needs, and integration with other existing technologies. In short, the technologies are expected to meet both the livelihood and lifestyle needs of people in a sustainable manner. In the era of liberalized and interdependent global economy, technology has emerged as the driving force behind: structure of domestic production, advantage in market competition, opportunities for cross border trade, and growth in standards of living of people. These are essential for eradication of poverty as well as for economic development. However, this technology-related development has increased the demand for energy as well as associated emissions of green house gases (GHGs). The concern is more serious with developing countries because they are adopting various policies for speeding up the process of economic development in attempting to catch up with developed countries. As recognition of increasing concern about environmental impacts, the international community is again looking towards technologies to provide a solace to this problem. It is thus not surprising that a frequently expressed view on global climate change has been "If the introduction of technologies created the problem, other new technologies will help in solving it".

Thus, the environmental issues arising out of energy-technology interactions are a cause of concern. Even though the main concern of developing countries was to meet the ever increasing demand for energy by its huge population, the global concern was how to mitigate the harmful environmental impacts of energy use. Climate change is one of the key challenges facing the international community. It will have severe negative implications for environmental, economic and social systems. This growing concern is mainly about global warming due to the increased concentration of greenhouse gases (carbon dioxide, methane, etc.) and the resulting socio-economic impacts.

As stated above, the other concern is poverty. Though, in general, poverty is measured in terms of income it reflects in several non-income dimensions involving the interface of environment, health, vulnerability, and empowerment and manifested in the quality of natural resource base, ecosystem services, property rights, air and water quality, access to water and sanitation, typology of energy use, quality of housing, and existence of slums (Bojo and Reddy 2003). The spectacular economic development measured in terms of GDP growth rates and technological advances is masking the human poverty prevailing in the world. The 2007 estimates suggest that out of a population of about 6.6 billion about 1.7 billion are living below an income of $1.25 a day and about 2.6 billion are living below an income of $2 a day (UNESCAP 2010a, World Bank 2009). The number of energy poor is also equally significant at about 1.4 billion without access to electricity and about 3.1 billion without any access to modern fuels for cooking. From this data, it could be easily hypothesized that income poor are also energy poor, and energy poverty spans beyond income poverty, if we define $2 a day as poverty line. About 860 million lack access to adequate water and about 2.5 billion do not have access to basic sanitation facilities (UNDP 2010a).

It appears that the majority of the deprived people live in Asia and the Pacific. The estimates for 2007 suggest that Asia and the Pacific is home to about 1.8 billion people who survive on less than $2.00 a day and 982 million people living below the poverty line of less than $1.25 a day (UNESCAP 2010a, World Bank 2009). More than 406 million people in rural areas and 93 million people in urban areas lacks access to adequate water, while more than 1.9 billion people in the region are living without basic sanitation facilities (ADB 2010a). About 800 million people in Asia and the Pacific do not have access to electricity and about 2 billion people rely on solid fuels for cooking and heating (WHO 2010a).

Thus, there is currently about 21% of the world population, mostly in rural areas, without electricity and relying on kerosene for meager lighting. On a more serious note, about 47% of the global population relies on solid and polluting fuels – coal, charcoal, wood, dung and agricultural residues – to meet their daily heating and cooking needs. This situation has serious impacts on people’s health and the condition of the natural environment. It also severely limits people’s economic opportunities and ability to overcome poverty. Major changes in the energy service delivery system are needed so that expansion of energy access can become an important instrument for sustainable development.

Without access to an adequate quantity and quality of modern energy services, achievement of the MDGs will not be possible. With human development being strongly linked to sustainable economic development (in terms of scope, growth, reach and spread) energy becomes the natural binder. Expanded energy services are essential to meet the MDGs for reducing hunger and poverty, improving health care and educational opportunities, and addressing gender equity. In addition, energy is central to all aspects of sustainable development, including access to water, agricultural and industrial productivity, health care, educational attainment, job creation and climate change impacts. Affordable, accessible and reliable energy supply for delivering modern energy services is critical for uplifting the poor as well as for economic growth of a country. In many developing countries, especially in sub-Saharan Africa and South Asia, large numbers of people still live without any access to modern energy services.

Thus, there appears the world, especially the developing world, is facing a herculean task of expanding access to modern energy carriers to majority of its population in order to achieve the desirable objectives of economic and human development with minimum contributions to climate change. The only choice available for the developing countries is to adopt a low-carbon pathway to development aiming at achieving universal energy access.

1.1. Objectives and Scope

The overall objective of this technical paper is to develop an evidence-based research paper analyzing issues, challenges and solutions related to energy-poverty nexus and their linkages with climate change from the human development perspective, focusing on the developing countries of Asia-Pacific. The specific objectives of the study are:

1. To illustrate that the economic growth in Asia-Pacific countries is reliant on the energy sector.

2. To analyze the patterns and cross-country differences in energy needs for poverty reduction and development, focusing on achievement of the MDGs.
3. To analyze the disparity in per capita energy use across countries and across population groups in Asia-Pacific?
4. To analyze the role of households and industrial sectors in energy consumption and their impact on GHG emissions.
5. To discuss the challenges and opportunities for pursuing more sustainable energy use strategy that contributes to reduction in GHG emissions.
6. To identify the main issues and challenges regarding energy access and availability to the poor and the vulnerable groups and study how can greater access help reduce climate change vulnerabilities and build resilience.
7. What are the main gaps in current energy and climate policies in the region? How can they be improved to include the specific concerns of the poor more effectively?
8. To discuss role of regulatory, institutional and incentive frameworks to support the region's management of energy use, as well as access for the poor.
9. What are the opportunities for promoting greater access to energy use by the poor, for example, while heightening efforts to reduce GHG emissions?
10. What are the barriers (policy/regulatory/technical/financial/attitudinal) to change in terms of transitioning to innovative, efficient and modern energy forms? What are the appropriate ways of overcoming these barriers?

In assessing the energy poverty, we have limited our analysis to two indicators, access to electricity for lighting and other basic end-uses, and modern fuels for cooking/heating, in the residential sector. The modern fuels for cooking include Liquefied Petroleum Gas (LPG), Natural Gas, Kerosene and Electricity. This assessment does not include energy use for productive and lifestyle end-uses and other sectors of rural economy (e.g., agriculture, industry, transport, etc.). The underlying assumption is that once the physical access, especially for electricity, is established it will function as a stimulus for other energy-using activities to emerge without any need for serious external interventions.

The data and estimates for each of the selected developing countries (Table 1) of Asia-Pacific region have been presented along with giving the total estimates for Asia-Pacific, which include all the developing countries[1] of the region. Further, the total estimates for Asia-Pacific are compared with the estimates obtained for the World and Sub-Saharan Africa. It is important to remember that the data and estimates for only the developing countries of the Asia-Pacific are included for the analysis and therefore in the subsequent discussions if Asia-Pacific is mentioned then it means only the total estimated for all the developing countries of the Asia-Pacific. The selection of countries have been made representative by including the major developing and fast industrializing countries that dominate energy consumption in Asia and the Pacific. In addition the selection also includes the under privileged countries representing groups like least developed countries (LDCs), landlocked developing countries (LLDCs) and small island developing states (SIDS). Out of 16 (in some cases 15) countries

[1] The other developing countries of Asia-Pacific (excluding those listed in Table 1) are – Afghanistan, Bhutan, Cook Islands, Fiji, Iran, Kiribati, Korea DPR, Lao PDR, Maldives, Marshall Islands, Micronesia, Nauru, Niue, Pakistan, Samoa, Timor-Leste, Tokelau, Tuvalu

selected for analysis, 7 are major developing economies, 5 countries are part of LDCs, 2 belong to LLDCs and 5 are SIDS (Table 1). Some countries belong to more than one category.

Table 1: Countries selected for analysis and their groupings

Categories	Countries
Major Developing Countries (MDCs)	China, India, Indonesia, Malaysia, Philippines, Thailand, Viet Nam, Sri Lanka
Least Developed Countries (LDCs)	Bangladesh, Cambodia, Nepal, Solomon Islands, Vanuatu
Landlocked Developing Countries (LLDCs)	Mongolia, Nepal
Small Island Developing States (SIDS)	Papua New Guinea, Palau, Solomon Islands, Tonga, Vanuatu

Source: Based on UNESCAP 2010b, TOR_TBP3 2010, UNDP 2010

1.2. Energy Security of Poor and Climate Change Mitigation: Conflicting Challenges

Energy security, fulfilling one's energy needs in a *sustainable* manner, is an important issue both from the perspective of economic development aiming at eradication of prevailing extreme poverty and climate change which is threatening the existence of humanity. Energy, development and climate change are correlated and the causation is both ways. Higher energy use enhances production, promotes economic development and improves standard of living of people. These in turn, promotes higher energy consumption and thereby increased emissions of greenhouse gases. Energy is closely linked to economic opportunity, security and empowerment. Majority of the households in the developing world, especially in the Asia-Pacific, can neither afford to have modern energy carriers nor reconcile to have standard of living below poverty line because of energy starvation. Energy poverty defined in terms of lack of access to modern energy services is a direct outcome of income poverty. The poor cannot afford modern energy carriers and live in houses, which are unfit to be connected to the modern energy systems, for example, to the electricity grid or to a gas network. Similarly, a poor nation is constrained by inadequate access to energy and capital resources, and therefore cannot build adequate infrastructure to create connectivity to modern energy carriers. Thus, "un-affordability" due to poverty and "inaccessibility" due to inadequate infrastructure are the root causes of lack of access to modern energy. Lack of energy access has implications for economic development, livelihoods, social dignity and environmental sustainability.

Access to energy has strong links with poverty reduction through income, health, education, gender, and the environment (Saghir 2005). With energy being the driver of technology which in turn drives the economy, access to education, water, health, sanitation, information, employment and other essential services rely completely on energy access. It is a vicious circular chain of linked events, one leading to another and finally getting back to original position of poor "individual" and "country" (Balachandra 2010). UNDP's millennium development goals (MDGs) are the reflection of the desires of the suffering humanity. Even though there is no MDG directly addressing energy, it is clear that reaching the Goals will require great improvements in the quality and quantity of energy services in the developing world. The Johannesburg Plan of Implementation, which was adopted at the 2002 World Summit on Sustainable Development, recognized a direct link between energy services and poverty reduction, and called for joint actions to improve access to reliable and affordable energy services "bearing in mind that access to energy facilitates the eradication of poverty"

(CSD9 2002). The authors (Modi et al, 2005) of the report Energy Services for the Millennium Development Goals, published in 2005 by the World Bank/ESMAP, UNDP and the UN Millennium Project, recommend that national governments "place the issue of energy services at par with other MDGs". They also recommend that countries systematically integrate their energy sector development strategies into a comprehensive MDG-based national development strategy (Modi et al, 2005).

Thus, it is not an exaggeration to state that expanding energy access is at the core of achieving MDGs. Many stakeholders including national governments, international organizations, NGOs have recognized these linkages as well as the need for expanding energy access. However, the experiences as well as the literature suggest that the gap between recognition of the need for expanding energy access and action towards this is very wide and ever expanding. The issues of energy access are only treated superficially in national and international development plans (UNDP 2007a). Partially, this is because energy governance is always biased towards "supply-side" and suggested solutions always revolve around "hardware" aspects. The "demand-side" aspects of energy have always been neglected. Energy service for sustainable development has never been the focus of energy planning. The focus of the energy sector is usually on expanding electrical generation and refinery capacity, and transmission & distribution lines, and maintaining steady supply of fossil fuels (Balachandra 2010).

The outcome of such lopsided energy policies is the large number of energy poor in the developing countries of the world living with primitive energy lifestyles. As in 2007, there were 1.4 billion (22%) without access to electricity and 3.1 billion (40%) depending on solid fuels for cooking out of a total of 6.6 billion world population. Most of the deprived population lives in the rural regions of the developing countries. Out of the total global rural population of 3.3 billion about 79% (2.6 billion) depends on solid fuels for cooking and about 37% (1.2 billion) is without access to electricity (IEA 2009, UNESCAP 2010a). Energy empowerment through access to modern energy services is an essential component of any policy aiming to address health, education or welfare issues of rural people.

Climate change is the most important global environmental challenges facing humanity with implications for food production, natural ecosystems, fresh water supply, health, coastal settlements, etc. Historically, compared to the developed countries, developing countries have contributed little to the climate change in the form of GHG emissions. However, this cannot be said about the future. The developing countries, especially in the Asia-Pacific, are experiencing spectacular economic growth and thereby enhanced energy consumption levels as well as consumption of other resources. This indicates that the Asia-Pacific region is likely to emerge as one of the significant emitters of GHGs. In most of the countries, the benefits of high economic growth are yet to reach the large section of the population. Imperatives of high GDP growth and all inclusive development will cause high demand for resources and resultant emissions. There will be pressures internally as well as internationally to alter the path of development by adopting environment friendly alternatives. In the long run this might prove advantageous to the country.

Climate change is the buzzword in international negotiations, national planning and academic interactions. It is due to the inevitable catastrophic events predicted to happen in the next 30–100 years and threaten the existence of humanity in its current form and style. Global community, including scientists, economists, policy makers, is calling for immediate action to mitigate the negative impacts of climate change. Actions are being initiated and at the same time there are calls for more action and unhappiness over the inaction or limited action by the major polluters. Critical issue in this sphere of action and no action is the indecisiveness of the politicians and policy makers. There is indecisiveness with regard to who needs to take action to mitigate climate change and who has to pay for it. Also, there is a critical need for making the large majority of the poor part of the development process. Science of global warming is well established, however, the resulting impacts are still probabilistic. Thus, scientific, political, economic and social reasons have contributed to make climate change a challenging issue. Global warming is caused by indiscriminate use of resources for variety of human needs and is largely responsible for climate change. Past actions of greedy mankind and continued desire to pursue the same path has resulted in such an outcome. The current definition of progress is largely confined to economic wellbeing of humankind dictated by access to modern technologies, which are driven by modern energy carriers. While meeting development needs of human kind, the production and use of energy also contributed to the degradation of the environment. Thus, energy production and use are the main causes of global warming. Among the greenhouse gases (GHGs), which are responsible for global warming, CO_2 is the most prominent one.

According to World Energy Outlook 2009 of the International Energy Agency (IEA), the energy sector contributes 84% of global CO_2 emissions and 64% of the world's greenhouse-gas emissions (IEA, 2009). If no action is initiated, the contributions will increase to about 91% of the global CO_2 emissions by 2030 and the share in GHG emissions is likely to reach 71%. In absolute sense, energy related emissions are expected to increase from 28.8 Gt in 2007 to 40.2 Gt in 2030. To limit the global average temperature increase of 2^oC, the concentration of greenhouse gases in the atmosphere would need to be stabilized at a level of around 450 ppm CO_2e. The energy sector contribution is expected to be very significant to achieve this target. According to the IEA, in this scenario, the global energy related CO_2 emissions are expected to peak at 30.9 Gt by 2020 and decline thereafter to 26.4 Gt in 2030, a reduction of 2.4 Gt from the 2007 level and 13.8 Gt below that in the business-as-usual or reference scenario in 2030. To achieve these reductions in CO_2 emissions, the energy demand has to reduce substantially. The projections suggest that in the 450 ppm scenario, the estimated energy demand would be 13,600 mtoe in 2020 and 14,389 mtoe by 2030. The corresponding figures in the case of reference energy scenario are 14,450 mtoe in 2020 and 16,790 mtoe in 2030. This indicates a reduction in energy demand of 850 mtoe by 2020 and 2401 mtoe by 2030 (IEA 2009). The strategy as proposed by IEA is to increase contributions from low carbon energy technologies like renewable energy, hydro, nuclear and natural gas. In addition, energy efficiency is expected to be one of the largest contributors to abatement of CO_2. Developing countries are worried about what these reductions imply for continuing economic development and efforts in eradication of poverty. Does climate change mitigation results in sacrificing human development? It is postulated that these reductions can have very serious implications for economic growth as well as sustainable development of the poor countries. Unless approached strategically by opting for optimally chosen options it can lead to catastrophic consequences for human development.

1.3. Emphasizing the Asia-Pacific Region in the Global Context

Asia and the Pacific is the dominant region with a population of 3.72 billion out of a total world population of 6.61 billion in 2007 accounting for a share of about 56% (UN Data 2009). The developing countries in the region account for more than 94% of the total Asia-Pacific population. Though not at same scales, the economy of Asia-Pacific region is also significant with about 25% share in the total world GDP of about 61 Trillion US$ in 2008 (UNESCAP 2010a). Though developing Asia-Pacific accounts for 94% of the population its economic dominance is limited to only 51% share in the total Asia-Pacific GDP of about 7.6 Trillion US$ in 2008. Since our focus is on the developing countries of Asia and the Pacific all the future comparisons are made between the developing Asia-Pacific and the World to show the significance of the region both in terms of development and deprivation.

A comparison of some of the important indicators of energy, economic and human development as well as contributions to climate change is presented in Table 2 to show the significance of the developing Asia-Pacific in the global context. A ratio of World by Asia-Pacific for every indicator is developed for making easy comparison. For indicators, which contribute positively to the development (economic, human, environmental, efficiency, productivity, etc.), any value above one for the ratio indicates that Asia-Pacific is worse off compared to the world average and higher values suggest the extent of bad performance. Any value lower than one for these indicators, convey a favourable situation for the Asia-Pacific. Similarly, for the indicators, which contribute negatively to the development, the ratio value greater than one indicates a favourable situation for the Asia-Pacific and any value lower than one connotes the opposite.

The indicators related to per capita energy consumption suggest that the developing countries of Asia-Pacific need to do a lot to catch up if they like to reach the consumption levels of world at large. This is especially true with respect to electricity consumption where world average is 2.5 times larger than the per capita electricity consumption in Asia-Pacific and this ratio increases to about 3.4 for per capita household electricity consumption indicating low consumption levels in the homes of Asia-Pacific. However, per capita wood fuel consumption in Asia-Pacific is lower than the world average. Asia-pacific is energy inefficient as indicated by the higher energy intensity of GDP (Table 2). About a quarter of energy production and consumption in quantitative terms occurs in the developing countries of Asia-Pacific. It appears that the energy supply in Asia-Pacific is more sustainable which is indicated by the higher share of renewable energy. However, this may be largely due to the high dependency of residential sector on traditional biomass for cooking and heating. Indicators of economic development suggest that the developing countries of Asia-Pacific on an average have only a third of per capita GDP of the world. However, the share of extremely poor people in Asia-Pacific is a shade better than world share where as more than half of the population in Asia-Pacific is moderately poor. Indicators of human development show that countries of Asia-Pacific, except for access to sanitation, are marginally inferior compared to the world average. In terms of contributions to GHGs, on an Average Asia-Pacific performs better than world as a whole (Table 2). The region fares better both in terms of per capita emissions of CO_2 as well as carbon intensity of GDP. Low carbon intensity of GDP is noteworthy considering that fact that China dominates the world in manufacturing, which is typically energy intensive. Low per capita emissions are mainly due to large scale modern energy (mostly fossil fuel based) deprivation prevailing in the region.

Overall, the comparison of indicators of energy, economic and human development suggests that the countries of Asia-Pacific need to perform a lot to reach the global average levels. Only solace is the performance on the climate change contribution front. However, in the process of achieving the development targets it is natural to expect worsening of the climate change performance. In other words, carbon emissions are bound to rise. However, the global priorities are towards reducing the carbon emissions and there is insistence for the involvement of major developing countries of Asia-Pacific in such efforts. In such a situation the suggested alternative is to adopt low carbon pathway to achieve the development targets. Thus, energy efficient technologies and processes, renewable energy sources and other nonfossil fuel-based energy sources should become equally important alternatives for meeting the ever growing energy demand.

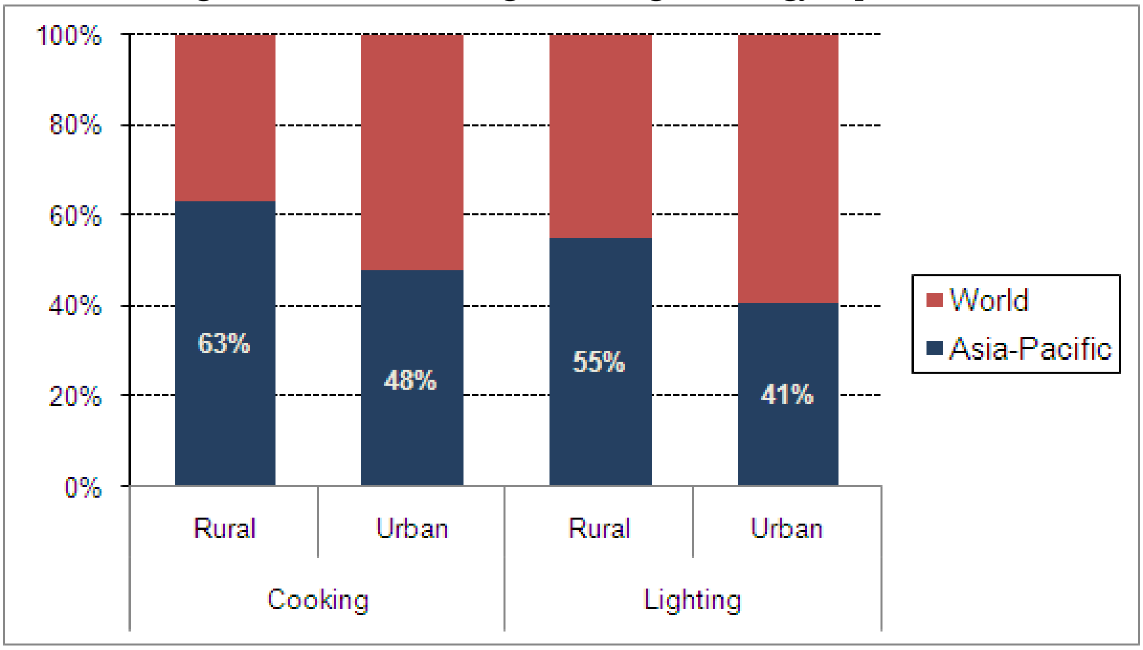
Table 2: Developing Asia-Pacific in the global context – Comparing indicators

Indicators	Asia-Pacific	World	Share (%)	Ratio of World to the Asia-Pacific
Population in 2007 (Million)	3,509	6,614	53.05	1.88
Per capita Energy Consumption (GJ)				
Primary Energy	40.3	76.4		1.89
Electricity	4.57	11.66		2.55
Wood Fuel	2.22	2.84		1.28
Household electricity	0.73	2.49		3.41
Energy/GDP (in '000 GJ; 2005 PPP$)	10.5	7.8		0.74
Energy Supply and Demand				
Gross electricity production in 2007 (TWh)	4,969	19,855	25.02	4.00
Primary Energy Production in 2007 (MTOE)	3,045	11,974	25.43	3.93
Primary Energy Consumption in 2007 (MTOE)	3,133	12,137	25.81	3.87
Production-Consumption Ratio	0.97	0.99		1.02
Share of fossil energy in primary energy supply (%)	64.9	79.0		1.22
Share of renewable energy in primary energy supply (%)	34.8	21.0		0.60
Indicators of Economic Development				
GDP Per capita in 2008 (2005 PPP$)	3,172	9,634		3.04
% Population living below $1.25 (2005 PPP)	23.5	26.2		1.11
% Population living below $2.0 (2005 PPP)	51.8	40.0		0.77
Indicators of Human Development				
Human Development Index (HDI) Value	0.564	0.624		1.11
Gender Inequality Index (GII)	0.637	0.560		0.88
Non-income HDI value	0.633	0.663		1.05
Life expectancy at birth in 2010 (years)	67.9	69.3		1.02
Mean years of schooling in 2010 (years)	6.6	7.4		1.11
Population with access to Water (%)	83	87		1.05
Population with access to Sanitation (%)	65	62		0.96
Indicators of Climate Change				
CO_2 Emissions from the Consumption of Energy (Million Tonne)	9,378	29,784	31.49	3.18
CO_2 emissions (tCO_2/capita)	2.67	4.50		1.68
Carbon Intensity using (tCO_2/'000 2005 PPP$)	0.37	0.46		1.26

Source: Estimated based on ADB 2010a, EIA 2010, UNDP 2010b, UNESCAP 2010a, UN Data 2010, Nation Master 2011

Most discouraging fact is the extent of energy deprivations prevailing in the developing countries of Asia-Pacific. Energy deprivations measured in terms of lack of access to electricity and modern fuels for cooking show that Asia-Pacific accounts for significant share of the world population who are deprived of access to electricity and modern fuels (Figure 1). About 63% of the world rural population without any access to modern fuels for cooking lives in Asia-Pacific. Similarly, 55% of the world rural population lacking electricity access is located in the developing countries of Asia-Pacific. Access status with respect to urban population is better in Asia-Pacific with less than 50% share in deprived population (Figure 1). With about 61% of the world rural population living in Asia-Pacific, the burden of energy deprivation in terms of lack of access to modern fuels for cooking is more than its share of rural population. However, with 55% of the world rural population lacking access to electricity belonging to Asia-Pacific, which is less than its share of rural population, the performance of Asia-Pacific could be said better than the world performance in expanding electricity access.

Figure 1: Asia-Pacific region has higher energy deprivation



Source: Based on WHO 2010a, UNESCAP 2010a

1.4. Energy Access – Concept and Definition

Energy access is a term mostly used in the context of describing the energy use pattern of poor people in the world (Sagar 2005, IEA 2010b, UNDP-WHO 2009). It basically means extent of access these poor people have to the energy end-use services delivered by the modern energy carriers like electricity, petroleum products and modern biofuel. The typical energy end-uses considered for determining access levels are household cooking and lighting, which are treated as basic energy needs. In some cases, end-uses contributing to productive livelihoods like mechanical power are also included. Residential uses of energy are expected to positively impact the rural quality of life or improve rural living standards. Thus, access to electricity enables satisfaction of need for energy services like lighting, space cooling, information and communication and income generating livelihoods. The productive use of energy in rural areas is expected to result in increased rural productivity, greater economic growth, and a rise in rural employment, which would not only raise incomes but also reduce the migration of the rural poor to urban areas (Cabraal et al 2005). In the present context, only two residential end-uses, cooking and lighting are included for assessing the energy access levels. In the present study, the modern energy carriers considered for cooking are liquefied petroleum gas (LPG), kerosene, cattle dung or soft biomass based biogas and electricity, and that for lighting it is electricity. In general, energy access does not mean just a physical access to the energy carrier, it is beyond that. We have made an attempt here to present a broader concept of energy access (Balachandra, 2011a).

Conceptually **energy access** means that modern energy services should be physically **accessible** and **available** to the people, should be of **acceptable** quality, reliability and preference, should be **affordable** in terms of low capital and operating cost, and also in the context of income levels, and finally it should be **adequate** in terms of abundance.

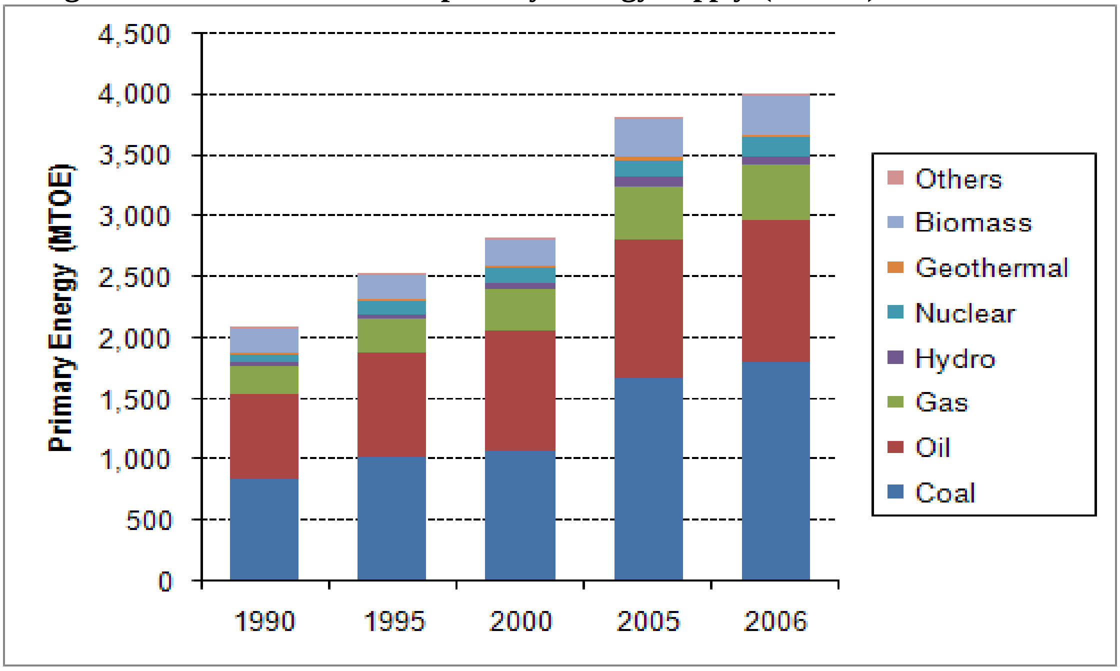
In the case of electricity access for lighting and other end-uses, for example, mere extending the electricity grid to the village and connecting the household to the grid alone do not ensure "Energy Access" as defined above. Opening a LPG agency in the village, installing biogas plants and having a PDS kerosene shop alone do not ensure access to modern cooking fuels. Only when it conforms to above conditions and provides modern energy-based end-use services for meeting the basic and livelihood needs for all, one could say that the goal of energy access is achieved. Thus, lack of energy access could be due to any of the following reasons:

- ***Lack of physical access*** because the villages remain un-electrified or the house is not connected to the grid in an electrified village or the building/house is unfit for electricity connection. In the case of cooking energy, lack of access could be due to absence of LPG or PDS kerosene outlets in the vicinity or lack of biogas plants or other decentralized energy systems in the village. Lack of motorable roads for transporting cooking fuels is another reason for not having physical access.
- ***Lack of physical availability*** because of no locally available energy resources to produce required energy carriers, lack of adequate generation and supply capacity resulting in power blackouts, power cuts and load shedding, diversion of energy carriers to other sectors or un-intended end-uses, stock-outs, non-availability of skilled human resources for operation and maintenance and repairs,
- ***Lack of acceptability*** due to low quality of electricity supply with frequent interruptions, and voltage fluctuations. Lack of convenience in use of fuel and inability to perform activities in a desired way, need for changes in conventional cooking habits, technological complexities and extra effort to procure the energy carrier, reluctance due to the influence of behavioral/social/information factors like ignorance, indifference and lack of information. Unwillingness to shift from free to priced energy carriers. Expecting other benefits like livelihood opportunities.
- ***Lack of affordability*** due to high initial cost of connectivity and income poverty resulting in inability to pay for the energy carriers and to invest for connectivity.
- ***Lack of adequacy*** due to energy resource constraints and inadequate production capacity resulting in energy shortages, financial resource constraints preventing construction of new production facilities, transmission & distribution systems, and transport infrastructure.

2. Energy Supply and Consumption in Asia-Pacific: An Overview

The energy scene in the Asia-Pacific region is dominated by the supply and use of fossil fuels with a share of around 85%. In fact, the fossil fuel share in total primary energy supply has gone up from 84.4% in 1990 to 85.5% in 2006. Figure 2 shows the source composition of primary energy supply in the Asia-Pacific region[2] for the selected years during the last 16 years (ADB 2009c). The analysis of the trend suggests that the total primary energy supply has grown at an annual rate of 4.1% to reach a level of 4,007 MTOE in 2006 from 2,095 MTOE in 1990. Geothermal energy experienced the highest growth rate of 5.3% followed by coal at 4.9%. It is disheartening to note that the share of renewable energy sources in primary energy supply has declined from about 12% in 1990 to 10.8% in 2006. The analysis of the data for 2006 shows that coal with a share of about 45%, oil with a share of 29% and gas with a share of 11.4% are the dominant fuels in the total primary energy supply. It is crucial to note that the share of coal in primary energy supply has increased from 40% in 1990 to 45.1% in 2006 indicating increasing reliance on coal has a primary fuel for driving economic growth. Both China and India are the major coal consumers mainly for power generation. This trend requires to be reversed if climate change issues need to be addressed.

Figure 2: Fuel-wise trends in primary energy supply (MTOE) in Asia-Pacific



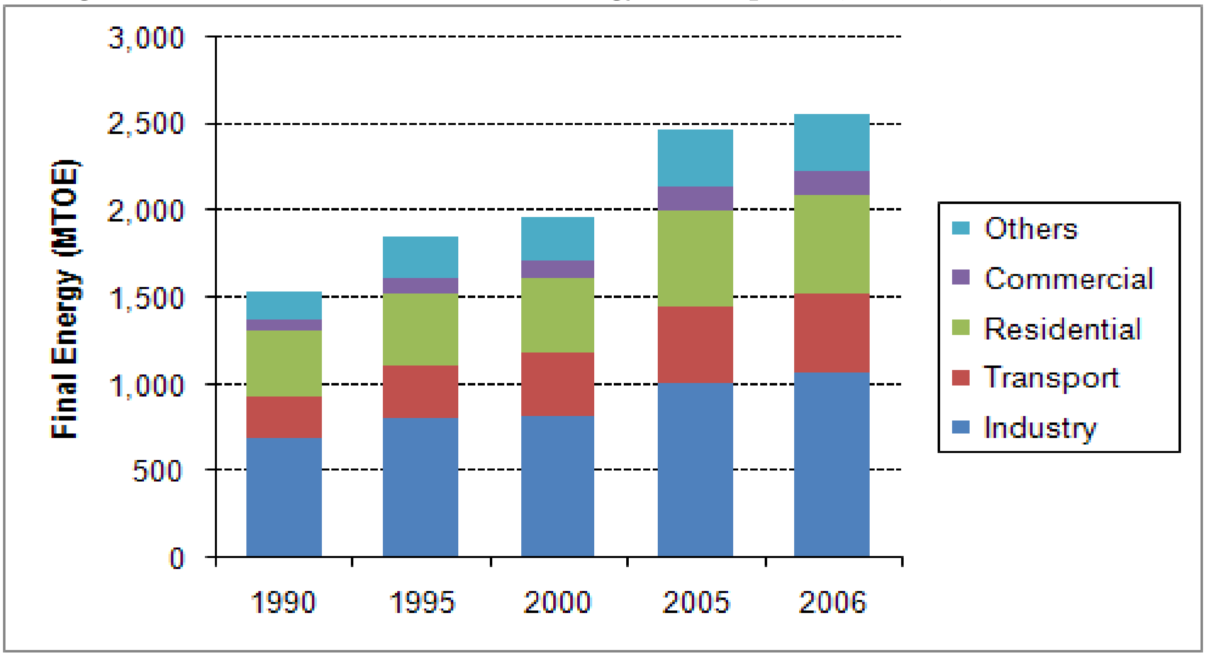
Source: Based on ADB 2009c

The trends in sector-wise final energy consumption in the Asia-Pacific region are shown in Figure 3. A detailed analysis of the data suggests that the final energy consumption in the commercial sector is growing at the rate of 5%, which is highest compared to other sectors. Transport sector at 4% is placed second. The energy consumption in both the industrial and residential sectors is growing at slower rates at 2.8% and 2.4% respectively. The share of

[2] In this particular analysis (discussed in section 2), the Asia-Pacific region is as defined by the ADB classification, which includes the developed and developing countries of the region as well as those from the central Asia, and excludes Iran. However, in the cases of all the remaining analyses, only the developing countries of the Asia-Pacific region are considered, which include Iran but exclude countries of the central Asian region.

industrial sector in total final energy consumption has in fact declined from 44.6% in 1990 to 41.9% in 2006. The decline may be mainly due to improvements in energy use efficiencies in the industrial sector resulting in reduced energy intensities. Two sectors, namely transport and commercial, experienced increase in the shares of final energy consumption during this period.

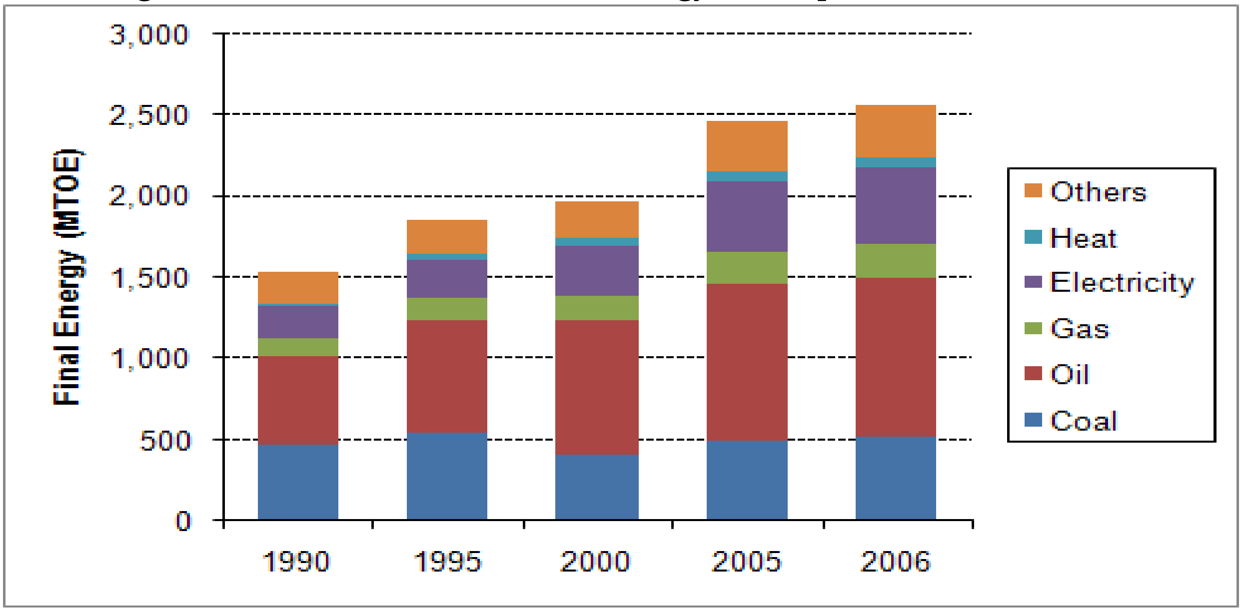
Figure 3: Sector-wise trends in final energy consumption (MTOE) in Asia-Pacific



Source: Based on ADB 2009c

Among the energy carriers, oil has the dominant share in the total final energy consumption in the Asia-Pacific (Figure 4). The final energy consumption accounts for only the direct energy consumption. For example, coal and gas used for power generation is accounted under electricity. The trends for the last 16 years suggest that the direct consumption of coal is growing merely at 0.6% where as electricity consumption at 5.5%, gas at 4.3% and oil at 3.7% are showing relatively high growth rates. Deeper analysis of the data shows that the share of coal in total final energy consumption has declined sharply from 30.5% in 1990 to 20.1% in 2006. On the other hand the share of electricity consumption has increased from 12.8% to 18.3% during the same period, oil consumption from 35.4% to 38.4% and gas from 7.1% to 8.5%. This indicates that the dirtier coal as a main fuel is slowly getting replaced by other cleaner fuels. However, it is important to note, from the previous analysis that though the direct use of coal is declining its use in power generation is increasing rapidly in the Asia-Pacific region.

Figure 4: Source-wise trends in final energy consumption in Asia-Pacific



Source: Based on ADB 2009c

The summary of the status of energy production and consumption for the selected developing countries of Asia-Pacific is given in Table 3. We may observe from the table that the developing countries of Asia-Pacific together account for about 25% of the gross electricity as well as the primary energy produced in the world whereas the primary consumption is about 26% of the world consumption. Another interesting aspect is that nearly 35% of the primary energy supply in Asia and the Pacific is provided by the renewable sources of energy whereas this is just 21% for the world as a whole. This high share may be mainly due to the inclusion of traditional biomass in the total primary energy supply. China is the dominant energy producer as well as the consumer in Asia-Pacific accounting for 66% of the electricity production, 59% of primary energy production and 63% of the primary energy consumption. India is a distant second in all these aspects. Energy supplies appear to be environmentally sustainable in countries like Nepal and Cambodia, and to a certain extent in Sri Lanka and Vietnam with a dominant share by renewable energy sources. However, it is important to verify how much of this is accounted by the traditional biomass sources, which are typically used inefficiently. Higher values of ratio of production to consumption indicate the extent of a country's dependency on its own resources for energy supply. Countries like Indonesia, Malaysia and to a certain extent Vietnam are relatively more energy secure with ratios of above one. However, countries such as Cambodia, Sri Lanka, and Pacific Island countries, Solomon Island, Tonga and Vanuatu are highly vulnerable with mostly depending on energy imports for their commercial energy needs.

Table 3: Status of energy production and consumption in 2007

Country	Gross electricity production (GWh)*	Primary Energy Production (MTOE)@	Primary Energy Consumption (MTOE)@	Production-Consumption Ratio	Primary Energy Supply (MTOE)*	Share in primary energy supply (%)$	
						Fossil fuel	Renewable
Bangladesh	24,378	15.44	20.22	0.76	25.8	66.2	33.8
Cambodia	1,349	0.014	1.66	0.01	5.1	29.1	70.6
China	3,279,233	1803.1	1965.6	0.92	1,955.8	86.9	12.3
India	803,409	329.8	475.0	0.69	594.9	70.0	29.2
Indonesia	142,236	292.6	142.0	2.06	190.6	68.8	31.2
Malaysia	101,325	88.7	58.6	1.51	72.6	95.2	4.7
Mongolia	3,833	2.10	2.21	0.95	3.1	96.0	3.4
Nepal	2,806	0.74	1.85	0.40	9.6	10.7	89.2
Philippines	59,611	12.97	32.8	0.40	40.0	57.0	43.0
Solomon Islands	73	0.000	0.076	0.00	0.086		
Sri Lanka	9,901	0.97	5.60	0.17	9.3	45.5	54.5
Thailand	143,378	47.24	97.4	0.49	104.0	81.2	18.5
Tonga	52	0.000	0.064	0.00	0.064		
Vanuatu	42	0.000	0.040	0.00	0.051		
Viet Nam	69,487	36.01	35.0	1.03	55.8	51.4	48.6
Asia-Pacific	4,968,647	3,045	3,133	0.97	3,329	64.9	34.8
World	19,854,871	11,974	12,137	0.99	12,029	79.0	21.0

Source: *UNESCAP 2010a, @EIA 2010, $UNDP 2010b, UNESCAP 2008,

The data on final energy consumption again suggests that China accounts for more than 55% of that consumed by the whole of Asia and the Pacific (Table 4). This is more than proportionate to its population share which is nearly 38%. Compared to China, India is an under performer with a share of only about 17% in final energy consumption though having a population share of about 32%, which is marginally less than China. Asia-Pacific as a whole consumes about 27% of world's final energy. The sectoral shares of final energy consumption make some interesting observations. Among these developing countries, the countries with higher industrial energy shares appear to be economically more developed compared those having higher residential energy shares. Comparatively countries like Malaysia and China are better performing than Nepal and Cambodia. The industrial energy consumption contributes to economic development through the production of goods and services. The industrial sector in Asia-Pacific as a whole accounts for 38.3% of the final energy consumption, which is higher than the 27.5% observed for the global average. Similarly, the share of residential sector is also higher in Asia-Pacific at about 31% compared to about 23% in the case of world as a whole. The higher share of traditional fuel in residential energy consumption in the case of Asia-Pacific may be the reason for such a difference. This is indicated by the significant consumption of wood fuel, which predominantly happens in the residential sector (Table 4).

Table 4: Final energy consumption and its distribution in 2007

Country	Final Energy consumption ('000 TOE)*	Sectoral share in total final energy consumption (%)*				Wood fuel Consumption ('000 M^3)$
		Industry	Transport	Residential	Others	
Bangladesh	19,899	15.0	8.2	58.1	18.7	27,662
Cambodia	4,592	1.7	8.5	86.5	3.3	9,221
China	1,248,225	45.9	11.1	25.3	17.7	207,251
India	392,905	29.0	10.4	41.4	19.1	305,485
Indonesia	145,109	32.6	16.8	39.0	11.7	82,194
Malaysia	43,400	44.3	31.2	9.3	15.2	3,068
Mongolia	2,207	34.3	24.1	26.1	15.4	621
Nepal	9,470	4.6	3.1	89.6	2.7	12,692
Philippines	22,870	23.6	37.9	27.7	10.9	12,950
Solomon Islands						122
Sri Lanka	8,317	25.4	25.7	41.5	7.5	5,584
Thailand	69,645	33.3	26.1	15.2	25.3	19,866
Tonga						2
Vanuatu						42
Viet Nam	48,538	21.3	16.2	56.6	6.0	26,350
Asia-Pacific	2,258,638	38.3	13.5	31.0	17.2	750,371
World	8,286,068	27.5	27.7	23.4	21.4	1,920,253

Source: *UNESCAP 2010a, $Gumartini 2009

The estimates of per capita energy consumption given in Table 5 show varied levels energy development across the countries of Asia-Pacific. Only Malaysia enjoys higher per capita primary energy consumption compared to the global average. This is true even for electricity consumption. Countries from South Asia have the lowest energy consumption per capita indicating large-scale energy deprivation. They have per capita energy consumption levels, both primary energy and electricity, lower than that observed for the sub-Saharan Africa. The people of Bangladesh and Nepal are deprived of the most modern and versatile energy carrier electricity. The four of the five least developed countries (LDCs) chosen for analysis such as Solomon Islands, Nepal, Cambodia and Bangladesh have the least per capita household electricity consumption levels. Only exception is Vanuatu. This indicates the close association between income and energy poverty. All these four countries have higher per capita wood fuel consumption indicating high dependency on traditional fuel which is mostly available free of cost. The energy intensity of GDP, a measure of energy efficiency of the economy, is low for all the Pacific Island countries. The reason could be that the major share of GDP coming from the non-manufacturing sectors like agriculture, forestry, etc. Both Nepal and Cambodia have high energy intensities, which are detrimental to sustainable development considering that they are LDCs. Asia-Pacific as a whole is relatively energy inefficient in relation to the World average; however, its performance is better than sub-Saharan Africa (Table 5).

Table 5: Energy consumption indicators in 2007

Country	Per capita Energy Consumption				Energy consumption per unit of GDP (kgoe/'000; 2005 PPP $)**
	Primary Energy (kgoe)#	Electricity (kWh)@	Wood Fuel (m3/year)*	Household electricity consumption (kWh)$	
Bangladesh	163	144	0.32	60	139
Cambodia	358	94	0.66	43	209
China	1484	2332	0.16	273	292
India	529	542	0.27	104	203
Indonesia	849	566	0.36	211	241
Malaysia	2733	3667	0.12	700	214
Mongolia	1182	1138	0.24	316	387
Nepal	338	80	0.47	30	343
Philippines	451	586	0.15	185	141
Solomon Islands		124	0.26	22	58
Sri Lanka	464	417	0.29	160	116
Thailand	1553	2055	0.32	419	212
Tonga		459	0.02		104
Vanuatu		186	0.2	213	42
Viet Nam	655	728	0.31	273	267
Asia-Pacific	960	1271	0.22	203	250
Sub-Saharan Africa	662	550	0.77		312
World	1819	3240	0.29	693	186

Source: *Gumartini 2009, $UNESCAP 2010a, #World Bank 2010, @ADB 2010a, **EIA 2010, Nation Master 2011

The summary of the past and future trends in primary energy demand for the selected countries as well as for the Asia-Pacific region is presented in Table 6 (ADB 2009b). The past trends suggest that the primary energy demand in the region increased by 1.8 times in 15 years from 1990 to 2005, and almost similar increase is expected in the next 25 years during from 2005 to 2030 with a projected increase by 1.9 times. In other words, the future growth in primary energy demand is expected to be significantly less compared to the past years, which can be observed from the declining growth rates. Exceptions are Cambodia and Papua New Guinea where the demand for primary is expected to grow at faster rates compared to the past. The dominance of China is expected to continue even in the future with a share of about 50.8% of the total primary energy demand in 2030 compared to 51.2% in 2005, a negligible decline. However, considering the projected share of 54% in 2015, this decline is significant, which suggests that post-2015; the growth rate in primary energy demand in China is likely to decline sharply. India is expected to increase its share from 16% in 2005 to 18.2% in 2030 indicating higher future growth in energy demand. Among the selected countries, many are projected to experience higher growth in primary energy demand during 2015-30 compared to 2005-15. This may be due to the imperative of economic growth in these countries.

Table 6: Primary energy demand (MTOE) outlook for selected countries and Asia-Pacific region

Country	1990	2000	2005	2006	2015	2030	Growth rates (%)		
							1990-2005	2005-15	2015-30
Bangladesh	12.8	18.7	24.2	25	35	56.5	4.3	3.8	3.2
Cambodia	3.4	4	4.8	5	6.7	12	2.3	3.4	4.0
China	863	1,106	1,720	1,879	2,440	3,281	4.7	3.6	2.0
Fiji	0.5	0.5	0.8	0.8	0.9	1.2	3.2	1.2	1.9
India	320	460	538	566	692	1172	3.5	2.6	3.6
Indonesia	103	151	176	179	225	328	3.6	2.5	2.6
Malaysia	23.3	51.3	65.9	68.3	79.6	131	7.2	1.9	3.4
Mongolia	3.4	2.4	2.6	2.8	3.4	4.5	-1.8	2.7	1.9
Nepal	5.8	8.2	9.2	9.4	11.6	16.4	3.1	2.3	2.3
Papua New Guinea	0.9	1.1	1.6	1.6	4	6.3	3.9	9.6	3.1
Philippines	26.2	42.4	43.6	43	52.8	79.6	3.5	1.9	2.8
Sri Lanka	5.5	8.1	9.1	9.4	12.6	17.4	3.4	3.3	2.2
Thailand	43.9	75	100.6	103.4	126.1	213	5.7	2.3	3.6
Timor-Leste			0.1	0.1	0.5	0.8		17.5	3.2
Viet Nam	24.3	37.2	51.3	52.3	68.6	132	5.1	2.9	4.4
Asia-Pacific	1,857	2,488	3,359	3,573	4,523	6,455	4.0	3.0	2.6

Source: ADB 2009b

3. Energy Access Status and Sources of Energy for Poor

3.1. Status of Energy Access

As stated earlier, the most important indicators of energy poverty are the extent of access the population has to electricity and modern fuels for cooking. Table 6 contains details of the status for the region as a whole as well as for the selected countries where as the Figure 2 shows the access status for all the developing countries of the region. The status in Asia-Pacific suggest that as a whole about 77% of the population had access to electricity as against the world average of about 78% (Table 7). This compares very favourably with the 26% access level observed in the case of sub-Saharan Africa. However, the region has countries like Papua New Guinea, Myanmar, Afghanistan, Solomon Islands, Vanuatu, Timor-Leste, Cambodia and Korea, DPR where the electricity access levels are lower than that is observed in sub-Saharan Africa (Figure 5). In the region, countries such as Malaysia, China and Thailand have almost achieved universal access to electricity. The estimates suggest that the lack of electricity access is a serious issue in the rural region of the Asia-Pacific. The urban region with electricity access levels of almost 94% is almost on the verge of achieving universal access. In the Asia-Pacific region, 20 of the 33 countries for which data is available have achieved urban electricity access levels of 90% or more. However, still 43% of the rural population does not have access to electricity in the region and this compares favourably with the 89% of the rural population not having electricity access in sub-Saharan Africa. Low access levels are mostly prevailing in LDCs with Myanmar, Korea, DPR, Afghanistan and Cambodia having provided electricity access to less than 12% of its rural population. The issue is more serious with Pacific Island countries where the rural electricity access levels range between 5-7%.

Table 7: Status of access to modern energy carriers in 2007

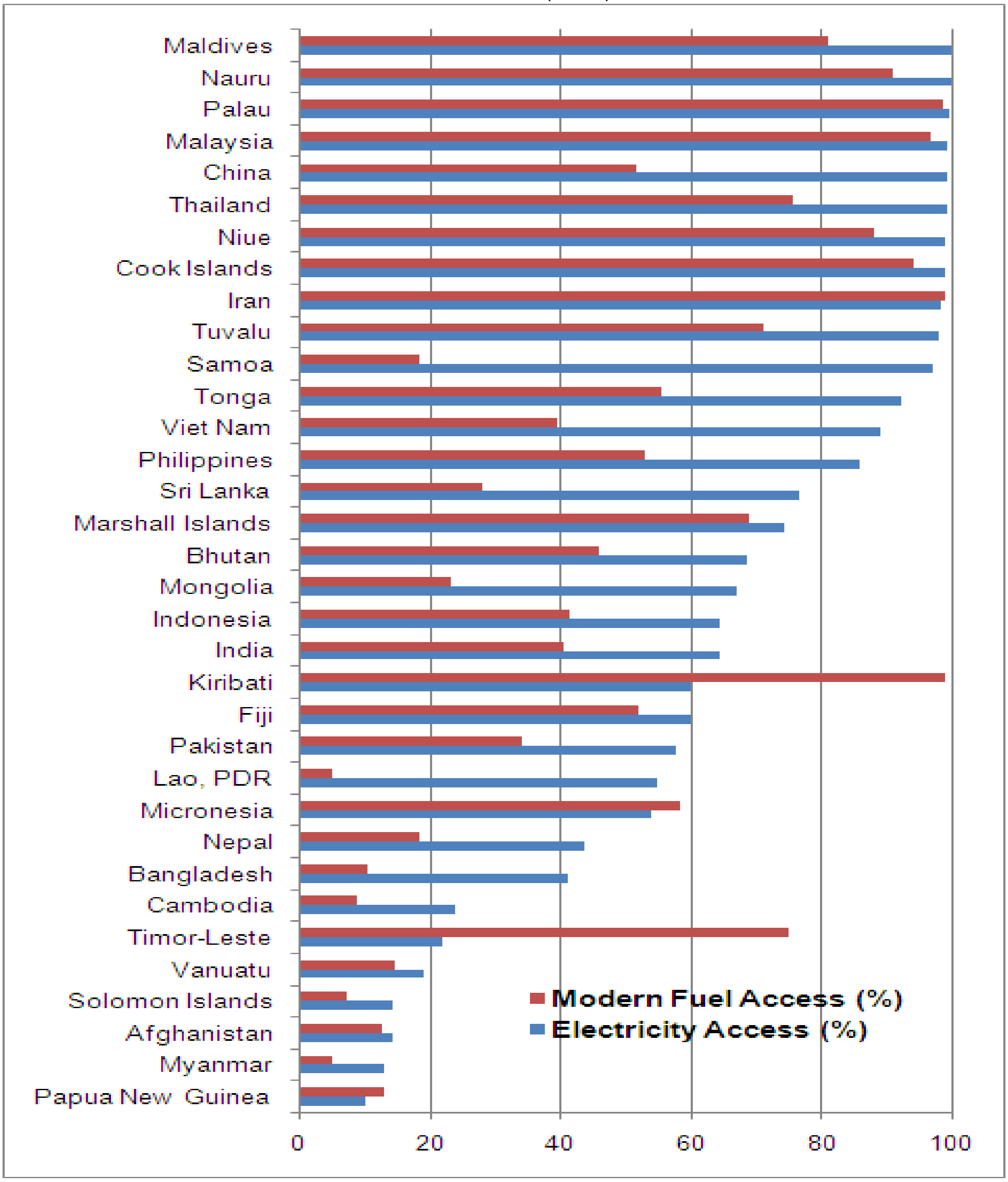
Country	Electricity Access (%)*			Modern Fuel Access (%)#		
	National	Rural	Urban	National	Rural	Urban
Bangladesh	41.0	28.0	76.0	10.4	1.0	40.1
Cambodia	24.0	12.5	66.0	9.0	4.4	36.1
China	99.4	99.0	100.0	51.8	28.7	77.2
India	64.5	52.5	93.1	40.4	11.9	75.4
Indonesia	64.5	32.0	94.0	41.6	20.4	77.1
Malaysia	99.4	98.0	100.0	96.7	95.3	97.4
Mongolia	67.0	36.0	90.0	23.2	5.0	39.1
Nepal	43.6	34.0	89.7	18.4	8.6	63.7
Philippines	86.0	65.0	97.0	52.9	29.5	73.5
Solomon Islands	14.4	5.1	70.6	7.4	2.0	40.0
Sri Lanka	76.6	75.0	85.8	27.9	18.7	68.3
Thailand	99.3	99.0	100.0	75.5	52.7	88.7
Tonga	92.3	90.7	97.7	55.4	49.8	90.6
Vanuatu	19.0	7.0	61.0	14.5	4.6	47.0
Viet Nam	89.0	85.0	99.6	39.4	27.9	79.8
Asia-Pacific	77.0	66.7	93.6	44.1	18.7	74.2
Sub-Saharan Africa	26.0	11.0	54.0	17.0	5.0	42.0
World	78.2	63.0	93.0	53.0	21.0	76.0

Source: #WHO 2010a, #*UNDP-WHO 2009, *IEA 2010b, UNESCAP 2010a, Nation Master 2011

At the outset, Asia-Pacific region appears to have better electricity access levels with 77% having access compared to just 26% in sub-Saharan Africa. However, in terms of absolute numbers Asia-Pacific region with about 807 million people without access to electricity lags behind sub-Saharan Africa at about 591 million without access. Further, the south-Asian region consisting of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, has the highest number of energy deprived population. Though it accounts for about 43% of the population of Asia-Pacific it has about 82% of the Asia-Pacific population without any access to electricity. In absolute terms, in south-Asia, about 605 million people live without electricity compared to about 591 million in sub-Saharan Africa. India with about 400 million people without access to electricity takes the lead position. The poor people without access to electricity rely mostly on kerosene for lighting. Other choices available for the poor are either to live in dark or depend on vegetable oils, candles and firewood.

The status of access to modern fuels for cooking is far worse than that for electricity access for lighting and other end-uses (Table 7 and Figure 5). About 44% of the population of the Asia-Pacific region had access to modern fuels like LPG, electricity, kerosene, natural gas, and biogas for cooking in 2007 compared to 53% in the world and just 17% in sub-Saharan Africa. As in the case of electricity access, there are significant variations across countries in providing access to modern fuels. Out of the 34 countries in the region, 8 have access levels lower than that in sub-Saharan Africa and another 8 have access levels of more than 80%. Surprisingly, out of these 8 countries with more than 80% of the people having access to modern fuels 6 belong to small island countries (SIDs) (Figure 5). Even China, which has achieved spectacular success in providing access to electricity for 99.4% of its population, has failed to achieve similar progress with access to modern cooking fuels with only 52% of population having access. The urban-rural comparisons suggest that a significant majority of the people using modern fuels for cooking belong to urban areas. About 74% of the urban population in Asia-Pacific use modern fuels for cooking whereas only 19% of the rural population has access to modern fuels (Table 7). These shares are comparable to the world averages and significantly better than sub-Saharan Africa.

Figure 5: The share of population having access to electricity and modern fuels in Asia-Pacific (2007)



Source: WHO 2010a, Nation Master 2011, UNDP-WHO 2009, UNESCAP 2010a, IEA 2010b

As in the case of electricity access, in terms of absolute numbers, the countries of Asia-Pacific have majority energy poor. About 73% of population depending on solid fuels for cooking in the world lives in the Asia-Pacific. This is an extremely serious situation. Out of a total population of 3,109 million relying on solid fuels in the world about 2,280 million belong to Asia-Pacific and about 662 million to sub-Saharan Africa. India with about 801 million and China with 765 million are two countries with largest number of people without access to modern fuels. As in the case of electricity access, south-Asian region with about 1,119 million people (accounting for 49% of the population without modern fuel access in Asia-Pacific) using solid fuels has the highest number of deprived people.

Table 8 contains details of the shares of households using different fuels for cooking in the selected countries of Asia-Pacific. Except for few countries wood is the dominant fuel on which majority of the households depends for their cooking energy needs. Almost 96% of the Malaysian households use LPG for their cooking needs. Kerosene is the second most dominant fuel for cooking in Indonesia (Table 8). Significant share of households in Mongolia and Cambodia rely on electricity for cooking. Solomon Islands is the only country in the region which depends on Charcoal for cooking. China and Mongolia depend on coal for meeting significant share of cooking energy requirements. All the major developing countries of the region have diversified into different types of fuel for cooking. The pattern of cooking energy use suggests that it is quite varied and mostly relying on conventional fuels.

It appears from the above analysis that, in terms of prioritizing global efforts in providing universal access to modern energy carriers, the focus should be on the south-Asian region. This region has the highest number of energy poor population in the world with about 1,119 million lacking access to modern fuels for cooking and about 605 million people living without electricity. Any action on mitigating the impacts of climate change or building resilience to adapt to climate change cannot ignore such a large population deprived of modern energy and living in poverty.

Among the population relying on solid fuels for cooking a significant proportion use improved cooking stoves. The estimates suggest that about 30% of the population relying on solid fuels for cooking use improved cookstoves (Table 9). In the rural regions of the Asia-Pacific, about one-third of the people relying on solid fuels use modern cookstoves. Out of the total population depending on improved cook stoves nearly 79% live in China. Though India occupies the second position it could not show similar success in spreading the use of improved stoves with a share of only about 10%. Both in Mongolia and Thailand, almost all the population relying on solid fuels use improved cookstoves (Table 9). Thus, the achievements of three countries, China, Mongolia and Thailand, are significant with respect to the deployment of modern cookstoves, which other countries could not emulate. Among others, Sri Lanka and Viet Nam appears to be making some progress.

Table 8: Household energy consumption - Share of population using particular fuel for cooking (2007 or latest year)

Country	% of the national population - Fuels used for cooking#									Population having access to modern fuels ('000)	Population relying on solid fuels ('000)
	Electricity	Gas/LPG	Kerosene	Charcoal	Wood	Dung	Coal	Other	Access to modern fuels		
Bangladesh	0	8.8	0	0	82.6	8.3	0	0.3	8.8	13,882	143,870
Cambodia	0.2	7.3	0	7.9	84.4	0.1	0	0.1	7.5	1,083	13,363
China	10.6	31.1	0.3	0	26.7	0	28.9	2.5	42.0	553,690	765,938
India	0.4	25.2	3.2	0.4	57.9	10.6	1.9	0.4	28.8	323,939	800,848
Indonesia	0.2	11.2	34.2	0.4	53.4	0	0	0.6	45.6	102,887	122,743
Malaysia	0.5	95.8	0.3	0.1	0.8	0	2.5	1.5	96.7	25,673	1,566
Mongolia	22.9	0.3	0	0.2	34	23.3	19.4	0	23.2	605	2,006
Nepal	0.1	12.6	3.5	0.1	75.2	8	0	0.5	16.2	4,553	23,554
Papua New Guinea	3	3	7	0	87	0	0	0	13.0	822	5,502
Philippines	1.3	43.4	4.7	6.8	41.8	0	0	2	49.4	43,827	44,891
Solomon Islands	0.3	7.1	0	88.1	1.8	0	2.4	0.3	7.4	37	459
Sri Lanka	0	17.1	2.4	0	79.5	0	0	1	19.5	3,902	16,108
Thailand	3.4	59.7	0	18.8	18.1	0	0	0	63.1	42,264	24,715
Tonga	3.5	53.6	2	0	40.9	0	0	0	59.1	61	42
Vanuatu	0.9	12.2	1.4	0.5	84.5	0	0	0.5	14.5	33	193
Viet Nam	0.4	32.3	1.3	3.5	56.8	0	5.2	0.4	34.0	28,953	56,117
Asia-Pacific	4.3	26.5	3.6	1.2	44.5	4.4	11.7	1.3	34.3	1,205,044	2,209,893
Sub-Saharan Africa	6.0	4.0	7.0	11.0	69.0	1.0	1.0	1.0	17.0	135,689	662,481

Source: Based on #UNDP-WHO 2009, Gumartini 2009

Table 9: Population using modern cookstoves for cooking (2007 or latest year)

Country	% of population relying on solid fuels for cooking that use improved cooking stoves			Population (in '000) using improved cooking stove		
	National	Rural	Urban	National	Rural	Urban
Bangladesh	2.1	2.3	1.4	3,019	2,654	365
Cambodia	6.7	---	---	895	---	---
China	73.2	77.0	46.2	524,019	430,305	93,714
India	8.3	8.2	9.1	68,418	58,847	9,572
Indonesia	5.1	5.4	4.6	5,830	4,580	1,251
Lao, PDR	12.4	13.7	9.0	693	651	41.6
Malaysia	6.5	9.6	0.0	102	35.7	---
Marshall Islands	5.8	1.5	27.5	1.16	---	---
Mongolia	99.1	99.2	99.0	1,988	1,090	898
Myanmar	4.8	5.5	2.7	2,186	1,807	380
Nauru	3.0	---	3.0	0.05	---	---
Nepal	6.0	6.1	4.5	1,403	1,316	87
Pakistan	14.7	15.7	12.8	16,483	14,703	1,779
Sri Lanka	41.2	41.1	43.0	6,545	6,040	505
Thailand	95.7	95.6	96.3	22,673	20,232	2,441
Vanuatu	6.1	6.0	6.4	11.6	9.7	1.89
Viet Nam	22.0	21.0	31.1	12,221	10,277	1,944
Asia-Pacific	30.2	33.3	29.8	666,490	552,548	112,980

Source: Based on UNDP-WHO 2009

3.2. Sources of Energy for Poor

The poor households in the developing countries of Asia and the Pacific mostly depend on various kinds of solid fuels as main sources of energy for their day-to-day cooking and heating needs. A minority of relatively high income earning households use LPG, electricity and kerosene as main energy carriers. This situation is more prevalent in the industrialized countries like Malaysia and Thailand, where these energy carriers have a major share. Electricity is mainly used for lighting in addition to other end-uses like audio/video, space cooling, etc. Table 10 contains the details of the quantity of various energy carriers consumed by the households in 2005. Because of their sheer population size and inadequate access to modern cooking fuels, both India and China consume large quantity of fuel wood. In addition, India consumes other types of biomass like cattle dung and agro-waste. A significant share of rural population in China depends on coal for meeting their cooking and heating energy needs. Use of cattle dung for energy purpose mainly prevails in the countries of south Asia. India and Indonesia are the major consumers of Kerosene. In rural India, kerosene is mostly used for lighting.

To assess the significance of various types of fuels consumed by the households, especially the poor households, the quantum of consumption given in individual units (Table 10) have been converted into common unit (TJ) and presented in Table 11. The quantities of different types of fuels are comparable only in terms of energy inputs to the end-use devices and the actual useful energy derived will vary according their efficiency of use. In total, the households of Asia-Pacific region consumed about 18,503 PJ of energy in 2005. Out of this, about 63% share is accounted by the solid fuels and the remaining by modern fuels. Wood with about 42% share occupies the top position and electricity with nearly 14% share is a distant second. In poorer countries like Cambodia and Nepal, the solid fuels account for over 90% of the household energy consumption (Table 11). Among the selected countries, the households of Mongolia and Solomon Islands again depend on solid fuels with around 85% share. India is not far behind these countries with about 78% of household energy coming from solid fuels. This indicates seriousness of energy deprivation in these countries and low efficiency levels with which the solid fuel is being used.

It is interesting to note that the households of both China and India consume same amount of energy with a share of about 32% each in the total household energy consumption in the Asia-Pacific. Together these two countries account for almost 65% of the total household energy consumption in the Asia-Pacific, which is reasonable considering that they account for nearly 70% of the population. The unfortunate aspect is that most of this energy is derived from the conventional solid fuels.

In summary, the earlier analysis suggests that in the Asia-Pacific region nearly 52% of the population is poor (surviving on less than $2.00 a day). This includes the 24% of the extremely poor population surviving on less than $1.25 a day. Further, in Asia-Pacific 56% of the population use solid fuels for meeting their cooking and heating needs and 23% lack electricity access. A simple hypothesis based on comparing these figures suggest that the poor in Asia-Pacific use solid fuels for cooking and the extremely poor do not have access to electricity. Thus, poverty appears to be most important cause as well as an outcome of lack of access to modern energy. The subsequent sections elaborate on these aspects by empirically showing the relationship between poverty and energy access, and possible implications of these on socio-economic, human and environmental systems.

3.3. Implications of Household Energy Consumption for Climate Change

Dependency on traditional fuels has implications for both local and global pollution. Emissions from burning solid fuels in open fires and traditional stoves also have significant global warming effects, due to incomplete combustion of fuel carbon (UNDP-WHO 2009, Smith et al. 2000). In reality, however, household energy consumption has never been the focus for climate change mitigation related interventions. This is because most solid fuels (excluding coal) are considered renewable with zero net addition of CO_2 to the atmosphere. The underlying assumption is that most of the energy consumed is for cooking or heating and this is mostly derived from renewably harvested fuel wood or agricultural waste, which are considered carbon neutral. This reliance by the households on the so-called 'climate-friendly' biomass energy sources combined with their low levels of energy use has resulted in a lack of motivation for policy-makers and NGOs to focus on household energy use in the context of climate change (Sagar 2005). However, if the wood burned is not replaced with new plant growth, then a net addition of CO_2 to the atmosphere does occur (Sagar 2005, Bond et al. 2004). It is agreeable that all the cattle dung, crop waste and a large share of fuel wood is harvested on a sustainable basis and the carbon is recycled within a short period compared with climate change processes (Smith et al. 2000). Earlier studies have reported that on an average, in India, 40% of the fuel wood is typically obtained from unsustainable means in the sense that it is not from renewable biomass source (Parikh and Reddy 1997).

Table 10: Household energy consumption - An indicator of energy development (2005)

Country	Coal (Tonne)	Charcoal (Tonne)	Wood (Tonne)	Dung (Tonne)	Electricity (GWh)	LPG (Tonne)	Kerosene (Tonne)	Natural Gas/ LNG (TJ)	Other biomass & wastes (TJ)
Bangladesh	0	0	18,072,507	2,316,330	9,465	20,000	704,000	75,183	106,582
Cambodia	0	0	6,024,387	9,104	621	0	42,000	0	0
China	87,390,000	0	135,403,987	0	359,899	13,287,000	254,000	295,956	0
India	350,000	0	199,583,533	46,605,368	116,978	9,851,000	9,377,000	26,397	1,169,359
Indonesia	0	537,000	53,700,080	0	47,608	746,000	8,083,000	727	0
Malaysia	0	0	2,004,427	0	18,585	672,530	50,210	209	0
Mongolia	81,000	0	405,720	354,640	622	0	0	0	0
Nepal	0	0	8,292,107	1,125,177	843	35,000	260,000	0	21,356
Papua New Guinea	0	0	492,613	0	1,202	0	22,000	0	0
Philippines	0	0	8,460,667	0	16,413	664,000	222,000	0	0
Solomon Islands	0	0	79,707	0	11	1,000	2,000	0	0
Sri Lanka	0	0	3,648,213	0	3,202	113,000	203,000	0	0
Thailand	0	3,947,000	12,979,120	0	28,064	1,655,000	7,000	0	0
Tonga	0	0	1,307	0	0	1,000	3,000	0	0
Vanuatu	0	0	27,440	0	48	0	1,000	0	0
Viet Nam	1,537,000	631,000	17,215,333	0	23,247	524,000	140,000	0	0
Asia-Pacific	89,358,000	5,211,600	518,600,089	53,458,405	711,322	30,198,530	25,295,210	1,809,394	1,314,297

Source: Nation Master 2011, FAO 2010

Table 11: Fuel-wise household energy consumption in 2005 (TJ)

Country	Coal	Charcoal	Wood	Dung	Electricity	LPG	Kerosene	Natural Gas	Other biomass	Total	Share (%)
Bangladesh	0	0	271,088 (49.7)	27,240 (5.0)	34,075 (6.2)	910 (0.2)	30,356 (5.6)	75,183 (13.8)	106,582 (19.5)	545,434	2.95
Cambodia	0	0	90,366 (95.6)	107 (0.1)	2,236 (2.4)	0	1,811 (1.9)	0	0	94,520	0.51
China	1,746,052 (29.2)	0	2,031,060 (33.9)		1,295,635 (21.7)	604,559 (10.1)	10,952 (0.2)	295,956 (4.9)	0	5,984,214	32.34
India	6,993 (0.1)	0	2,993,753 (49.7)	548,079 (9.1)	421,120 (7.0)	448,221 (7.4)	404,336 (6.7)	26,397 (0.4)	1,169,359 (19.4)	6,018,258	32.53
Indonesia	0	16,540 (1.2)	805,501 (58.5)	0	171,389 (12.4)	33,943 (2.5)	348,539 (25.3)	727 (0.1)	0	1,376,638	7.44
Malaysia	0	0	30,066 (23.1)	0	66,905 (51.5)	30,600 (23.5)	2,165 (1.7)	209	0	129,945	0.70
Mongolia	1,618 (11.5)	0	6,086 (43.1)	4,171 (29.5)	2,239 (15.9)	0	0	0	0	14,114	0.08
Nepal	0	0	124,382 (71.2)	13,232 (7.6)	3,036 (1.7)	1,593 (0.9)	11,211 (6.4)	0	21,356 (12.2)	174,809	0.94
Papua New Guinea	0	0	7,389 (58.4)	0	4,326 (34.2)	0	949 (7.5)	0	0	12,664	0.07
Philippines	0	0	126,910 (56.2)	0	59,086 (26.2)	30,212 (13.4)	9,573 (4.2)	0	0	225,781	1.22
Solomon Islands	0	0	1,196 (87.5)	0	39 (2.9)	46 (3.3)	86 (6.3)	0	0	1,367	0.01
Sri Lanka	0	0	54,723 (68.3)	0	11,526 (14.4)	5,142 (6.4)	8,753 (10.9)	0	0	80,144	0.43
Thailand	0	121,568 (24.7)	194,687 (39.5)	0	101,032 (20.5)	75,303 (15.3)	302 (0.1)	0	0	492,890	2.66
Tonga	0	0	20 (10.1)	0	0	46 (23.4)	129 (66.5)	0	0	194	0.001
Vanuatu	0	0	412 (65.5)	0	173 (27.6)	0	43 (6.9)	0	0	628	0.003
Viet Nam	30,709 (7.3)	19,435 (4.6)	258,230 (61.2)	0	83,690 (19.8)	23,842 (5.7)	6,037 (1.4)	0	0	421,943	2.28
Asia-Pacific	1,785,373 (9.6)	160,517 (0.9)	7,779,001 (42.0)	628,671 (3.4)	2,560,760 (13.8)	1,374,033 (7.4)	1,090,729 (5.9)	1,809,394 (9.8)	1,314,297 (7.1)	18,502,776 (100.0)	(100.0)

Note: Numbers in parentheses indicate % shares. *Source:* Nation Master 2011, FAO 2010

It has also been shown that inefficient combustion of traditional biomass fuels in cookstoves yields significant gaseous products of incomplete combustion (PICs) that are GHGs (Smith et al., 2000). This incomplete combustion results in emission of black carbon, which is a potent GHG. Another contribution of household fuels is emissions of light-absorbing carbon particles known as black carbon and of the gases that form ozone. Together, the warming effect is around 40 to 70% of that of CO_2 (Wallack and Ramanathan 2009). According to the authors, limiting their presence in the atmosphere is an easier, cheaper, and more politically feasible proposition than the most popular proposals for slowing climate change. Thus, black carbon from biomass combustion and access to modern energy services, have implications for climate change mitigation and adaptation respectively (Johnson and Lambe 2009). Household sector is considered as one of the major contributors of black carbon (BC), which contributes to global warming. It has been estimated that the global warming effect of black carbon is equal to 20 to 50% of the effect of CO_2 (Wallack and Ramanathan 2009). In other words, it is in general agreed that about 10-20% of the gross warming is due to black carbon (Baron et al, 2009) compared to about 40% by CO_2. Approximately, the residential sector is contributing 18% to 25% of the black carbon in the world (Baron et al. 2009, Smith 2009). In addition to all these, the biomass combustion in cook stoves emits other GHGs like CH_4 and N_2O.

For example, in India, cattle dung is first converted into cakes (mixing the wet dung and loose biomass from crop waste) and dried sufficiently before being used in conventional stoves for cooking. This open exposure of cattle dung results in release of CH_4 to the atmosphere. The experiments reveal that from one tonne of dung about 26% of gas potential is released when it is stored untreated in pits for a week to 10 days and when drying is slow. Thus, out of the gas potential of $45m^3$ /tonne dung, 25.73% = 11.58 m^3 of biogas with 60% methane (6.95 m^3 or 4.96 kg of CH_4) is wasted to the atmosphere. This is equal to about 104 kg CO_2 equivalent per tonne of cattle dung (Chanakya and Balachandra 2010). Same emission factor is used for other countries where cattle dung is used for cooking.

In addition to biomass, the households also use LPG, kerosene, natural gas and coal for meeting their cooking and heating needs. Similarly, these households use electricity and kerosene for lighting purpose. Electricity is also used for many other end-uses. Thus, total emissions of GHG from all these energy carriers are likely to be significant. In this study an attempt has been made to estimate the GHG as well as black carbon emissions from the household energy use given in Table 8. For this purpose, the emission factors of various types of pollutants are obtained or derived from various secondary sources (Balachandra 2010, Smith et al. 2000; Chanakya and Balachandra 2010, EIA 2007, Venkataraman et al. 2005, Baron et al. 2009, Herold 2003). The emission factors, thus obtained, are given in Table 12 for all the energy carriers that are being used by the households in the Asia-Pacific. As explained above, if the firewood supply is assumed to be obtained from unsustainable sources then the CO_2 has to be fully accounted and it will be zero if the wood is sourced from sustainable sources. Thus, we have two emission factors for firewood, one for sustainable firewood and second one for un-sustainable firewood. The emission factor for sustainable firewood includes emissions of CH_4 and N_2O whereas that for un-sustainable firewood includes emission of CO_2 in addition to CH_4 and N_2O. The emission factor for agro-waste includes just emissions of CH_4 and N_2O. In the case of cattle dung, the CH_4 emission from dung storage is included in addition to CH_4 and N_2O released during combustion for estimating the emission factor. All the GHG emission factors are in terms of CO_2 equivalent (CO_2e) and include emissions of CO_2, CH_4 and N_2O (Table 12).

Table 12: Emission factors for household energy carriers

Fuels	GHG emissions		Black Carbon (gBC/kg)
	gCO_2e/kg	gCO_2e/MJ	
Sustainable firewood	142.9	9.5	0.51
Un-sustainable firewood	1536.2	101.7	
Cattle Dung	218.9	18.6	0.13
Agro-waste	114.9	8.8	0.58
Kerosene	3047.6	70.7	0.15
LPG	3091.6	67.4	0.01
Electricity (gCO_2/kWh)	827.0	229.7	—
Coal	1800.0	90.1	8.00
Natural Gas ($kgCO_2/M^3$)	1.57	56.1	—
Charcoal	3449.6	112	0.20

Source: Based on Balachandra 2010, EIA 2007, Venkataraman et al. 2005, Smith et al. 2000, Chanakya and Balachandra 2010, Baron et al. 2009, Herold 2003
Note: "—" indicates not applicable

The estimated total GHG emissions from household fuel use for the selected countries of Asia-Pacific as well as for the whole region are given in Table 13. Two sets of estimations of GHG emissions from wood are made, one with an assumption that all the wood is from sustainable sources and the second one assumes all the wood is from un-sustainable sources. The actual emissions would be somewhere in between the two extremes. Thus, the total GHG emission from the household fuel use in the Asia-Pacific is expected to be in the range of 1,135 million tonne of CO_2e to 1,853 million tonne of CO_2e depending how the wood is sourced. The share of wood fuel in the total emissions is in the range of 6.5% - 42.7%. If we assume that the wood is from sustainable source, then most of the GHG emissions would be from modern fuels with a share of nearly 76% of the total emissions with emissions from electricity with a share of 52% contributing the most. Emissions from coal, a solid fuel consumed mostly in China, accounts for about 14% of the total GHG emissions. If the assumption is that the wood is from an un-sustainable source, then the traditional fuels with a share of nearly 54% dominate the GHG emissions. In this situation, un-sustainable wood will have a share of 43% and electricity with 32% will be the second highest contributor. With the sustainable wood assumption, China will be the major emitter with a share of nearly 47% and India occupying second position with a share of about 18% in total GHG emissions. However, with un-sustainable wood, the respective shares for China and India would be 39% and 26%.

Table 14 contains the estimates of black carbon emissions from household fuels. The total emission of black carbon is about 1.05 million tonne in the Asia-Pacific region. Coal used for household cooking in China contributes to about 68% of the black carbon emissions in the region. Wood with a share of about 25% is the second most important contributor. China, because of its extensive dependency on coal, accounts for about 73% of the black carbon emissions in the Asia-Pacific region. India with a share of nearly 16% is the second big emitter of black carbon. If China and India take initiatives to expand access to modern fuels, the black carbon emissions could be almost eliminated from Asia-Pacific. Secondly, emission of black carbon is mostly contributed by the poor who rely on solid fuels. Thus, expanding access to modern fuel for cooking has dual benefits – better life for the poor and high climate change mitigation potential.

Table 13: CO_2e emissions from household energy consumption in 2005 ('000 tonne)

Country	Coal	Charcoal	Sustainable Wood	Un-sustainable wood	Dung	Electricity	LPG	Kerosene	Natural Gas	Other biomass & wastes	Total with Sustainable wood (Million tonne)	Share (%)	Total with Un-sustainable wood (Million tonne)	Share (%)
Bangladesh	0	0	2,565	27,579	507	7,828	61	2,146	4,218	942	18.27	1.61	43.28	2.34
Cambodia	0	0	855	9,193	2	514	0	128	0	0	1.50	0.13	9.84	0.53
China	157,302	0	19,218	206,632	0	297,636	40,774	774	16,603	0	532.31	46.89	719.72	38.84
India	630	0	28,328	304,572	10,202	96,741	30,230	28,577	1,481	10,335	206.52	18.19	482.77	26.05
Indonesia	0	1,852	7,622	81,948	0	39,372	2,289	24,634	41	0	75.81	6.68	150.14	8.10
Malaysia	0	0	284	3,059	0	15,370	2,064	153	12	0	17.88	1.58	20.66	1.11
Mongolia	146	0	58	619	78	514	0	0	0	0	0.80	0.07	1.36	0.07
Nepal	0	0	1,177	12,654	246	697	107	792	0	189	3.21	0.28	14.69	0.79
Papua New Guinea	0	0	70	752	0	994	0	67	0	0	1.13	0.10	1.81	0.10
Philippines	0	0	1,201	12,911	0	13,573	2,038	677	0	0	17.49	1.54	29.20	1.58
Solomon Islands	0	0	11	122	0	9	3	6	0	0	0.03	0.003	0.14	0.01
Sri Lanka	0	0	518	5,567	0	2,648	347	619	0	0	4.13	0.36	9.18	0.50
Thailand	0	13,616	1,842	19,807	0	23,209	5,079	21	0	0	43.77	3.86	61.73	3.33
Tonga	0	0	0	2	0		3	9	0	0	0.01	0.001	0.01	0.001
Vanuatu	0	0	4	42	0	40		3	0	0	0.05	0.004	0.08	0.005
Viet Nam	2,767	2,177	2,443	26,271	0	19,226	1,608	427	0	0	28.65	2.52	52.47	2.83
Asia-Pacific	160,844	17,978	73,607	791,404	11,702	588,263	92,670	77,090	101,507	11,616	1,135.3	100	1,853.1	100
Share (%)	14.17	1.58	6.48	0	1.03	51.82	8.16	6.79	8.94	1.02	100			
Share (%)	8.68	0.97	0	42.71	0.63	31.75	5.00	4.16	5.48	0.63	100			

Source: Author's calculations based on Table 10 and Table 12

Table 14: Black carbon emissions from household energy consumption in 2005 (tonne)

Country	Coal	Charcoal	Wood	Dung	LPG	Kerosene	Other biomass & wastes	Total	Share (%)
Bangladesh	0	0	9,217	301	0	84	4,755	14,358	1.37
Cambodia	0	0	3,072	1	0	5	0	3,079	0.29
China	699,120	0	69,056	0	133	30	0	768,339	73.22
India	2,800	0	101,788	6,059	99	1,125	52,171	164,041	15.63
Indonesia	0	107	27,387	0	7	970	0	28,472	2.71
Malaysia	0	0	1,022	0	7	6	0	1,035	0.10
Mongolia	648	0	207	46	0	0	0	901	0.09
Nepal	0	0	4,229	146	0	31	953	5,360	0.51
Papua New Guinea	0	0	251	0	0	3	0	254	0.02
Philippines	0	0	4,315	0	7	27	0	4,348	0.41
Solomon Islands	0	0	41	0	0		0	41	0.004
Sri Lanka	0	0	1,861	0	1	24	0	1,886	0.18
Thailand	0	789	6,619	0	17	1	0	7,426	0.71
Tonga	0	0	1	0	0	0	0	1	0.0001
Vanuatu	0	0	14	0	0	0	0	14	0.001
Viet Nam	12,296	126	8,780	0	5	17	0	21,224	2.02
Asia-Pacific	714,864	1,042	264,486	6,950	302	3,035	58,638	1,049,317	100.00
Share (%)	68.13	0.10	25.21	0.66	0.03	0.29	5.59	100.00	

Source: Author's calculations based on Table 10 and Table 12

3.4. Access to Modern Energy Carriers: The Rich-Poor Divide

The previous discussions pointed towards the suggestion that income poor are most likely to be energy poor because of their incapability to afford highly priced modern energy carriers. The synthesis of the data suggested that the poor in Asia-Pacific use solid fuels for cooking/heating and the extremely poor live without electricity, mostly depending on kerosene or vegetable oil for lighting. To verify this, a deeper analysis of the data on energy access, poverty, energy consumption and GHG emissions is performed for the selected countries as well as for the Asia-Pacific region as a whole (Table 15). For convenience, the population is classified into rich (share of population living with an income of above $2.0 (2005 PPP) a day), poor (share of population living with an income between $2.0 and $1.25 (2005 PPP) a day) and extremely poor (share of population living with an income of below $1.25 (2005 PPP) a day). These three income groups are matched with the share of population classified into three groups formed based on different levels of energy access, namely, shares of population with access to both modern cooking fuels and electricity, with only electricity access and without access to modern fuels, and with no access to electricity as well as modern fuels (Table 7). Further, for these groups of population, the per capita household energy consumption and per capita GHG emissions are compared.

The results show that only in India and Indonesia, all the rich have access to both electricity and modern fuels. In the case of all other countries, significant share of rich population (as defined in the present study) do not have the access to both electricity and modern fuels. This is true even for Asia-Pacific region as a whole. Except for Cambodia and Papua New Guinea, the rich population of all the countries including the Asia-Pacific region as a whole, have access to electricity. Thus, the lack of access is mostly confined to modern fuels for cooking. Countries such as China, India, Philippines and Viet Nam have done well by extending the electricity access to all the poor and to the significant share of extremely poor people (Table 15). China has done exceedingly well on this aspect with only 0.6% of the population requiring to be electrified. This possibly indicates the effectiveness of electricity access programmes and affordable electricity prices achieved through subsidies. It may be observed from the table that even the Asia-Pacific region as a whole has the electricity coverage reaching all the poor population indicating few other countries achieving equally significant success in expanding electricity access. However, countries like Bangladesh, Cambodia, Nepal and Papua New Guinea with relatively low electricity access levels have failed to cover all the poor population. Expect in the case of India and to a certain extent Indonesia; in all the countries only the rich enjoy the privilege of using modern fuels for cooking. The highly subsidized prices associated with LPG and kerosene must have been the reason for the larger section of the poor in India having access to modern fuels for cooking. In summary, it may be stated that on an average, the rich in the developing countries of Asia-Pacific have access to electricity and modern fuels, the poor have access to only electricity and the extremely poor do not have access to both.

Extending this logic of relationship between access levels and income levels, the comparisons with per capita energy consumption and GHG emissions provide some interesting observations (Table 15). Comparing the average values for the Asia-Pacific, the section of the population with access to both electricity and modern fuels or the rich population has the lowest per capita energy consumption levels with highest per capita GHG emissions. This indicates the fossil fuel dominance of energy use and the high energy efficiency associated with its use. The poor people having access only to electricity and not to modern fuels has the highest per capita energy consumption levels suggesting the use of inefficient solid fuels for cooking along with electricity and their per capita emission levels are significantly high being very close to the levels of rich people. The extremely poor people with no access to electricity and modern fuels entirely rely on solid fuels for cooking and mainly kerosene for inadequate lighting. Though their per capita energy consumption levels are high due to inefficiency associated with the use of solid fuels and the per capita GHG emission levels are low due to dominant use of renewable biomass energy. Even the country specific results suggest the same. The GHG emissions on a per capita basis in the case of extremely poor people are very small even though their per capita energy consumption levels are high. The small island countries like Papua New Guinea, Solomon Islands and Vanuatu show a contradicting picture (Table 15). In their case both per capita energy consumption as well as emission levels are low indicating a greater divide between the rich and poor in quality and quantity of energy use. Even Bangladesh has similar conditions prevailing.

4. Sources of Energy in the Industrial sector

The industrial sector is the dominant consumer of final energy in Asia and the Pacific region including Central and West Asia, East Asia, Pacific region, South Asia, Southeast Asia and the developed group of countries in the region. As per the estimates of Asian Development Bank (ADB 2009c), the industrial sector accounted for nearly 42% of the total final energy consumption in 2006. Unlike the household sector, the industrial sector contributes directly to economic development through the production of goods and services.

Table 16 contains the details of the quantity of various energy carriers consumed by the industrial sector in 2007 for the Asia-Pacific region as a whole as well as for the selected developing countries of the region. Further, the regional data is compared with the world totals. Electricity and fuel oil are consumed by all the countries of the region. The analysis of the data shows that about 83% of the coal, 37% of the firewood, 52% of the bagasse, and 38% of the electricity consumed by the industries of the world are accounted by the industries of the developing countries of the Asia-Pacific. This domination is mainly because of China, where the industries consume 67% of the coal and 79% of the electricity consumed by the industrial sector of the Asia-Pacific. The higher firewood share is because of high industrial consumption in Indonesia (45%) and India (43%) in the region. India is the major consumer of bagasse with a share of 49%.

To assess the significance of various types of energy carriers consumed by the industrial sector of the region, the quantum of consumption given in individual units (Table 15) have been converted into common unit (TJ) and shown in Table 17. In total, the industries of the Asia-Pacific region consumed about 31,700 PJ of energy in 2007 compared to the total world industrial energy consumption of 79,111 PJ. This works out to a share of about 40%. Among the countries of the region, China accounts for nearly 61% and India for 16% of the total industrial energy consumption in the Asia-Pacific. China's very high energy share is mainly because of the high concentration of the energy intensive manufacturing industries in the country. The two most dominant industrial energy carriers in the Asia-Pacific are coal with nearly 40% and electricity with 31% shares where as the dominant energy carriers in the world are electricity with a share of about 32% and natural gas with a share of about 27%. Solid fuels with about 48% share dominate the industrial energy scene in the Asia-Pacific whereas they account for only 26.6% in the world industrial energy consumption. Coal is a dominant industrial fuel in China, India, Indonesia, Nepal and Viet Nam. India and Mongolia are the two main lignite using countries. The dominant industrial fuel in Bangladesh and Malaysia is natural gas. The small island developing countries of the Pacific region rely mostly on diesel and electricity for their industrial energy needs (Table 17).

Table 15: Energy access gap between rich and poor

Country	Population share (%) with						Per capita energy consumption (GJ)			Per capita GHG emissions (kgCO_2e/capita)		
	Access to electricity & modern fuels	Access to electricity & no access to modern fuels	No access to electricity & modern fuels	Rich (above $2.0 a day)	Poor (between $2.0 and $1.25 a day)	Extre-mely poor (below $1.25 a day)	Access to electricity & modern fuels	Access to electricity & no access to modern fuels	No access to electricity & modern fuels	Access to electricity & modern fuels	Access to electricity & no access to modern fuels	No access to electricity & modern fuels
Bangladesh	10.4	30.6	59.0	18.7	31.7	49.6	7.02	3.39	2.86	512.6	149.4	28.4
Cambodia	9.0	15.0	76.0	31.8	28.0	40.2	2.04	7.53	6.88	246.6	213.4	65.2
China	51.8	47.6	0.6	63.7	20.4	15.9	2.32	6.93	5.94	312.3	504.9	277.8
India	40.4	24.1	35.5	24.4	34.0	41.6	2.51	7.62	7.04	266.0	207.2	73.8
Indonesia	41.6	22.9	35.5	40.0	30.6	29.4	5.26	7.42	6.24	557.8	342.4	71.9
Mongolia	23.2	43.8	33.0	51.0	26.6	22.4	1.28	7.21	5.93	294.3	434.6	140.3
Nepal	18.4	25.2	56.4	22.4	22.5	55.1	2.72	7.18	6.93	230.9	127.2	70.3
Papua New Guinea	13.0	—	87.0	42.6	21.6	35.8	7.99	8.18	1.34	1652.9	1584.0	12.7
Philippines	52.9	33.1	14.0	55.0	22.4	22.6	1.62	3.81	3.04	235.7	206.6	28.7
Solomon Islands	7.4	7.0	85.6	—	—	—	4.14	3.16	2.61	376.3	151.0	24.7
Sri Lanka	27.9	48.7	23.4	60.3	25.7	14.0	3.24	4.55	3.79	345.7	208.6	35.9
Vanuatu	14.5	4.5	81.0	—	—	—	5.35	6.17	2.13	1020.2	947.3	20.2
Viet Nam	39.4	49.6	11.0	51.6	26.9	21.5	1.99	7.08	5.98	314.3	396.8	143.1
Asia-Pacific	44.1	32.9	23.0	48.2	28.3	23.5	3.71	6.90	5.95	392.8	358.3	140.7

Source: Based on Tables 7, 11, 13, 22 and UN Data 2010 for population data
Note: "—" indicates data is not available

Table 16: Industrial energy consumption - An indicator of energy productivity (2007)

Country	Coal ('000 Tonne)	Kerosene ('000 Tonne)	Lignite ('000 Tonne)	Firewood ('000 Tonne)	Diesel ('000 Tonne)	Bagasse ('000 Tonne)	LPG ('000 Tonne)	Natural Gas/LNG (TJ)	Fuel oil ('000 Tonne)	Electricity (GWh)
Bangladesh	700	5	—	—	68	554	1	73,798	150	9,075
Cambodia	—	—	—	—	26	—	—	—	26	284
China	416,956	404	—	—	15,947	40,913	2,710	1,140,939	15,781	2,149,172
Fiji	1	—	—	—	120	—	3	—	6	528
India	121,418	185	7,820	17,451	2,171	91,737	92	129,706	2,939	265,406
Indonesia	38,354	341	—	18,443	3,952	9,174	146	452,495	2,001	45,802
Malaysia	1,944	26	45	—	3,922	195	106	337,983	1,920	41,684
Mongolia	33		170	—	—	—	—	—	8	1,746
Nepal	437	11	—	242	4	456	—	—	1	871
Papua New Guinea	—	—	—	22	150	114	15	—	15	2,126
Philippines	1,769	16	3	465	178	4,049	85	3,239	948	16,522
Sri Lanka	68	—	—	2,658	54	128	—	—	217	2,627
Thailand	9,472	8	2,304	1,315	972	20,683	538	101,638	1,554	61,168
Viet Nam	7,688	13	—	—	1,115	4,078	140	25,191	870	32,154
Asia-Pacific	622,565	1,174	14,062	40,596	31,143	188,725	4,099	3,556,548	33,036	2,710,917
World	752,589	6,071	39,889	109,840	113,341	365,774	19,958	21,639,741	102,482	7,110,022

Source: UN Data 2010
Note: "—" indicates either data is not available or it is zero

Table 17: Fuel-wise industrial energy consumption in 2007 (TJ)

Country	Coal	Kerosene	Lignite	Firewood	Diesel	Bagasse	LPG	Natural Gas	Fuel oil	Electricity	Total	Share (%)
Bangladesh	14,196	216	—	—	3,101	5,431	46	73,798	6,540	32,670	135,997	0.43
	(10.4)	(0.2)			(2.3)	(4.0)	(0.0)	(54.3)	(4.8)	(24.0)		
Cambodia	—	—	—	—	1,186	—	—	—	1,134	1,022	3,342	0.01
					(35.5)				(33.9)	(30.6)		
China	8,455,868	17,420	—	—	727,183	400,947	123,305	1,140,939	688,052	7,737,019	19,290,734	60.85
	(43.8)	(0.1)			(3.8)	(2.1)	(0.6)	(5.9)	(3.6)	(40.1)		
Fiji	20	0	—	—	5,472	—	137	—	262	1,900	7,790	0.02
	(0.3)	(0.0)			(70.2)		(1.8)		(3.4)	(24.4)		
India	2,462,357	7,977	112,608	261,769	98,998	899,023	4,186	129,706	128,140	955,462	5,060,226	15.96
	(48.7)	(0.2)	(2.2)	(5.2)	(2.0)	(17.8)	(0.1)	(2.6)	(2.5)	(18.9)		
Indonesia	777,819	14,704	0	276,647	180,211	89,905	6,643	452,495	87,244	164,887	2,050,555	6.47
	(37.9)	(0.7)	(0.0)	(13.5)	(8.8)	(4.4)	(0.3)	(22.1)	(4.3)	(8.0)		
Malaysia	39,424	1,121	648	—	178,843	1,911	4,823	337,983	83,712	150,062	798,528	2.52
	(4.9)	(0.1)	(0.1)		(22.4)	(0.2)	(0.6)	(42.3)	(10.5)	(18.8)		
Mongolia	669	—	2,448	—	—	—	—	—	349	6,286	9,752	0.03
	(6.9)		(25.1)						(3.6)	(64.5)		
Nepal	8,862	474	—	3,627	182	4,469	—	—	44	3,136	20,795	0.07
	(42.6)	(2.3)		(17.4)	(0.9)	(21.5)			(0.2)	(15.1)		
Papua New Guinea	—	—	—	324	6,840	1,117	683	—	654	7,654	17,271	0.05
				(1.9)	(39.6)	(6.5)	(4.0)		(3.8)	(44.3)		
Philippines	35,875	690	43	6,977	8,117	39,680	3,868	3,239	41,333	59,479	199,301	0.63
	(18.0)	(0.3)	(0.0)	(3.5)	(4.1)	(19.9)	(1.9)	(1.6)	(20.7)	(29.8)		
Sri Lanka	1,379	—	—	39,873	2,462	1,254	—	—	9,461	9,457	63,887	0.20
	(2.2)			(62.4)	(3.9)	(2.0)			(14.8)	(14.8)		
Thailand	192,092	345	33,178	19,725	44,323	202,698	24,479	101,638	67,754	220,205	906,437	2.86
	(21.2)	(0.0)	(3.7)	(2.2)	(4.9)	(22.4)	(2.7)	(11.2)	(7.5)	(24.3)		
Viet Nam	155,913	561	—	—	50,844	39,964	6,370	25,191	37,932	115,754	432,529	1.36
	(36.0)	(0.1)			(11.8)	(9.2)	(1.5)	(5.8)	(8.8)	(26.8)		
Asia-Pacific	12,625,618	50,623	202,493	608,942	1,420,121	1,849,502	186,505	3,556,548	1,440,370	9,759,300	31,700,020	
	(39.8)	(0.2)	(0.6)	(1.9)	(4.5)	(5.8)	(0.6)	(11.2)	(4.5)	(30.8)		
World	15,262,498	261,773	574,402	1,647,597	5,168,353	3,584,588	908,086	21,639,741	4,468,195	25,596,079	79,111,311	
	(19.3)	(0.3)	(0.7)	(2.1)	(6.5)	(4.5)	(1.1)	(27.4)	(5.6)	(32.4)		

Note: Numbers in parentheses indicate % shares; "—" indicates either data is not available or it is zero

As in the case of household sector, the GHG and black carbon emissions of industrial energy use are estimated using the emission factors obtained from various secondary sources (Table 18). In the case of firewood, it is assumed that all the wood is sourced from un-sustainable sources. The estimated total GHG emissions from industrial energy use for the selected countries of Asia-Pacific as well as for the whole region are given in Table 19. Further, these emissions are compared with total global emissions from the industrial sector due to energy consumption. The total GHG emission from the industrial energy use in the Asia-Pacific region is estimated at 3,910 million tonne of CO_2e in 2007, which is about 41% of the world industrial emissions of 9,535 million tonne of CO_2e. In the Asia-Pacific region, GHG emissions from electricity consumption with 57% and coal with 29% shares account for the largest contribution to the total emissions. In the region, major share of the electricity is generated using coal. The estimates for the world show that electricity with 62%, coal with 14% and natural gas with 13% are the major contributors to the total emissions. It is obvious that with highest share in industrial energy consumption, China accounts for nearly 70% of the GHG emissions contributed by the Asia-Pacific region. This is significantly higher than its 61% share in energy consumption indicating carbon intensiveness of China's industrial energy use. India is a distant second with a share of about 13% in total GHG emissions which is less than its share of energy consumption of 16%.

Table 20 contains the estimates of black carbon emissions from the industrial energy use. The total emission of black carbon is nearly 285,000 tonne in the Asia-Pacific region, which is substantially less than the household emission of BC. Higher energy efficiency levels of industrial energy devices, better control measures and lesser dependence on solid fuels are the possible reasons for low emission of BC. The Asia-Pacific region accounts for nearly 38% of the world BC emissions due to industrial energy use. Diesel with 43% and bagasse with 38% shares are the major contributors to BC emissions in the region. Similar trend is observed even with respect to world emissions of BC with diesel having a share of 59% and bagasse having 28% share. China, because of its extensive dependency on coal, accounts for nearly 38% of the BC emissions in the Asia-Pacific region. India with a share of about 27% is the second big emitter of BC with Indonesia occupying the third position with a share of 11%.

Table 18: Emission factors for industrial energy carriers

Fuels	GHG emissions		Black Carbon (gBC/kg)
	gCO_2e/kg	gCO_2e/MJ	
Firewood	1536.2	101.7	0.51
Bagasse	114.9	8.8	0.58
Kerosene	3047.6	70.7	0.12
LPG	3091.6	67.4	0.01
Electricity (gCO_2/kWh)	827.0	229.7	—
Coal	1800.0	90.1	0.05
Natural Gas ($kgCO_2/M^3$)	1.57	56.1	—
Lignite	—	101.2	0.025
Diesel	—	74.1	3.9
Fuel Oil	—	77.4	0.04

Source: Based on Balachandra 2010, EIA 2007, Venkataraman et al. 2005, Baron et al. 2009, Herold 2003, Bond et al. 2004, ADB 2009, ETC/ACC 2003.
Note: "—" indicates not applicable

Table 19: CO_2e emissions from industrial energy consumption ('000 tonne)

Country	Coal	Kerosene	Lignite	Firewood	Diesel	Bagasse	LPG	Natural Gas/LNG	Residual fuel oil	Electricity	Total (Million tonne)	Share (%)
Bangladesh	1,279	15	—	—	230	48	3.1	4,140	506	7,505	13.7	0.35
Cambodia	—	—	—	—	88	—	—	—	88	235	0.4	0.01
China	761,790	1,231	—	—	53,860	3,544	8,316	64,007	53,232	1,777,365	2,723	69.64
Fiji	1.8		—	—	405		9.2		20	436	0.9	0.02
India	221,834	564	11,396	26,631	7,332	7,946	282	7,276	9,914	219,491	512.7	13.11
Indonesia	70,074	1,039	—	28,145	13,348	795	448	25,385	6,750	37,878	183.9	4.70
Malaysia	3,552	79	66		13,246	17	325	18,961	6,477	34,473	77.2	1.97
Mongolia	60		248	—	—	—	—	—	27	1,444	1.8	0.05
Nepal	798	34		369	14	39	—	—	3.4	720	2.0	0.05
Papua New Guinea	—	—	—	33	507	10	46	—	51	1,758	2.4	0.06
Philippines	3,232	49	4.4	710	601	351	261	182	3,198	13,664	22.3	0.57
Sri Lanka	124	—	—	4,056	182	11	—	—	732	2,173	7.3	0.19
Thailand	17,306	24	3,358	2,007	3,283	1,792	1,651	5,702	5,242	50,586	90.9	2.33
Viet Nam	14,046	40	—	—	3,766	353	430	1,413	2,935	26,591	49.6	1.27
Asia-Pacific	1,137,443	3,578	20,492	61,951	105,184	16,347	12,579	199,522	111,437	2,241,928	3,910	
World	1,375,000	18,501	58,129	167,620	382,803	31,682	61,245	1,213,989	345,689	5,879,988	9,535	

Source: Author's calculations based on Table 16 and Table 18
Note: "—" indicates either data is not available or it is zero

Table 20: Black carbon emissions from industrial energy consumption in 2007 (tonne)

Country	Coal	Kerosene	Lignite	Firewood	Diesel	Bagasse	LPG	Residual fuel oil	Total (Million tonne)	Share (%)
Bangladesh	35	0.6	—	—	265	321	—	6.0	628.2	0.22
Cambodia	—	—	—	—	101	—	—	1.0	102.4	0.04
China	20,848	48	—	—	62,193	23,730	27	631	107,477	37.76
Fiji	—	—	—	—	468	—	—	—	468.0	0.16
India	6,071	22	196	8,900	8,467	53,207	0.9	118	76,982	27.05
Indonesia	1,918	41	—	9,406	15,413	5,321	1.5	80	32,180	11.31
Malaysia	97	3.1	1.1	—	15,296	113	1.1	77	15,588	5.48
Mongolia	1.7	—	4.3	—	—	—	—	0.3	6.2	0.002
Nepal	21.9	1.3	—	123.3	15.6	264.5	—	—	426.6	0.15
Papua New Guinea	—	—	—	11.0	585.0	66.1	0.2	0.6	662.9	0.23
Philippines	88.5	1.9	0.075	237.2	694.2	2348.4	0.9	37.9	3,409	1.20
Sri Lanka	3.4	—	—	1,356	210.6	74.2	—	8.7	1,653	0.58
Thailand	473.6	1.0	57.6	670.7	3,791	11,996	5.4	62.2	17,058	5.99
Viet Nam	384.4	1.56	—	—	4348.5	2365.24	1.4	34.8	7,136	2.51
Asia-Pacific	31,128	141	352	20,704	121,458	109,460	41	1,321	284,605	
World	37,629	728	997	56,018	442,030	212,149	200	4,099	753,852	

Source: Author's calculations based on Table 16 and Table 18
Note: "—" indicates either data is not available or it is zero

5. Energy Access, Poverty, Sustainable Development and Climate Change

United Nation's Millennium Development Goals (MDGs) represent the economic, social and environmental aspirations of humanity for a dignified and sustainable living. The development process towards achieving the MDGs is expected to follow a sustainable development path taking into account the needs of the large number of poor and adverse impact on the environment. The MDGs formulated at the 2002 Johannesburg Summit explicitly acknowledged that access to modern energy services is an essential element of sustainable development. In this respect, in April 2001, the ninth session of the Commission for Sustainable Development (CSD) concluded that to implement the goal accepted by the international community to halve the proportion of people living on less than US $1 per day by 2015, access to affordable energy services is a prerequisite (CSD9 2002). Therefore, even though access to modern energy carriers for basic as well as productive livelihoods is not one of the eight MDGs, it has been considered as the most critical input to achieve each of the MDGs (UNDP 2005, Modi et al 2005). In this context, household energy access for cooking, lighting and many other important end-uses forms an important linkage in achieving the MDGs and thereby sustainable economic development.

Strong action supported by political commitment is critical for tackling the challenge of energy poverty resulting from lack of energy access. Therefore effective policies and programmes are needed to encourage the integration of energy into development programmes and processes at the sub-national level (UNDP, 2009b). One of the outcomes of lack of energy access is the continued dependence on traditional fuels like fuel wood and cattle dung. The inefficient production and use of traditional biomass based energy sources are posing serious economic, environmental, and health threats (Barnes and Floor 1996, Sagar 2005). The energy problems of the developing countries are both serious and widespread. Developing countries are far behind in expanding access to modern energy, whether to meet nationally set energy access targets or to facilitate achievement of the Millennium Development Goals (UNDP-WHO 2009). The use of traditional biomass as a survival fuel by poor in the developing countries have largely contributed to unsustainable development with outcomes like gender discrimination, health hazards, sub-standard living conditions and emission of products of incomplete combustion (PICs) contributing to climate change (Sagar and Kartha 2007).

Affordable and reliable access to electricity end-use services results in increased productivity in agriculture and labor, improvement in the delivery of health and education, access to communications (radio, telephone, television, mobile telephone), improved lighting, enabling the use of drudgery reducing mills, motors, and pumps, and increasing public safety through outdoor lighting (UNDP 2005). Rural electrification at a household level provides at the very minimum basic services such as lighting and communications (e.g. radio/television) and can increasingly meet the aspirations of the rural populations to own other household appliances. Lighting is an important household energy service as it is directly related to quality and productivity of life. Unlike heating or cooking, lighting is the energy end-use that is associated more exclusively with electricity as it can provide high levels of light at high efficiency compared to a kerosene-based light source (Dutt 1994). Household electrification also increases the likelihood that women will read and earn income.

Thus, lack of access to modern energy carriers has implications for economic, social and environmental well being of humanity. The implications could be in the form of income poverty, primitive lifestyles, loss of dignity, physical hardship, health hazards, lack of employment and polluted environment. By expanding access most of these negative impacts could be overcome. Further, the positive implications of universalizing access to modern energy carriers span the sphere of economic, human, social and environmental developments (Tables 21a and 21b).

Table 21a: Expanding energy access: Implications for economic, human, social and environmental developments

Development	Implications	Remarks
Economic Development	Employment Income generation Micro-enterprises Productive Livelihoods	• Employment opportunities due to new economic activities • Source of light for economic activities in evenings • Economic activities such as tailoring, hair salons, phone services, radio and television repair, and refrigeration for household businesses. • Enabling enterprise development, utilizing locally available resources, and creating jobs • Electricity needed for motive power for different end-uses and to enhance productivity. • Refrigeration for vaccines and food staples • Reducing post-harvest losses through better preservation • Distributed energy production supply chain • Transportation and communications to increase market access • Reducing energy expenditure
Human Development	Education	• Educated professionals, such as doctors, nurses, and teachers, are more willing to remain in villages. • Lighting allows children to study outside of daylight hours • Due to time saved on fuel collection and ill health, children will have more time for education. • Enabling access to media and communications that increase educational opportunities.
	Health	• Lighting in health clinics to extend hours of operation • Healthier conditions for domestic work and study. • Illness reduces earning capacities and leads to additional expenses for health care. • Reducing exposure to indoor pollution will make a significant contribution to reducing child morbidity and mortality. • Kitchen fires and kerosene wick lamps are a major cause of burns for infants and toddlers. • Cutting down indoor air pollution will contribute to better respiratory health among women. • Reduce physical burdens and associated health risks. • Exposure to indoor pollution increases the risk of tuberculosis. • Providing access to better medical facilities for maternal care. • Allowing for medicine refrigeration, equipment sterilization, and safe disposal by incineration. • Providing access to health education media • Enabling access to the latest medicines/expertise through renewable-energy based telemedicine systems

Table 21b: Energy access has implications for economic, human, social and environmental development

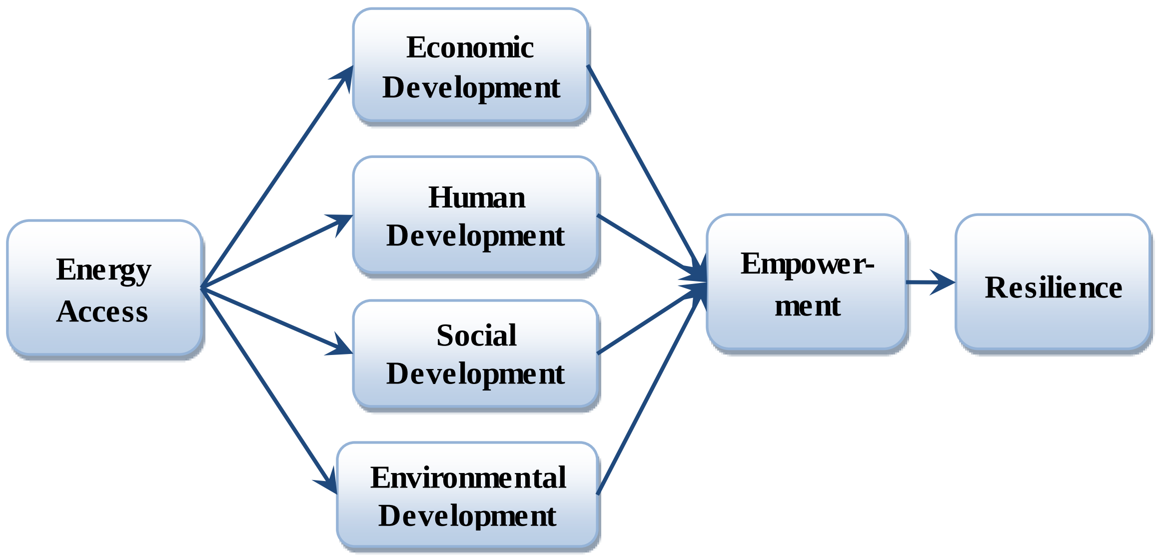
Development	Implications	Remarks
Human Development	Information & knowledge empowerment	• Television, radio, information/internet kiosk creates access to relevant information • Information related to markets for inputs and outputs • Informed decisions, enhanced awareness • Knowledge about rights and duties
	Gender empowerment	• Physical Drudgery reduction by lessening women's workload in collecting fuel • Time saving due to avoided wood collection and reduced cooking time through more efficient devices will allow for productive endeavours, adult education and child care • Eliminating the dependency on fuel collection far from home will reduce the risk of assault and injury for women and girls. • Involving women in household energy decisions contributes to promoting gender equality and empowering women. • Owning a less-polluting stove raises a woman's prestige - both as a sign of wealth and, indirectly, through a soot-free kitchen environment. • Freeing women's time from survival activities, allowing opportunities for income generation • Reducing exposure to indoor air pollution and improving health. • Lighting streets to improve women's safety.
Social Development	Safety and Security Community Participation Clean environment	• Increased security in public spaces and walkways • Empowerment enables social participation and collective decision making • Enhanced status due moving up the energy ladder and ownership modern devices • Clean local environment enables local recreation • Enhanced incomes and economic activities facilitates community initiatives, social gatherings and religious functions
Environmen-tal Development	GHG emissions Black carbon Mitigation options Climate adaptation & resilience	• Reducing deforestation for traditional fuels, reducing erosion and desertification. • Reducing greenhouse gas emissions by using renewable energy sources. • Moving up the energy ladder and using energy efficient devices decrease greenhouse gas emissions. • Reducing pressure on forests, particularly in areas where biomass is scarce. • Avoiding land degradation and desertification due to reduced deforestation. • Reducing emissions of products of incomplete combustion including methane, black carbon, etc. • Energy-efficient devices based on renewable sources, can substantially reduce harmful impacts on the environment • Building climate change adaptation capabilities and thereby climate resilience through empowerment

Source: WHO 2010b, OCHA 2010, REN21 2005

5.1. Expanding Energy Access for Building Empowerment and Resilience

As explained above expanding access to modern energy carriers provides direct and indirect as well as tangible and intangible benefits to the population, especially, to the poor population in the developing countries. The linkages establishing connection between energy access and human resilience to adverse events (e.g., climate change related) are straight forward and very strong (Figure 6). Access to modern energy carriers brings in development – enhanced income, opportunities for economic activities, access to better education and health facilities, connectivity to external world through TV, internet and other media, gender empowerment, clean environment, access to information facilitating knowledge gains, enhanced social status with ability to participate and interact, ability to take informed decisions, etc. All these could significantly enhance the adaptive capabilities of individuals as well as society as a whole. Further, with the adoption of low-carbon pathway to expand energy access has significant environmental and ecological benefits. All these contribute to empowering the poor and build resilience to adversities. Resilience could be built through economic, knowledge, human and social empowerments.

Figure 6: Linking energy access to sustainable development, empowerment and resilience



In the next few sections, we have discussed how the chosen countries have performed with respect to economic, human and environmental development indicators. Since there was no quantitative data with respect to social development, it was excluded from the analysis. The indicators of environmental development include two sets of indicators, namely, indicators measuring the extent of contributions to climate change and climate change vulnerability.

5.2. Implications for Economic Development Benefits Reaching the Poor

As discussed earlier, energy development through expanded access to modern energy carriers has implications for economic development. This could happen through employment generation, skill development through education and information dissemination, establishment of small and micro-enterprises, access to markets, expansion of economic activities, etc. Similarly, a country with higher economic development is expected to have better energy infrastructure and thereby more people with access to modern energy. Thus, GDP per capita measures the level of economic development of a country and the poverty counts indicates the extent of reach of the economic development to the larger section of the population (Table 22). The percentage population living below $1.25 a day could be categorized as extremely poor and that below $2 a day as poor. Even though the average GDP per capita of Asia-Pacific region is just one-third of that of the world its share of extremely poor population of 23.5% is less than the average for the world at 26.2%. This is indicates the benefits of economic development, though low, is better distributed in the Asia-Pacific. However, the share of poor population in the Asia-Pacific is high at 51.8% compared to the world average of 40%, which is an indicator of lower economic development in the region. Among the chosen countries, India though enjoys a higher GDP per capita compared to Viet Nam, the share of extremely poor people in India is almost double (41.6%) that of Viet Nam (21.5%). Even the share of poor people in India is significantly higher than that in Vietnam. This indicates poor distribution of wealth and suggests that mere increase in GDP will not help in eradication of poverty. Nepal and Bangladesh have the highest share of extreme poor as well as poor. India follows them at the third position. As per the earlier discussion, we found that the energy access situation in the south-Asia region is precarious and it is equally true with the extent of poverty prevailing in the region.

Table 22: Indicators of economic development – Access to economic benefits

Country	GDP Per capita in 2008 (2005 PPP)*	% Population living below $1.25/day (2005 PPP) in 2005*	% Population living below the national poverty line in 2005*	% Population living below $2.0 (2005 PPP) a day (2000-2007)#	Share of poorest quintile in income or consumption (%) in 2005*
Bangladesh	1,233	49.6	40.0	81.3	9.4
Cambodia	1,760	40.2	35.0	68.2	7.1
China	5,511	15.9	2.8	36.3	5.7
India	2,747	41.6	28.6	75.6	8.1
Indonesia	3,674	29.4	16.7	60.0	7.1
Malaysia	13,139	2.0		7.8	6.4
Mongolia	3,297	22.4	36.1	49.0	7.2
Nepal	1,028	55.1	30.9	77.6	6.1
Palau	7,600	22.6	32.6	—	—
Philippines	3,244	22.6		45.0	5.6
Solomon Islands	2,413	—	—	—	—
Sri Lanka	4,215	14.0	22.7	39.7	6.8
Thailand	7,120	2.0	13.6	11.5	6.1
Tonga	3,535	—	—	—	—
Vanuatu	3,677	—	—	—	—
Viet Nam	2,574	21.5	28.9	48.4	7.1
Asia-Pacific	3,172	23.5	14.8	51.8	7.0
World	9,634	26.2	20.9	40.0	—

Source: *UNESCAP 2010a, #World Bank 2009, CIA 2010
Note: "—" indicates data is not available

5.3. Implications for Human Development

The human development benefits associated with expanding energy access are related to better education facilities and opportunities, access to healthcare as well as better health conditions, access to relevant information resulting in knowledge empowerment which would enable making informed decisions, and gender empowerment through reduced drudgery, productive endevours, enhanced security and clean working environment. In addition, the enhanced income levels and employment opportunities would significantly reduce the poverty levels thereby enhancing the living standards of the people. This would also enhance the capacity of the people to access improved services related to water and sanitation. To make a comparison at the macro level, indicators related to poverty, gender, human development, health, education and access to improved services are used and the indicator values have been obtained from various secondary sources (Tables 23 and 24).

Poverty gap is the mean shortfall of the total population from the poverty line (counting the non-poor as having zero shortfall), expressed as a percentage of the poverty line. This measure reflects the depth of poverty as well as its incidence (UN 2010). The indicator is often described as measuring the per capita amount of resources needed to eliminate poverty. Poverty gap ratio expresses the total amount of money which would be needed to raise the poor from their present incomes to the poverty line, as a proportion of the poverty line, and averaged over the total population, which measures the depth of poverty (Harvey 2009). Multidimensional poverty index (MPI) is obtained from Alkire and Santos (2010). According to the authors, it is an index of acute multidimensional poverty and it is a combination of head count of poor and deprivations in very rudimentary services and core human functioning. The deprivations are measured as a composite indicator developed using individual indicators of health (child mortality, nutrition or malnourishment), education (years of schooling, child enrolment) and standard of living (lack of access to electricity, drinking water and sanitation, quality of flooring, type of cooking fuel, assets owned). Thus, the MPI is the product of two numbers: the headcount or percentage of people who are poor, and the average intensity of deprivation (Alkire and Santos 2010). Gini index is the measure of inequality in income distribution. Human development index (HDI) is the composite measure of human development, which is composed by using country level data on life expectancy, education and gross national income (GNI) per capita.

The values for these indicators for the selected countries as well as for the whole of Asia-Pacific region are given in Table 23. We have used these indicators as the measure of the extent of the reach of the benefits of economic and energy development to the poor. Asia-Pacific has a smaller poverty gap ratio compared to the world average indicating lesser depth in poverty. However, for countries like Nepal, Bangladesh, Cambodia and India there is a need for substantial efforts to bridge this gap. The high values associated with the multi-dimensional poverty index too points out to the deficiencies in these countries with respect to eradication of poverty and providing access to basic services required for dignified human living. Bangladesh has exhibited a lower inequality in income distribution even in poverty. This is not the case with Nepal where inequalities are very high, indicated by high value of Gini index. The estimates of HDI do not present a rosy picture for the countries of the Asia-Pacific. On an average, the human development is lower in Asia-Pacific compared to the world but far better than sub-Saharan Africa. Malaysia with the highest HDI rank of 57 and Afghanistan with a rank of 155 are the first and last countries among the developing countries of Asia and the Pacific. All the economic development influenced indicators (Table 23) show that the incidence of poverty and associated impacts are very high in majority of the countries of the region. Providing access to modern energy could be one of the major interventions that could enable these countries to improve upon their ranking based on human development index as well as multi-dimensional poverty index.

Table 23: Indicators of human development – Extent of reach of development benefits

Country	Poverty gap ratio (2005-2007)	Multi-dimensional Poverty Index (2000-2008)	Gini index (2000-2010)	Human Development Index (HDI)	
				HDI Rank in 2010	HDI Value in 2010
Bangladesh	13.1	0.291	31.0	129	0.469
Cambodia	11.3	0.263	40.7	124	0.494
China	4.0	0.056	41.5	89	0.663
India	10.5	0.296	36.8	119	0.519
Indonesia	4.6	0.095	39.4	108	0.600
Malaysia	0.5	—	37.9	57	0.744
Mongolia	6.2	0.065	33.0	100	0.622
Nepal	19.7	0.350	47.3	138	0.428
Papua New Guinea	—	—	—	137	0.431
Philippines	5.5	0.067	44.0	97	0.638
Solomon Islands	—	—	—	123	0.494
Sri Lanka	—	0.021		91	0.658
Thailand	0.5	0.006	42.5	92	0.654
Tonga	—	—	—	85	0.677
Vanuatu	—	—	—	—	—
Viet Nam	4.6	0.075	37.8	113	0.572
Asia-Pacific	6.6	0.158	38.6	—	0.564
Sub-Saharan Africa	—	—	—	—	0.389
World	7.3	—	—	—	0.624

Source: UNDP 2010b
Note: "—" indicates data is not available

Other set of indicators of human development that could be related to the outcome of energy and economic development are given in Table 24. These indicators are related to gender empowerment, non-income HDI value, life expectancy at birth, mean and expected years of schooling, access to improved services and impact of indoor air pollution. Though both life expectancy and education are part of non-income HDI value, we have retained them in the list of indicators for better comparison and to learn about the relative deficiencies. The gender inequalities are highest among poor countries and those are having low energy access levels (Table 24). China has the least gender inequality index (GII) value indicating higher levels of gender empowerment. The non-income HDI scores indicating the level of achievements with respect to life expectancy and education are relatively high for Tonga, Malaysia and Sri Lanka. These high scores could be further validated by observing the higher achievements of these countries with respect life expectancy of above 74 years and mean schooling years of 8 and above. Sri Lanka though a poor country in terms of per capita GDP has done well with respect to other development indicators. This is true even with respect to providing access to better sanitation and potable water with more than 90% of the people having access. Cambodia, India and Nepal are the worst performers with respect to providing access to good sanitation facilities (Table 24). Their performance is same as that of sub-Saharan Africa. Except for Papua New Guinea and Cambodia, all other countries in Asia-Pacific have done well with providing access to clean drinking water to the majority of the population. Most direct impact of using solid fuels for cooking is the indoor air pollution. The indoor air pollution is considered as one of the most important causes of deaths in the world. Cambodia with 1,304 deaths per million people in 2004 and India with 954 deaths occupy the top two positions. This indicates their over reliance on traditional fuels for cooking in the closed environment. Next two countries with highest deaths are the neighbouring countries of India, namely, Nepal and Bangladesh. This should be the single most important reason for these countries to prevent the use of solid fuels and promote the climbing of the energy ladder.

Table 24: Indicators of human development - Outcome of development

Country	Gender Inequality Index (GII) Value 2008	Non-income HDI value in 2010	Life expectancy at birth in 2010 (years)	Mean years of schooling in 2010 (years)	Expected years of schooling in 2010 (years)	Population with access to improved services (%) in 2008		Deaths due to indoor & outdoor air/ water pollution in 2004 (per million people)#
						Water	Sanitation	
Bangladesh	0.734	0.543	66.9	4.8	8.1	80	53	821
Cambodia	0.672	0.566	62.2	5.8	9.8	61	29	1,304
China	0.405	0.707	73.5	7.5	11.4	89	55	693
India	0.748	0.549	64.4	4.4	10.3	88	31	954
Indonesia	0.680	0.663	71.5	5.7	12.7	80	52	505
Malaysia	0.493	0.775	74.7	9.5	12.5	100	96	60
Mongolia	0.523	0.710	67.3	8.3	13.5	76	50	318
Nepal	0.716	0.506	67.5	3.2	8.8	88	31	877
Papua New Guinea	0.784	0.447	61.6	4.3	5.2	40	45	737
Philippines	0.623	0.726	72.3	8.7	11.5	91	76	322
Solomon Islands	—	0.550	67.0	4.5	9.1	—	—	433
Sri Lanka	0.599	0.738	74.4	8.2	12.0	90	91	315
Thailand	0.586	0.683	69.3	6.6	13.5	98	96	345
Tonga	—	0.792	72.1	10.4	13.7	100	96	0
Vanuatu	—	—	70.8	—	10.4	83	52	0
Viet Nam	0.530	0.646	74.9	5.5	10.4	94	75	438
Asia-Pacific	0.637	0.633	67.9	6.6	11.0	83	65	532
Sub-Saharan Africa	—	0.436	52.7	4.5	9.0	58	31	—
World	0.560	0.663	69.3	7.4	12.3	87	62	—

Source: UNDP 2010b, #Gumartini 2009
Note: "—" indicates data is not available

The above assessment suggest that there are significant benefits in terms of both economic and social gains due to interventions like switching from biomass to modern fuels, reducing exposure to indoor pollution, using efficient cookstoves and the benefits clearly outweigh the costs of such interventions. Economic benefits include reduced health expenditure due to less illness, the economic value of productivity gains due to less illness and death, time savings due to less time spent on fuel collection and cooking, and reduced environmental impacts at the local and global level (WHO, 2006b). In addition to indoor air pollution and physical drudgery, energy (especially electricity) plays an important role in maternal health, and in preventing and treating diseases. The bundling of services like water, sanitation and education with electricity has disproportionately larger benefits; the whole is substantially larger than the sum of the parts (UNDP 2007a).

Another serious implication of solid fuel use for cooking is health impacts due to indoor air pollution. At present about 37% of the world's population rely on biomass as their primary fuel for cooking. Over half of those people live either in India or Sub-Saharan Africa. Reliance on solid fuels often results in regular exposure to harmful emissions of carbon monoxide, hydrocarbons and particulate matter. Exposure to these is an important cause of disease and mortality in developing countries. The indoor pollution caused by burning these fuels in conventional stoves has significant affect on the health of women and children. Conservative estimates of global mortality show that in 2000 between 1.5 and 2 million deaths were attributed to this risk factor. This accounts for approximately 3% to 4% of total mortality worldwide. Approximately one million of the deaths were due to childhood acute (lower) respiratory infections (ALRI), with the remainder due to chronic obstructive pulmonary disease (COPD) followed by lung cancer among adult women (Ezzati and Kammen 2002). According to the estimates of the World Health Organization (WHO) about 1.5 million premature deaths occur each year due to indoor air pollution. In addition, it is estimated that indoor air pollution causes about 36% of lower respiratory infections and 22% of chronic respiratory disease (WHO, 2006a). The recent estimates confirm these findings. According to a study by UNDP and WHO, globally almost two million deaths occur annually from pneumonia, chronic lung disease, and lung cancer are associated with exposure to indoor air pollution resulting from cooking with biomass and coal, and 99% of them occur in developing countries (UNDP-WHO 2009, Ezzati and Kammen 2002). Exposure to respirable particles is strongly associated with acute respiratory infections (ARI) among children accounting for the largest number of child deaths (World Bank 2004). Combination of disease and biomass collection burden decreases productivity and quality of livelihoods of the poor and reduces the time children spend in school, thus contributing to the vicious cycle of poverty and ill health (World Bank 2004). Women and children, especially the girl children, suffer most from indoor air pollution, because traditionally they are responsible for household chores. Also women and children are typically responsible for biomass collection, an exhausting task that can result in long-term physical damage (IEA 2009).

5.4. Implications for Environmental Development

The implications for environmental development are analysed keeping in mind the possibilities of mitigating the negative effects of climate change and building climate change resilience. In this regard, lack of modern energy access and over dependency on solid fuels has significant negative implications for climate change. It has significant global warming effects, due to incomplete combustion of carbon present in the fuel (UNDP-WHO 2009, Smith et al. 2000) as well as due emission GHGs. These aspects have already been discussed in the earlier section (Section 3.3). In this section, we have limited our focus to study the implications of inadequate energy and economic developments, which result in lack of access to modern energy carriers and income poverty, on the climate change by analyzing various indicators related to CO_2 emissions (Table 25). In addition, the indicators of environmental/ecological development and degradation are used to study how lack of development in economic and energy systems has contributed to such a status as well as how such level of degradation will impact the poor people and countries (Table 26). We have assumed that these indicators are appropriate for representing the extent of vulnerability to climate change adversities.

The analysis suggests that all the developing countries of the Asia-Pacific together accounted for about 31% of the global energy related CO_2 emissions with China accounting for almost 67% of this amount (Table 25). India is a distant second with a contribution of just 15%. In terms of per capita emissions only Malaysia and China have higher emissions compared to the global average. As a whole, Asia-Pacific appears to be a low carbon intensive region both in terms of per capita emissions as well as carbon intensity of GDP. The countries with highly inadequate energy development such as Bangladesh, Cambodia and Nepal have very low per capita emission levels. Excepting Tonga, the situation is similar even in Pacific Island countries. These low per capita emissions in these countries are an outcome of poverty and dependency on traditional biomass fuels. Asia-Pacific region as a whole is a carbon efficient economy with a lower carbon intensity (for GDP measured in PPP $) then the global average (Table 25). All the poorer countries of the region have very low carbon intensities ranging between 0.10-0.16 tCO_2/'000 2005 US$. It appears to be a fact that all these countries are adopting a low-carbon path to economic development, albeit at a very slow rate. However, this is an undesirable low-carbon pathway, which promotes poverty, both income and energy. The carbon intensities in these countries are bound to increase with the climbing of the energy ladder and modernization of the economy. This may be noted from the higher carbon intensities observed in the case of emerging economies like China, Thailand, Indonesia and India.

Table 25: Indicators of contributions to climate change - Carbon emissions (2007)

Country	CO_2 Emissions from the Consumption of Energy (Million Tonne)*	CO_2 emissions (tonne/capita)#	Carbon Intensity using Market Exchange Rates (tCO_2/'000 2005 US$)*	Carbon Intensity using PPP (tCO_2/'000 2005 US$)*
Bangladesh	46.28	0.29	0.71	0.12
Cambodia	4.14	0.29	0.54	0.10
China	6260.03	4.75	2.16	0.89
India	1378.29	1.23	1.37	0.46
Indonesia	388.63	1.72	1.21	0.49
Malaysia	148.39	5.59	0.96	0.43
Mongolia	7.58	2.91	2.71	0.90
Nepal	3.18	0.11	0.36	0.11
Papua New Guinea	4.28	0.68	0.80	0.36
Philippines	75.78	0.85	0.68	0.27
Solomon Islands	0.22	0.44	0.44	0.16
Sri Lanka	13.16	0.66	0.47	0.10
Thailand	245.86	3.67	1.26	0.50
Tonga	0.19	1.80	0.72	0.30
Vanuatu	0.11	0.50	0.24	0.12
Viet Nam	88.77	1.04	1.43	0.42
Asia-Pacific	9378.31	2.67	1.00	0.37
World	29784.38	4.50	0.60	0.46

Source: *EIA 2010, #UN Data 2010

Ecological footprint is a measure of human demand on the Earth's ecosystems. In other words, it indicates the sustainability of earth’s resources. The data for the Asia-Pacific suggest that on an average it has a better ecological footprint at 1.5 hectares per capita compared to the global average of 1.8 hectares per capita (Table 26). The smaller Pacific Island countries exert higher pressure on the earth’s resources with ecological footprint ranging from a high of 3.7 hectares per capita in the case of Fiji to 1.7 hectares per capita for Solomon Islands and Papua New Guinea. China is another country with a relatively high ecological footprint. Countries like Cambodia, Sri Lanka and Thailand with high share of protected areas could be less vulnerable to natural disasters. People living on the degraded land would be the most vulnerable to climate change related impacts. Cambodia, Mongolia and Sri Lanka with high share of population living on the degraded land expected to suffer more during disasters. There would be additional threats to the meager resources they own. To the frequently occurring natural disasters at present, the impending climate change related disasters would add further misery. The poor would suffer more due to such disasters. The rates of human sufferings due to such disasters are the highest in Mongolia (Table 26). These indicators provide enough hints to the likely human sufferings and intensity of vulnerability of poor towards the impending climate change related crisis.

Table 26: Indicators of climate change vulnerability

Country	Ecological footprint of consumption in 2006 (hectares per capita)	Protected area in 2009 (% terrestrial area)	Population living on degraded land in 2010 (%)	Average Population affected by natural disasters (average per year, per million people) (2000-2009)
Bangladesh	—	1.6	11.3	49,538
Cambodia	0.9	24.0	39.3	62,992
China	1.8	16.6	8.6	96,359
India	0.8	5.3	9.6	55,557
Indonesia	—	14.1	3.1	4,935
Malaysia	—	17.9	1.2	1,667
Mongolia	—	13.4	31.5	120,113
Nepal	—	17.0	2.3	9,611
Papua New Guinea	1.7	3.1	0.0	5,078
Philippines	—	10.9	2.2	60,119
Solomon Islands	1.7	0.1	—	2,050
Sri Lanka	0.9	20.8	21.1	31,444
Thailand	1.7	19.6	17.0	46,173
Tonga	—	14.5	—	18,168
Vanuatu	—	4.3	—	36,308
Viet Nam	1.0	6.2	8.0	25,632
Asia-Pacific	1.5	9.8	11.1	27,942

Source: UNDP 2010b
Note: “—” indicates data is not available

6. Energy development versus Economic, Human and Environmental Developments: An Indicator-based Assessment

To assess the linkage between energy, poverty, development and climate change an indicator based approach is adopted. As discussed earlier, provision of modern energy to the people has many outcomes – reducing poverty; stimulating economy-wide development; empowering people with knowledge, skills, education and health; promoting gender equality; reducing harmful effects of pollution and promoting environmental development through mitigating the impacts of climate change and building climate resilience. We have made an attempt to empirically validate these relationships. This has been done in two ways –

a. Constructing indices of development - energy, economy, human and environment – for the 24 selected developing countries of the Asia-Pacific using the relevant indicators for each of the development system for representing the status of development in each country. Further, a composite index is developed by integrating individual development indices and the countries are ranked according their composite index scores. A higher composite index score for a country indicates that it has better adaptive capabilities in the event of adversities, has a resilient economy as well as population with better empowerment.

b. The relationship between energy development and economic development, human development, environmental development, multi-dimensional poverty and gender empowerment are analyzed.

The indices related to human development, multi-dimensional poverty and gender empowerment for the selected countries are obtained from the Human Development Report of the UNDP (UNDP 2010a).

6.1. A Composite Development Index

As stated above, the composite development index for the 24 developing countries of the Asia-Pacific developed by integrating individual indices of energy, economic, human and environmental developments. Again, these individual indices are built using several related indicators. For example, the energy development index (ENDI) is composed of indicators related to extent of electricity and modern fuel access, energy intensity of GDP measuring efficiency of energy use, energy production-consumption ratio indicating the energy security level and per capita household electricity consumption as a proxy to measure the extent of modern energy use (Table 27). Countries with higher values for electricity and modern fuel access, production-consumption ratio and per capita household electricity consumption obtain higher index scores. A value of more than one for production-consumption ratio indicates that the country is self reliant in energy. On the other hand, smaller value for energy intensity of GDP gives higher index score.

Table 28 contains the indicators used for constructing economic development index (EDI). These indicators are expected to measure the macro-economic development of a country. Real GDP growth rate indicates how fast the national economy is growing; GDP per capita represents the economic strength of a country and it determines a country's affordability levels; Balance of payments on current account represents a country's capability to pay for the imports; Budget balance represents a country's capacity to pay from internal sources to support many development programmes. Any budget surplus can act as a cushion at the time of crisis; and Import cover basically suggests that how long a country can manage its monthly imports bills through accumulated foreign exchange reserves (UNDP 2007b). Higher values for all the indicators are considered to be good and give high index scores for a country.

Table 27: Indicators of energy development (2007)

	Electricity Access (%)#	Modern Fuel Access (%)*	Energy consumption per unit of GDP in kgoe per 1,000 (2005 PPP $)	Production-Consumption Ratio	Household Electricity (kWh/capita)$
Afghanistan	14.4	12.6	19	0.44	5
Bangladesh	41.0	10.4	54	0.76	60
Bhutan	68.5	45.8	450	1.30	69
Cambodia	24.0	9	39	0.01	43
China	99.4	51.8	281	0.92	273
Fiji	60.0	52	291	0.17	221
India	64.5	40.4	157	0.69	104
Indonesia	64.5	41.6	180	2.06	211
Iran	98.4	99	275	1.65	705
Lao, PDR	55.0	5	67	1.12	88
Malaysia	99.4	96.7	170	1.51	700
Maldives	100.0	81.19	215	0.00	198
Mongolia	67.0	23.2	264	0.95	238
Myanmar	13.0	5	33	2.26	35
Nepal	43.6	18.4	67	0.40	30
Pakistan	57.6	34	123	0.66	195
Papua New Guinea	10.0	13	145	1.44	190
Philippines	86.0	52.9	116	0.40	185
Samoa	97.0	18.57	75	0.18	254
Solomon Islands	14.4	7.4	58	0.00	22
Sri Lanka	76.6	27.9	44	0.17	160
Thailand	99.3	75.5	198	0.49	419
Vanuatu	19.0	14.5	42	0.00	213
Viet Nam	89.0	39.4	167	1.03	273

Source: *WHO 2010a, #*UNDP-WHO 2009, #IEA 2010b, $UNESCAP 2010a, Nation Master 2011

The indicators of environmental development index (EVDI) consist of indicators that measure the extent of contribution to climate change as well as the capability to build climate resilience (Table 29). Lower values for per capita CO_2 emissions, carbon intensity of GDP, share of population living on degraded land and average population affected by natural disasters are considered to be good where as a higher value for share of protected area is desirable.

For each of the indicators given in Tables 27, 28 and 29, which are considered as indicators representing different dimensions, a relative indicator is estimated using the specific data for the selected countries given in the tables. The relative indicator for each indicator is developed by using a scaling technique where the minimum value is set to 0 and the maximum to 1. The equation used for this is[3]

[3] This formula draws on the methodology for development of the International Energy Agency's Energy Development Index

$$\text{Relative indicator} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}}$$

Table 28: Indicators of economic development (2007)

	Real GDP growth rate*	GDP per capita#	Balance of payments: current account*	Budget balance*	Import cover*#
Afghanistan	12.10	737.3	0.88	-1.8	11.85
Bangladesh	6.32	1,311.0	1.10	-3.2	3.28
Bhutan	17.95	4,862.4	11.00	0.6	13.68
Cambodia	10.21	1,945.2	-2.65	-2.9	3.58
China	13.01	5,378.4	10.99	0.6	19.33
Fiji	-6.60	4,121.5	-17.30	-1.8	4.12
India	9.30	2,556.6	-1.02	-5.4	17.15
Indonesia	6.28	3,726.5	2.43	-1.2	7.36
Iran	7.83	10,712.8	11.92	-5	18.48
Lao, PDR	7.46	2,050.3	-17.98	-4.5	6.02
Malaysia	6.35	13,385.1	15.37	-3.2	8.29
Maldives	7.21	4,585.1	-40.28	-7.9	3.38
Mongolia	10.22	3,231.5	6.74	2.9	5.51
Myanmar	11.93	1,107.8	9.19	-4.0	13.18
Nepal	3.19	1,078.4	0.44	-1.8	8.26
Pakistan	6.02	2,571.5	-4.78	-4.3	4.91
Papua New Guinea	6.52	1,970.8	1.76	2.5	8.46
Philippines	7.19	3,383.3	4.94	-0.2	6.98
Samoa	5.99	5,450.2	-6.12	1.1	4.76
Solomon Islands	10.20	1,918.7	-2.78	-0.3	4.95
Sri Lanka	6.80	4,265.4	-4.33	-7.7	3.73
Thailand	4.93	7,925.7	5.71	-1.1	7.50
Vanuatu	6.80	3,998.1	-5.90	0.1	7.19
Viet Nam	8.48	2,602.5	-9.83	-5.5	4.02

Source: *ADB 2009a, #IMF 2009

For example, the indicator “Electricity Access” in Table 27 is transformed into relative indicator representing electricity access by using the above equation for the values given in Table 27. Similarly, all the indicators in Tables 27, 28 and 29 are converted into relative indicators representing different dimensions. Since comparing or combining absolute indicators with different dimensions values (e.g., electricity access in % and per capita household electricity consumption in kWh) is not possible the dimension less relative indicators are developed. Collectively, a group of indicators or relative indicators are used to represent a larger dimension or a factor. For example, the indicators give in Table 27 or the relative indicators developed using these, collectively assumed to represent the larger dimension “energy development”. Similarly, separate set of indicators are used to represent dimensions “economic development” (Table 28) and “environmental development” (Table 29).

Table 29: Indicators of environmental development (2007)

	CO_2 emissions tonne/capita$	Carbon Intensity using PPP (tCO_2/'000 2005 US$)#	Protected area in 2009 (% terrestrial area)*	Population living on degraded land (%) 2010*	Average Population affected by natural disasters (Numbers/ year/million people) (2000-2009)*
Afghanistan	0.027	0.035	0.4	11.0	23,278
Bangladesh	0.277	0.125	1.6	11.3	49,538
Bhutan	0.856	0.142	28.4	0.1	1,782
Cambodia	0.310	0.097	24.0	39.3	62,992
China	4.919	0.894	16.6	8.6	96,359
Fiji	1.740	0.594	1.3	0.0	6,720
India	1.384	0.456	5.3	9.6	55,557
Indonesia	1.768	0.492	14.1	3.1	4,935
Iran	6.847	0.674	7.1	25.1	58,770
Lao, PDR	0.252	0.082	16.3	4.1	24,535
Malaysia	7.323	0.430	17.9	1.2	1,667
Maldives	2.986	0.621	2.0	0.0	4,901
Mongolia	4.053	0.905	13.39	31.5	120,113
Myanmar	0.268	0.072	6.3	19.2	5,989
Nepal	0.121	0.114	17.0	2.3	9,611
Pakistan	0.903	0.277	10.3	4.5	8,953
Papua New Guinea	0.524	0.356	3.1	0.0	5,078
Philippines	0.799	0.269	10.9	2.2	60,119
Samoa	0.900	0.174	3.4	0.0	3,277
Solomon Islands	0.397	0.165	0.1	0.0	2,050
Sri Lanka	0.619	0.104	20.8	21.1	31,444
Thailand	4.143	0.500	19.6	17.0	46,173
Vanuatu	0.452	0.119	4.3	0.0	36,308
Viet Nam	1.293	0.425	6.2	8.0	25,632

Source: #EIA 2010, $UN Data 2010, *UNDP 2010b

Thus, the next step involved in the analysis is to derive these larger dimensions (or dimension index) from the appropriate group of relative indicator variables determined as explained above. The dimension index is computed as the arithmetic mean[4] of the relative indicators belonging to that particular dimension. For example, the arithmetic mean of the relative indicators developed from the data given in Table 27 gives rise to energy development index (ENDI). Similarly, economic development index (EDI) and environmental development index (EVDI) are developed. The next step is to develop the composite development index (CDI) from these dimensions. Again the arithmetic mean of these three dimension indices is estimated to compute the CDI.

The Table 30 contains the estimated, as explained above, indices of individual dimensions related to economic, energy, environmental and human developments as well as overall

[4] This follows from the computing of human development index (HDI), which is an arithmetic mean of indices of Life expectancy index, Education index and GDP index (HDR 2009) and also the method used for developing energy development index (EDI) by International Energy Agency (IEA 2010c).

composite development index. All the 24 countries have been ranked according their index scores for individual dimensions as well as CDI. Malaysia obtains the top rank because of its good scores on energy, human and economic development indices. However, it ranks lowly 17 on the basis of environmental development index. Overall, Malaysia can be treated as the country with most empowered and resilient population. Bhutan takes the second position with very high scores on economic and environmental development indices. It is weak on energy development. Among the Pacific Island countries, only Samoa with a high rank of 6 on the basis of CDI can claim to be a resilient country. Others countries like Solomon Islands with a rank of 19, Papua New Guinea at 15th rank and Fiji at 20th rank have low scores on most of the dimensions. Afghanistan with a lowest CDI score of 0.462 is ranked 24th, the last.

Table 30: Indicators of empowerment and resilience: A composite development index (CDI)

	Economic Development Index EDI	Energy Development Index ENDI	Environmental Development Index EVDI	Human Development Index HDI	Composite Development Index CDI	Rank
Afghanistan	0.520 (9)	0.265 (22)	0.710 (12)	0.352 (24)	0.462	24
Bangladesh	0.350 (18)	0.347 (18)	0.645 (14)	0.543 (22)	0.471	22
Bhutan	0.736 (2)	0.351 (17)	0.952 (1)	0.619 (14)	0.665	2
Cambodia	0.388 (17)	0.242 (23)	0.643 (15)	0.593 (18)	0.466	23
China	0.775 (1)	0.535 (6)	0.382 (22)	0.772 (4)	0.616	7
Fiji	0.260 (23)	0.361 (16)	0.625 (18)	0.741 (9)	0.497	20
India	0.518 (10)	0.422 (12)	0.563 (20)	0.612 (16)	0.529	16
Indonesia	0.481 (14)	0.566 (4)	0.725 (10)	0.734 (10)	0.626	5
Iran	0.706 (3)	0.824 (2)	0.291 (23)	0.782 (3)	0.651	3
Lao, PDR	0.313 (21)	0.401 (15)	0.838 (3)	0.619 (15)	0.543	13
Malaysia	0.655 (4)	0.857 (1)	0.629 (17)	0.829 (1)	0.742	1
Maldives	0.175 924)	0.526 (7)	0.592 (19)	0.771 (6)	0.516	18
Mongolia	0.573 (5)	0.403 (14)	0.224 (24)	0.727 (11)	0.482	21
Myanmar	0.530 (8)	0.409 (13)	0.724 (11)	0.586 (19)	0.562	10
Nepal	0.407 (16)	0.324 (20)	0.874 (2)	0.553 (21)	0.539	14
Pakistan	0.346 (19)	0.432 (11)	0.758 (6)	0.572 (20)	0.527	17
Papua New Guinea	0.535 (7)	0.339 (19)	0.728 (9)	0.541 (23)	0.536	15
Philippines	0.505 (11)	0.512 (8)	0.691 (13)	0.751 (8)	0.615	8
Samoa	0.485 (12)	0.484 (9)	0.765 (4)	0.771 (5)	0.626	6
Solomon Islands	0.452 (15)	0.202 (24)	0.759 (5)	0.610 (17)	0.506	19
Sri Lanka	0.303 (22)	0.445 (10)	0.757 (7)	0.759 (7)	0.566	9
Thailand	0.551 (6)	0.627 (3)	0.557 (21)	0.783 (2)	0.630	4
Vanuatu	0.481 (13)	0.289 (21)	0.740 (8)	0.693 (13)	0.551	12
Viet Nam	0.316 (20)	0.548 (5)	0.638 (16)	0.725 (12)	0.556	11

Note: (1) Numbers in parentheses show the rankings of countries against each indicator
(2) Data on Human Development index is for 2007 and obtained from UNDP (2009a)

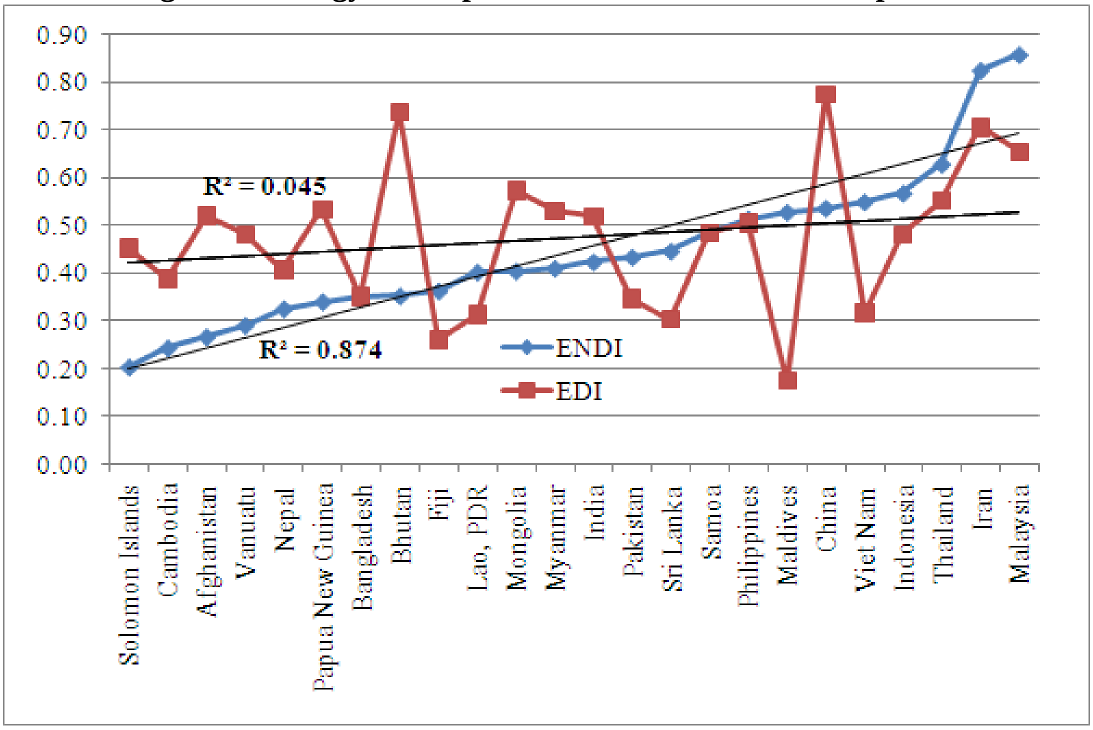
Though Iran has obtained 3rd rank on the basis of CDI scores, its performance related to environmental development is very poor and it ranks a lowly 23. It may be observed from the table that the countries, which have done well with respect to economic and energy development indices have fared poorly with respect to environmental development. The individual dimension related indicators as well as the overall CDI could be useful in identifying the relative strength and weakness of a country with respect to different dimensions of sustainable development.

6.2. Implications of energy development on the other development indicators – An analysis of relationships

As discussed previously, the energy development index, a measure of extent, quantity and quality of access to modern energy carriers has implications for sustainable development. To validate this, we have tried to correlate the energy development index (ENDI) with all the possible development indicators that are relevant to achieve the goal of sustainable development. The values given Table 30 for all the indices are used for analyzing these relationships.

Figure 7 shows the relationship between ENDI and economic development index (EDI). Though the linear relationship is not significant, there appears an increasing trend in EDI with the increase in ENDI. For the countries with low energy development, any gain in ENDI scores is likely to result in similar increase in EDI scores. However, these gains do not appear to happen for countries with high ENDI scores. Overall the relationship appears to be weak. Beyond a certain level, energy development alone cannot influence economic development; other factors will have significant roles to play in achieving higher economic growth. With technological advances and structural changes occurring in the economy, countries at higher levels of economic development would experience decoupling of economic growth from energy demand growth.

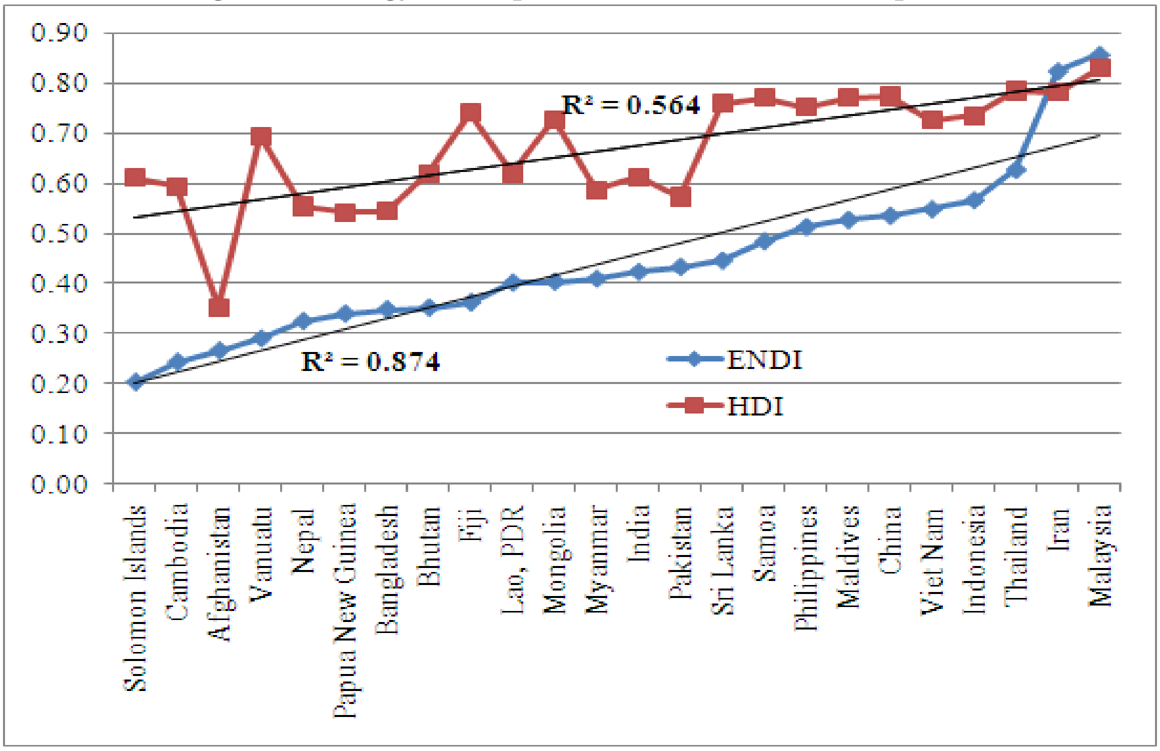
Figure 7: Energy development versus economic development



Source: Author's estimate based on Table 30

The relationship between ENDI and human development index (HDI) appears to be strong (Figure 8). With rising ENDI scores one could observe an increase in HDI scores. In other words, countries with higher ENDI scores are likely to have higher HDI scores. Thus, the present analysis provides a reasonably strong indication that energy development is one of the prerequisites for achieving human development.

Figure 8: Energy development versus human development

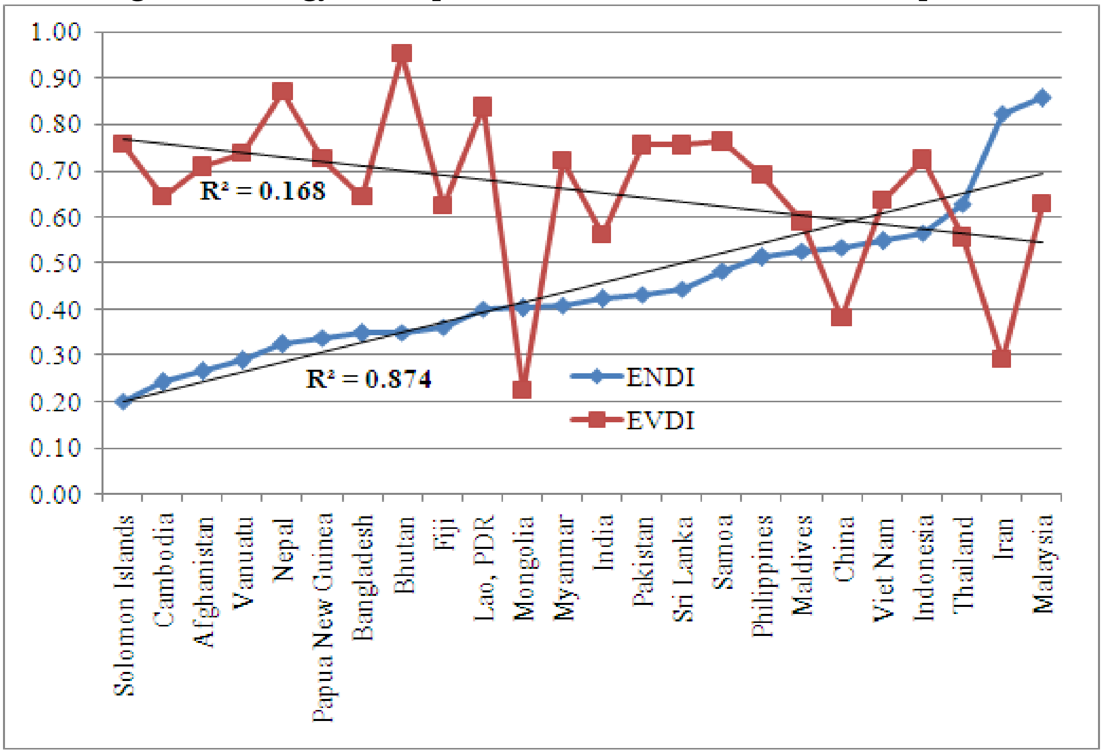


Source: Author's estimate based on Table 30

Even though we cannot observe a linear relationship between ENDI and environmental development index (EVDI) there appears a relatively strong association between the two (Figure 9). However, the relationship appears to opposite. We could observe a decrease in EVDI scores with the increase in ENDI scores. It conveys that energy development is likely to result in environmental degradation. Basically, it suggests that energy development with current technology mix and fuel choices is likely to result in environmental degradation. Therefore, the need is to adopt low carbon technologies and pathway to achieve the goal of sustainable energy development.

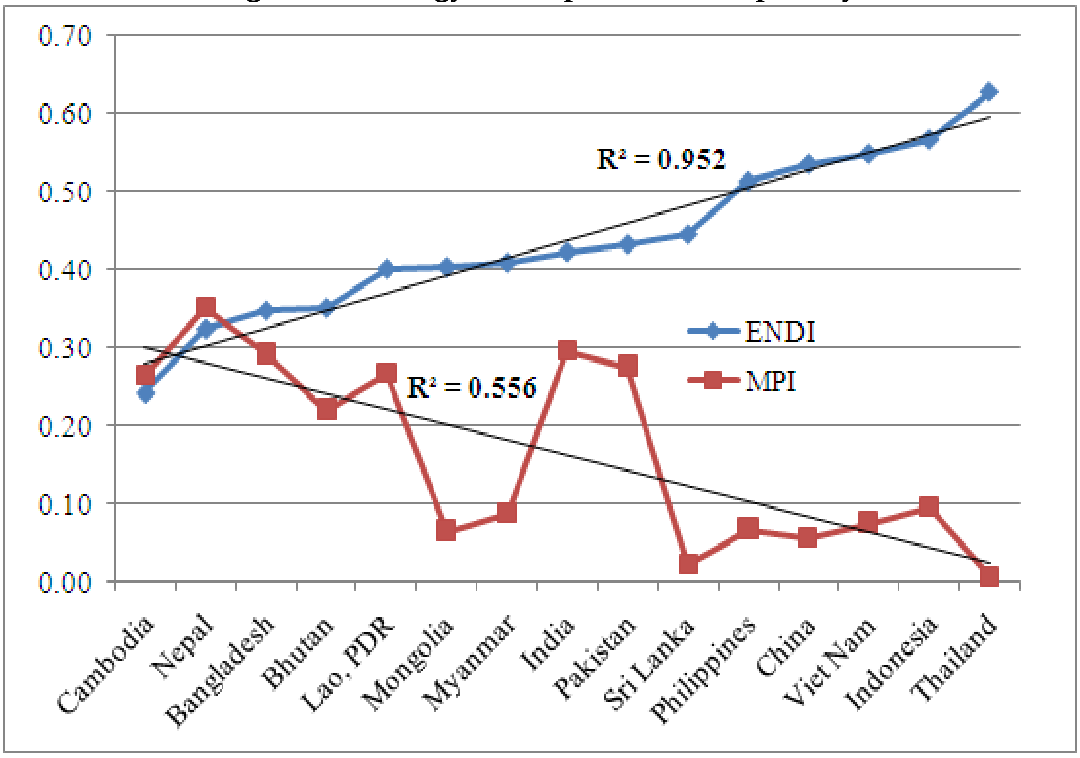
We may observe from Figure 10 that there is a significant negative linear relationship between ENDI and multidimensional poverty index (MPI). With higher values of MPI indicating higher incidence of poverty there is a decrease in poverty levels with higher energy development. In other words, we could observe from the figure that with the increase in ENDI there appears a linear decrease in MPI scores. Thus, it may be safe to conclude that energy development has a significant role to play in reduction of poverty.

Figure 9: Energy development versus environmental development



Source: Author's estimate based on Table 30

Figure 10: Energy development versus poverty

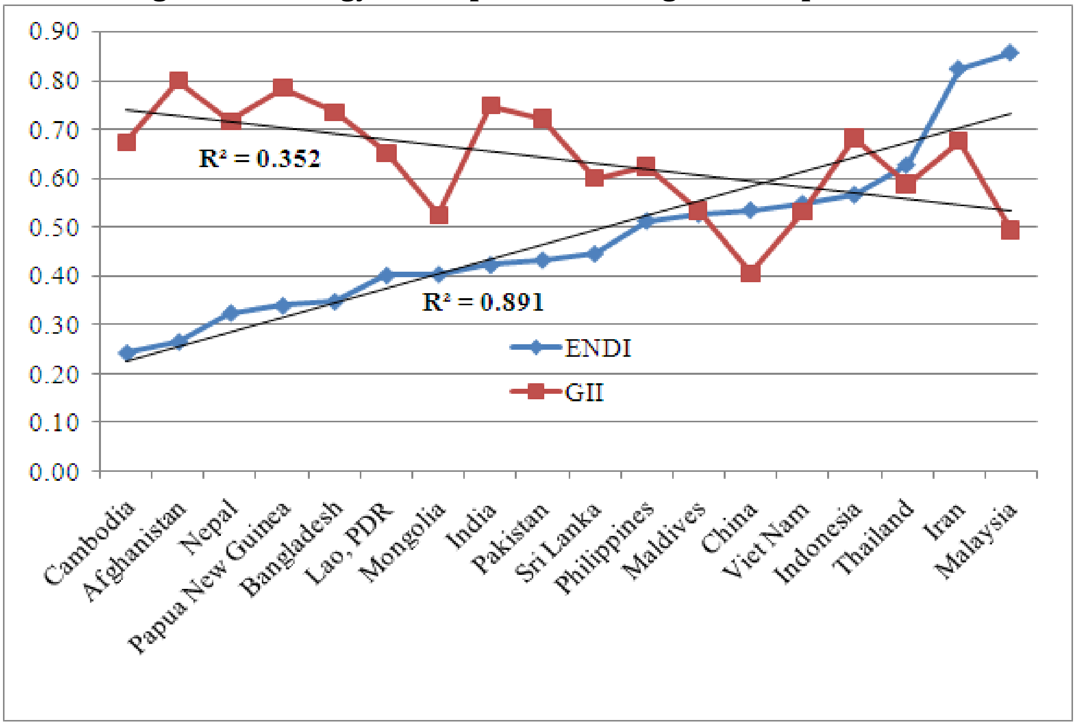


Source: Author's estimate based on Table 30

The energy development index has a negative relationship with gender inequality index (Figure 11). In other words, energy development may be one of the influencing factors for gender empowerment. We may observe from the figure that with the increase in ENDI scores there is a decrease in gender inequality index (GII) scores. Though not significant, there appears a strong negative linear relationship between ENDI and GII. This is an expected relationship considering that energy development expands access to modern energy carriers, which can result in better living standards for the women with reduced drudgery, more free time for productive activities and clean indoor environment.

Thus, it is clear from the above analysis that energy development with the main objective of expanding access to modern energy can bring in many other developmental benefits. However, it is crucial to adopt a low-carbon pathway to achieve this energy development goal to make the overall development sustainable in the long-run.

Figure 11: Energy development versus gender empowerment



Source: Author's estimate based on Table 30

7. Energy Access Policies and Programmes

The status of modern energy access in the Asia-Pacific as in 2007 suggests that about 77% of the population had access to electricity and about 44% had access to modern fuels for cooking. Relatively high access level in electricity was the outcome many successful programmes implemented across Asia-Pacific. For example, in the early 90s China was electrifying villages at the rate of 30 per day and Viet Nam gave almost 400 people access to electricity per hour for 15 years (AGECC 2010). Though not as successful as in the case of electricity there were programmes targeting expansion of cooking fuel access. The biogas for cooking programmes implemented in China and India were reasonably successful. Many governments enacted enabling policies to strengthen these programmes. Broadly, the policies and programmes for expanding could be classified into the following four categories:

- Large-scale government initiated focused programmes
- Price controls to enhance affordability through energy subsidies and tax incentives
- Promoting technology dissemination – Biogas for cooking, biomass power, advanced biomass cookstoves, small and micro-hydro for power generation

- Small-scale NGO and private sector initiated programmes with donor funding and government support.

7.1. Large-scale Government Initiatives

China's national electrification rate in 2009 was 99.4% as with rural electrification of 99% and 100% in urban areas. Latest statistics suggest that in 2008, still 9-10 million people lacked electricity in China (IEA 2010e). This success is an outcome of government's focused rural electrification programme providing electricity to over 900 million people during the period 1950-2004. Key factors in China's success were the government's ability to mobilize contributions at the local level, creation of local enterprises and the domestic production of low-cost components (AGECC 2010). Electricity generation from small hydropower, with an installed capacity of 31.2 GW in 2003, played a particularly large role in electrifying remote rural regions (Jiahua et al. 2006). Viet Nam achieved extremely rapid electrification, expanding coverage from about 10% in 1986 to 96.6% in 2009, that is, in just 23 years (Box 1). Of the electrified households, 96.34% are connected to the grid and 0.26% to the off-grid. Access to low-cost finance, funding from multiple sources and insistence on cost recovery, through tariffs or from government budget, were important in achieving this success rate. (AGECC 2010, Tuan 2010).

Box 1: Expanding electricity access: A success story from Vietnam

Viet Nam has achieved very high rates of electrification during the past 23 years. Access grew from about 10% in 1986 to 96.6% in 2009, an increase of nearly 87%. Of the electrified households, 96.34% are connected to the grid and 0.26% to the off-grid. The most intensive growth period was during 1995-2008, when an average of 3.4 million people provided with electricity access each year. This was achieved largely through extension of the grid by Electricity of Viet Nam (EVN). Existing infrastructure was severely underdeveloped, requiring a massive programme, which tripled the national installed capacity and involved the construction of a 500kV line stretching the length of the country. As a result, EVN had limited additional capacity to develop the distribution grid, and relied heavily on local distribution utilities (LDUs), community cooperatives and service agents to install, operate and maintain low voltage lines as well as managing invoicing and revenue collection. Recovery of operational costs from end-users was critical to success of the programme. Funding was from multiple sources including government subsidies, provincial government funds, international loans and grants, and cross-subsidies. International development association (IDA) helped the government to prepare a Master Plan for Rural Electrification. Despite the high overall success, there are a number of challenges resulting from the intense pace of implementation – including limited capacity to ensure quality standards and provide sufficient capability-building to local participants. In certain regions, poor-quality grid infrastructure was installed and subsequent maintenance has been lacking. Grid refurbishment projects are underway and many of the community cooperatives have been incorporated into LDUs in an effort to reduce losses and improve revenue collection.

Source: AGECC 2010, Tuan 2010

India is the third country, which is in the midst of implementing a large scale electrification programme to achieve universal rural electricity access (Box 2). Towards this goal, the government of India, designed, planned and implemented an ambitious rural electrification programme titled Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) by involving all the relevant stakeholders within the government system. The programme is entirely funded by the government except for the cost of final connection, which is to be borne by the households who are above the poverty line whereas it is free for the below poverty line (BPL) households. During the last three years, RGGVY programme has provided connections at the rate of about 3.7 million households per year for a total of 11 million households.

7.2. Price Controls: Energy Subsidies and Tax Incentives

The market determined prices of energy carriers are mostly out of reach of the poor households. Governments, either through subsidies or through tax controls or using both options moderate the prices for the poor. Subsidies are typically targeted at the consumers whereas tax incentives are provided for the producers of the energy carriers. In addition, the high costs of electricity services for the poor are typically addressed by pricing them at a level that low-income users can afford to pay. These prices would be substantially lower than the cost incurred in producing and delivering the energy carrier. In many cases, governments rather than funding the subsidies targeted at the poor transfer burden to high-income consumers through cross-subsidies. In such instances, the high-income consumers are required to pay prices, which are substantially higher than the cost plus profit based prices. Governments often subsidize commonly used household fuels such as kerosene and LPG. Most commonly, either due to political compulsions or due to difficulties in administration, the subsidized prices are made universally applicable to consumers from all income levels. For example, the prices of public-sector distributed LPG are subsidized for all the consumers in India (Box 3).

Box 2: Universal rural electrification in India – A large-scale government programme

Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) a scheme for developing rural electricity infrastructure and expanding household electrification was launched by the government of India on 4th April, 2005 with the objective of providing access to electricity to all households and improving the rural electricity infrastructure. Under this scheme 90% capital subsidy will be provided for developing rural electrification infrastructure through creation of rural electricity distribution infrastructure and promotion of decentralized distributed generation (DDG) and supply system from renewable or non-conventional energy sources for villages/habitations where grid supply is not cost effective. Balance 10% will be loan assistance on soft terms. The scheme, however, provides for funding of electrification of all un-electrified below poverty line (BPL) households with 100% capital subsidy. Above the poverty line rural households are expected to pay the final connection costs. Many unique features like decentralized management, franchisees, local community involvement, distributed generation, etc., are included to make the programme very robust. The total cost of the programme as per the latest information is about Rs. 287.3 billion (US$ 6.4 billion). The latest results suggest that out of about 115,000 un-electrified villages in 2005, 70,000 villages have been electrified. By April 2010, about 118,000 villages have been electrified and 10.5 million connections have been provided to below poverty line (BPL) households. During the last three years, RGGVY programme has provided connections at the rate of about 3.7 million households per year for a total of 11 million. For the latest year, 2009-10, it has crossed 5.4 million households. During the last five years free connections have been provided to more than 10.5 million rural BPL households, benefitting about 60 million rural people. If India is to achieve the goal of 100% rural household access to electricity by 2015, as targeted, the yearly electrification rates will need to be more than doubled, and reach 10 million households per year.

Source: Balachandra 2010, RGGVY 2010

Although well intentioned, the majority of energy subsidies have proved to be counterproductive, destroying markets and benefiting people who are already better off (UNESCAP 2005). However, there are no straight-forward methods to tackle this problem. A reduction or removal of pricing subsidies to overcome these problems can have potential adverse impacts on the poor. The partial withdrawal of kerosene price subsidies in Sri Lanka and Myanmar, for example, forced people in some rural areas to return to the use of fuel-wood. Both these countries suffer from deforestation and this could have serious environmental implications for them in the long run (UNESCAP 2005).

7.3. Promoting Technology Dissemination

Many of the governments initiated large-scale programmes to support dissemination of renewable energy and energy efficient technologies. Most of these programmes had provision of modern energy carriers to the people, especially in rural areas, as one of the objectives in addition to promoting technology dissemination. Biogas plants, advanced biomass cookstoves, micro-hydro power plants, biomass power generation systems, solar water heaters, solar PV and home lighting systems are some prioritized technologies chosen for dissemination. Biogas plants are one of the technologies, which had the maximum dissemination, especially in India and China (Box 4). India has an exclusive ministry, Ministry of New and Renewable Energy (MNRE), entirely focusing on renewable energy technologies.

Box 3: Energy subsidies in India: Essentially not targeted at Poor

Both LPG and kerosene are subsidized heavily in India. But they are not essentially targeted at the poor. These subsidies are universally applicable to all categories of consumers of these products. In the case of kerosene, in addition to subsidized pricing, it is distributed through a government controlled public distribution system. Further, kerosene supply has a quantity constraint as well, i.e., households are allotted consumption quotas that vary by the state and region (urban and rural) they live in, and whether they have an LPG connection or not. The latest data suggest that the Indian government contributed a total amount of Rs. 26.7 billion in 2008-09 towards subsidizing kerosene and LPG for households. Out of this, about Rs. 17 billion is provided for subsidizing LPG, which is predominantly used by middle and high income urban households. The subsidy component provided by the government does not compensate the losses incurred by the public sector oil companies due to selling of kerosene and LPG below market prices. As per the estimates available, the total under-recovery due to the sale of these fuels is to the tune of Rs. 458 billion in 2008-09. Nearly 62% of the under recovery is accounted by the under-priced sale of kerosene through public distribution system (PDS). The study carried out by the National Council for Applied Economic Research (NCAER) in 2005 revealed that nearly 39% of the PDS kerosene was being illegally diverted (NCAER, 2005). It is generally believed that the diverted kerosene is used to adulterate diesel and petrol for transport on account of price differential between these fuels. If the national average itself is 39% then the illegal diversion in rural quota of PDS kerosene could be easily above 50%. Thus, universally subsidized LPG and partially available kerosene do not serve the needs of the poor.

Source: Balachandra 2010

Box 4: Biogas program in China: Expanding access to modern cooking fuel

Large scale biogas plant dissemination began in China in 1973 and it is reported that by the 1980s, 7 million plants were built. Very soon most of them went into disuse due to faulty design and construction methods. These were gradually rectified and by 1990s the functional plants remained at around 5.5 million. Over the past 10 years, China has increased the number of biogas installations from 6.8 million household biogas plants at the end of 1997 to 26.5 million in 2007. China's potential for biogas plants is estimated to be around 75 million. Recently, China has re-stated the objective of the biogas program as a renewable energy source and secondly, as a way to recycle agricultural materials. The government has brought in a large level of capital (RMB 1 billion) and at the same time has made biogas plant more people and location friendly, resulting in higher productivity from farms. Micro-credit and low interest loans are now available to farmers wanting to build these plants. Furthermore, having learned from earlier failures, there are now about 150,000 trained personnel to build and maintain biogas plants. In addition to creating a positive environment for these plants, it has also enacted laws that favor the construction and use of biogas plants in rural areas. By 2030, it is estimated that there would be about 50 million plants, covering nearly two thirds of biogas potential in China and will attempt to reach at least 20% of the rural population. In this way China has put in an appropriate blend of institutional and administrative infrastructure, easy finance access and some degree of user's stake in continued use of biogas plants and finally overall economic support through CDM methods. The enactment of an enabling law is expected to ensure large scale implementation.

Source: Chanakya and Balachandra 2010, Bhattacharya and Salam 2002, Methane to Markets-China 2009, Quichun 2008

7.4. NGO and Private Sector Initiated Programmes with Donor Funding and Government Support

Large number of projects focusing on providing access to modern energy carriers has been implemented across the region. Most of these projects are implemented by the local NGOs, government agencies and private sector entities with funding from international donor agencies. Global Environmental Facility (GEF) is one of the most important funding sources, which has supported such initiatives by providing incremental fund support. UN agencies like UNDP, UNEP have also supported energy access projects in many countries. Development finance institutions, multi-lateral and bilateral financial institutions, foreign governments, international foundations, multinational corporate organization and even global large energy companies have funded large number of developmental projects targeted at providing access to modern energy carriers to the poor. Funding has been largely restricted to renewable energy technology-based energy access programmes with twin objectives climate change mitigation and energy access. Small and micro-hydro, solar PV systems, solar home lighting systems, advanced biomass cookstoves, biogas systems, biomass-based power generation systems, biofuel production and wind energy are some of the popular technology-based projects implemented in the regions (Box 5, 6 and 7).

Box 5: Biogas programme - Nepal

Nepal installed over 170,000 biogas plants, benefiting more than a million people, in a 13-year programme during the 1980s and 1990s. Over 90 per cent of these are still in operation today. This intensive programme was supported by the development of a local private sector biogas manufacturing and construction capacity, as well as training and certification facilities to ensure that quality standards were maintained. Between 35 and 50 per cent of the capital costs were subsidized through grants from international donors such as the German development finance institution Kreditanstalt für Wiederaufbau (KfW). Loan capital was made available for the remaining capital costs.

Source: AGECC 2010

Box 6: Powering rural clinics in Myanmar

In Myanmar, Green Empowerment has installed solar PV panels in 18 rural clinics to improve basic living conditions and provide quality health care to the thousands of people living in the conflict-ridden east. A total of 2,340 watts of power illuminating the clinics has allowed indigenous Karen refugees and internally displaced people access to medical care, making these clinics critical to refugee survival. The medics treat landmine victims and other casualties of the conflict, as well as patients affected by malaria and other illnesses resulting from harsh conditions. An estimated 54,000–90,000 people have benefited from the clinics since August 2003. The solar systems allow medics to address nighttime emergencies, have proper lighting for medical procedures, and use electric medical devices and laptop computers. Having built the systems themselves, the medics are fully trained to install, operate, maintain, and move the specially designed mobile systems. Each unit consists of one 130-watt solar panel, 1 deep cycle battery, 2–3 fluorescent 20-watt lights, 1 LED light, 1 12-volt outlet, and 1 charge controller. The total cost of the project is estimated at $55,712.

Source: REN21 2005

7.5. Barriers to Expanding Energy Access to the Poor

- ***Lack of effective policies***: Policies provide guidelines and plan of action for achieving the desired objectives. Considering that the large majority of the poor people in the Asia-Pacific region lack access to modern energy carriers it appears that most of the national governments have failed to enact targeted and effective energy access policies.
- ***Lack of effective programmes***: Expanding energy access to the poor needs to follow programmatic mode of implementation with multi-stakeholder participation. With poor being incapable of paying adequately for the services market mechanisms alone will not be sufficient to include them in the regular expansion programmes. Therefore, the need is to develop and implement effective energy access programmes exclusively targeted at the poor.
- ***Lack of large scale finance:*** Obtaining large scale finance to support programmes targeted at the poor is extremely difficult. Low affordability levels, risk of default and low opportunity to make profits force the bankers to treat these projects as risky and unviable projects. Government and donor funding are crucial for the success of such projects.
- ***Lack of institutional framework:*** Institutions are essential to implement, manage, coordinate and monitor the policies and programmes created by the government. Most countries appear to lack such institutions created exclusively for expanding energy access to the poor.

- ***Inefficient and ineffective governance:*** Government centric programmes have to endure the governance related ineffectiveness. Bureaucratic inefficiencies typically result in delayed approvals and release of funds, ineffective monitoring, favoritisms, low quality output, etc. Lack of tangible incentives to perform leads to low motivation among the people involved in implementation. Short tenures associated with specific ministries and organizations tend to compromise on the long-term sustainability of the process, especially, post-implementation. Political motivations typically overshadow the social and economic objectives of the programmes. Combination of these factors makes a programme or policy which appears to be very effective on paper to be a massive failure on implementation.
- ***Misdirected focus and targets:*** Many government implemented programmes on expanding energy access were not successful because of lack of proper focus and inappropriate targets. For example, technology focused programmes like dissemination/deployment of solar PV, biogas plants, improved cookstoves, micro-hydro, etc., have dissemination as their primary objective and thus numbers deployed or capacity installed become the targets for measuring success. Similarly universally applicable subsidies on energy carriers in many countries are not targeted at the poor. Even the high and middle income households enjoy the benefits of subsidy putting unnecessary burden on the governments' finances.
- ***Ineffective delivery mechanisms:*** The quality and reliability of energy access as well as its sustainability depends largely on the effectiveness and robustness of the mechanisms established in the villages or local locations. Any energy access expansion programme involve creation of local infrastructure and make provisions for energy production and distribution, repair and maintenance, new connections, billing and collection, monitoring and reporting, and few other activities. These linkages are critical and they need to be performed effectively for the sustenance of energy access programmes. However, it appears that such mechanisms are missing in most of the countries.
- ***Lack of private benefits:*** Energy access programmes tend to be successful provided the individual households accrue perceived and real benefits. Poor rural households do not perceive it to be beneficial shifting from free biomass to priced cooking fuels like kerosene or LPG even if they are subsidized. With low opportunity cost of labor and starved of cash, the saved efforts in biomass collection do not translate into benefits. Health benefit of clean cooking fuels is not perceived as benefit because of lack of knowledge. There are no forces within the villages/towns which influence shift to clean cooking fuels. On the other hand market forces have a played a major role in pushing the fast moving consumer goods, typically classified as luxury items in the rural context, and influencing rural people to adopt them. Such forces are absent with respect to modern energy carriers.

In the next section we have discussed a proposal for achieving universal energy access in the Asia-Pacific region. The implementation programme recommended for this is expected to overcome most of the barriers listed above.

Box 7: Samoa – Putting excess coconuts to use

Samoa, similar to many other Pacific island nations, rates as "highly vulnerable" to oil price pressures for its dependence on imported oil for electricity generation. In 2008, as oil prices soared above US$100/barrel, electricity prices rose steeply, which had the highest impact on the poor and most vulnerable households and communities. Now, locally produced coconut oil, which can be fed into existing diesel electric generators, has emerged as part of the solution to energy security and oil price vulnerability in Samoa and other Pacific countries including Vanuatu, Fiji, Solomon Islands, Papua New Guinea, the Philippines and the Republic of the Marshall Islands.

In Samoa, this development has re-ignited interest from local businesses and farmers in the previously defunct industry, with disused coconut plantations being revitalised. Coconut farming creates much needed employment in locally owned and operated plantations, reducing the trend of rural-urban migration and injecting much needed income at the village level. Furthermore, there are no "food versus fuel" concerns as plantations are pre-existing and the vast majority of nuts fall to the ground as organic waste each year. Local producers are supplying up to 5% of the national electricity utility's fuel requirements, with a growth target to displace up to a quarter of its needs by 2020. Yet even now, coconut oil has difficulty competing with lower diesel prices in 2009, meaning farmers' margins are incredibly small, limiting both potential coconut oil production and rural community benefits.

Enhanced international efforts, could ensure that carbon-financing mechanisms are more easily available to improve viability of such small-scale projects; while other aid support could help to develop "added value" coconut export products from wood, husks and shells. This support along with assistance towards developing other emission-free indigenous renewable energy sources is vital to deliver greater social, economic and environmental outcomes through the energy sector in vulnerable Pacific Islands.

Source: ISF 2010

8. Universal Energy Access in Asia and the Pacific – The Way Forward

The earlier discussions established the fact that universalizing access to modern energy carriers for the large majority of the poor in the Asia-Pacific has multiple benefits. Keeping this in mind, we have discussed a proposal to achieve universal energy access in the Asia-Pacific. The proposal targets at 100% access to modern energy carriers for cooking, lighting and other basic electricity-based uses by 2030, i.e., in another 20 years starting from 2010. Providing universal energy access has large implications. To ascertain the implications of 100% access on energy requirements, investments, operating and capital costs, GHGs and black carbon emissions, and the incremental number of people provided with access, two scenarios are developed:

a. **Baseline Scenario (BS)** for all the developing countries of the Asia-Pacific region tracking the expansion of modern energy access in 2015 and 2030 with a base year status as on 2009. This scenario is similar to the New Policies Scenario of the World Energy Outlook 2010 (IEA 2010a). The assumptions underlying the New Policies Scenario are used here to arrive at the number of people without access to electricity and modern fuels in 2015 and 2030. The population projections for 2015 and 2030 are obtained from the United Nations Population Division (UNPD) projections (UNPD 2009) and the 2009 population is obtained from the Population Reference Bureau's World Population datasheet for 2009 (PRB 2010). The modern fuel access in 2009 for each country is an extrapolation from the 2007 data (UN data 2010). The baseline access status in 2015 and

2030 for the world and sub-Saharan Africa are obtained from the World Energy Outlook 2010 (IEA 2010a).

b. **Universal Energy Access Scenario (UAS)** for all the developing countries of the Asia-Pacific tracking the expansion towards universal access. The number of people without access to electricity and modern fuel in 2015 is estimated using the same assumption used in the World Energy Outlook 2010 for universal access (IEA 2010a). According to this scenario there will be no one in 2030 without access to modern energy carriers/technologies. Other inputs and assumptions are similar to that used for baseline scenario.

The implications of these scenarios on the resources requirements are analysed based on following:

- The energy needs are proposed to be met with a judicious mix of energy supply from both centralized energy systems (electricity grid and LPG) and decentralized energy systems (Mini-grid and Off-grid electricity systems, biogas from distributed biomass energy systems, advanced biomass cookstoves).
- As proposed by Bazilian, et al (2010), an electricity supply mix of 50% from centralized grid, 40% from mini-grid and 10% from off-grid is used in the proposed scenario.
- For universal cooking energy access, the proposed technology/fuel mixes are 40% share from LPG, 15% from biogas and 45% from advanced biomass cookstoves. These assumptions are a slight modification from that used in IEA (2010b).
- An annual electricity consumption norm of 500 kWh per urban household and 250 kWh per rural household and an average annual LPG consumption 22 kg per capita are used to estimate the energy demand for universal energy access (IEA 2010b).
- The costs of electricity generation from different technologies are estimated using the estimates from Bazilian, et al (2010).
- The investment needed for adding the required installed capacity is estimated based on the assumption made in IEA (2010b).
- The capital cost associated with LPG, Biogas and advanced biomass cookstoves are estimated again using the unit cost estimates obtained from IEA reports (IEA 2010b, IEA 2010d).

It is proposed that the whole programme of universal energy access is to be implemented with the involvement of national governments, stakeholders from public and private organizations/enterprises, NGOs and international organizations.

8.1. Universal Energy Access Scenarios: Implications for Resources

The projected status of access to electricity and modern fuels for cooking in 2015 and 2030 for the selected countries of the Asia-Pacific is given in Tables 31 and 35. The status is given for both the baseline and universal energy access scenarios. Even though the scenarios are developed for all the developing countries of the region, the results have been presented for only the selected countries.

The incremental electricity requirement for providing universal electricity access is about 73,930 GWh in the Asia-Pacific and the associated generation requirement is nearly 87,000 GWh (Table 32). This estimate includes the electricity requirement of only those people who have been given access under the universal energy access programme. India accounts for nearly 54% of this requirement. The total incremental annual cost of providing universal electricity access is about US$ 12 billion by 2030 with India accounting for about US$ 6.5 billion (Table 33). The total investment required over the period of 20 years is about US$ 40 billion with India accounting for more than 50% of it. The investment required for providing universal electricity access in sub-Saharan Africa is more than that of Asia-Pacific at about US$ 47 billion. The results indicate that India has a major role to play in providing universal electricity access in the region. The solace is that India has already moved ahead with implementing such a programme to provide electricity access to all (Box 2). The incremental CO_2 emissions due to universal electricity access are negligible at about 25 million tonne per year by 2030 (Table 34).

With respect to universal access to modern fuels for cooking, about 4 billion people in the world need to be provided with access in the next 20 years (Table 35). This is the incremental number of people who would not have got the access but for the universal access programme. Nearly 2.8 billion of them would be from the Asia-Pacific with India accounting for 1 billion and China for about 750 million of them. Annual LPG requirement for this incremental population with access by 2030 would be about 24 million tonne in the Asia-Pacific and nearly 36 million tonne globally (Table 36). This is not a significant increase in relation to the current world consumption of about 218 million tonne. Most of the incremental energy needed for cooking under universal energy access scenario would be met from the biomass resources through biogas plants and advanced cookstoves. Total investment (only capital cost of the systems) required over a period of 20 years in the Asia-Pacific is about US$ 72 billion with most of the investments happening in India and China in that order (Table 37).

Thus the total incremental investment required for providing universal energy access in the Asia-Pacific is estimated to be nearly US$ 112 billion over a period of 20 years.

Table 31: Universalization of energy access (electricity) in the Asia-Pacific in next 20 years during 2010-2030

Country	Population (Million)#			People without Access (Million)			People with Access in BS (Million)		People with Access in UAS (Million)		Incremental Access in UAS (Million)		Population without Access in BS (%)			Population without Access (%) in UAS
	2009	**2015**	**2030**	**2009**	**2015**	**2030**	**2015**	**2030**	**2015**	**2030**	**2015**	**2030**	**2009**	**2015**	**2030**	**2015**
Bangladesh	162	175	203	96	82	62	93	141	115	203	21	62	59.0	46.7	30.7	34.6
Cambodia	15	16	20	11	10	7.4	6.7	13	9.2	20	2.5	7.4	76.4	59.1	36.6	43.7
China	1,331	1,396	1,462	8.1	5.0	0	1,391	1,462	1,392	1,462	1.3	0.0	0.6	0.4	0.0	0.3
India	1,171	1,294	1,485	404	389	293	905	1,192	1,006	1,485	101	293	34.5	30.1	19.7	22.2
Indonesia	243	244	271	82	70	53	174	218	193	271	18	53	33.5	28.6	19.6	21.1
Malaysia	28	30	35	0.2	0.2	0.1	30	35	30	35	0.0	0.1	0.7	0.6	0.4	0.4
Mongolia	2.7	2.9	3.2	0.9	0.8	0.6	2.1	2.7	2.3	3.2	0.2	0.6	33.3	27.0	18.1	20.0
Nepal	29	33	41	17	14	11	18	30	22	41	3.7	11	57.9	43.4	26.4	32.1
Papua New Guinea	6.6	7.7	10.1	5.9	5.1	3.9	2.6	6.2	3.9	10.1	1.3	3.9	89.7	65.9	38.3	48.8
Philippines	92	102	124	10	8.1	6.2	94	118	96	124	2.1	6.2	10.3	8.0	5.0	5.9
Solomon Islands	0.50	0.60	0.79	0.44	0.38	0.29	0.22	0.50	0.32	0.79	0.10	0.29	88.0	62.9	36.4	46.5
Sri Lanka	21	21	22	4.7	4.0	3.1	17	19	18	22	1.0	3.1	22.9	19.0	13.8	14.1
Thailand	68	70	73	0.50	0.43	0.33	70	73	70	73	0.11	0.33	0.7	0.6	0.4	0.5
Tonga	0.10	0.10	0.12	0.01	0.01	0.01	0.10	0.11	0.10	0.12	0.00	0.01	10.0	8.2	5.6	6.0
Vanuatu	0.20	0.28	0.37	0.19	0.16	0.12	0.11	0.25	0.16	0.37	0.04	0.12	95.0	58.8	33.5	43.5
Viet Nam	87	94	105	2.1	1.8	1.4	92	104	92	105	0.47	1.37	2.4	1.9	1.3	1.4
Asia-Pacific	3,622	3,895	4,363	799	725	545	3,169	3,818	3,358	4,363	189	545	22.1	18.6	12.5	13.8
Sub-Saharan Africa	836	970	1,308	585	635	652	335	656	526	1,308	191	652	70.0	65.5	49.9	45.8
World	6,810	7,302	8,309	1,441	1,406	1,213	5,896	7,096	6,291	8,309	395	1,213	21.2	19.3	14.6	13.8

Source: Author's estimates based on IEA 2010a, UN Data 2010, #PRB 2010, #UNPD 2009

Table 32: Incremental energy needs for universal energy access scenario (electricity)

Country	Incremental Energy Requirement in UAS (GWh)			Total Generation in UAS (GWh)	Share of electricity generation systems		
	2015	2030	Total		Grid (50%)	Mini-grid (40%)	Off-grid (10%)
Bangladesh	2,144	6,278	8,422	9,909	4,954	1,982	198
Cambodia	253	741	995	1,170	585	234	23
China	131	0	131	154	77	31	3.1
India	10,190	29,520	39,710	46,717	23,359	9,343	934
Indonesia	1,828	5,353	7,182	8,449	4,224	1,690	169
Malaysia	4.5	13.1	17.6	20.7	10.4	4.1	0.4
Mongolia	20.2	59.0	79.2	93.2	46.6	18.6	1.9
Nepal	370	1,082	1,452	1,708	854	342	34
Papua New Guinea	133	388	521	613	306	123	12
Philippines	213	623	836	984	492	197	20
Solomon Islands	9.9	28.9	38.7	45.6	22.8	9.1	0.9
Sri Lanka	105	308	414	487	243	97	9.7
Thailand	11.2	32.8	44.0	51.8	25.9	10.4	1.0
Tonga	0.2	0.7	0.9	1.0	0.5	0.2	0.0
Vanuatu	4.3	12.5	16.7	19.7	9.8	3.9	0.4
Viet Nam	47	138	185	217	109	43	4.3
Asia-Pacific	18,999	54,931	73,930	86,977	43,488	17,395	1,740
Sub-Saharan Africa	19,193	65,689	84,882	99,861	49,931	19,972	1,997
World	39,796	122,210	162,006	190,595	95,298	38,119	3,812

Source: Author's estimates based on Table 31 and Bazilian et al (2010), IEA (2010b)

Table 33: Cost implications of universal energy access (electricity)

Country	Annualized Cost of Electricity Generation (Million US$/year)								Capital cost of Generation (Million US$)		Investment (Million) at 10%		
	Types of Generation Systems				Composition of Cost								
	Grid (@US Cents 9.5/kWh)	Mini-grid (@US Cents 30.2/kWh)	Off-grid (@US Cents 73.1/kWh)	Total	Capital	O&M	Fuel	Total	2010-15	2015-30	2010-15	2015-30	Total
Bangladesh	642	599	145	1,386	695	229	462	1,386	177	518	671	3,941	4,611
Cambodia	76	71	17	164	82	27	55	164	21	61	79	465	544
China	10	9.3	2.3	22	11	3.6	7.2	22	11	0	41	0	41
India	3,027	2,826	683	6,535	3,277	1,081	2,178	6,535	841	2,436	3,188	18,528	21,716
Indonesia	547	511	124	1182	593	195	394	1182	151	442	572	3,360	3,932
Malaysia	1.3	1.3	0.3	2.9	1.5	0.5	1.0	2.9	0.4	1.1	1.4	8.2	10
Mongolia	6.0	5.6	1.4	13.0	6.5	2.2	4.3	13.0	1.7	4.9	6.3	37	43
Nepal	111	103	25	239	120	40	80	239	31	89	116	679	795
Papua New Guinea	40	37	9.0	86	43	14	29	86	11	32	41	244	285
Philippines	64	59	14	138	69	23	46	138	18	51	67	391	458
Solomon Islands	3.0	2.8	0.7	6.4	3.2	1.1	2.1	6.4	0.8	2.4	3.1	18	21
Sri Lanka	32	29	7.1	68	34	11	23	68	9	25	33	194	226
Thailand	3.4	3.1	0.8	7.2	3.6	1.2	2.4	7.2	0.9	2.7	3.5	21	24
Tonga	0.07	0.06	0.02	0.14	0.07	0.02	0.05	0.1	0.02	0.05	0.07	0.41	0.48
Vanuatu	1.3	1.2	0.3	2.8	1.4	0.5	0.9	2.8	0.4	1.0	1.3	7.8	9.2
Viet Nam	14	13	3.2	30	15	5.0	10	30	3.9	11	15	86	101
Asia-Pacific	5,635	5,261	1,271	12,167	6,101	2,012	4,054	12,167	1,568	4,533	5,943	34,477	40,421
Sub-Saharan Africa	6,470	6,040	1,460	13,970	7,004	2,311	4,655	13,970	1,584	5,421	6,004	41,230	47,233
World	12,349	11,528	2,786	26,663	13,369	4,410	8,884	26,663	3,284	10,085	12,449	76,705	89,154

Source: Author's estimates based on Table 31 and Bazilian, et al (2010), IEA (2010b)

Table 34: Carbon emissions due to universal energy access (electricity) in 2030

Country	CO_2 emissions ('000 tonne)			
	Grid (50%)	Mini-grid (40%)	Off-grid (10%)	Total
Bangladesh	2,216	599	75	2,890
Cambodia	262	71	8.8	341
China	34	9.3	1.2	45
India	10,445	2,825	353	13,624
Indonesia	1,889	511	64	2,464
Malaysia	4.6	1.3	0.2	6.0
Mongolia	21	5.6	0.7	27
Nepal	382	103	13	498
Papua New Guinea	137	37	4.6	179
Philippines	220	59	7.4	287
Solomon Islands	10	2.8	0.3	13
Sri Lanka	109	29	3.7	142
Thailand	12	3.1	0.4	15
Tonga	0.23	0.06	0.01	0.30
Vanuatu	4.4	1.2	0.1	5.7
Viet Nam	49	13	1.6	63
Asia-Pacific	19,447	5,260	658	25,365
Sub-Saharan Africa	22,328	6,040	755	29,122
World	42,615	11,527	1,441	55,583

Source: Author's estimates based on Table 32 and Table 12

Table 35: Universalization of energy access (modern fuels for cooking) in the Asia-Pacific in next 20 years during 2010-2030

Country	Population (Million)			People without Access (Million)			People with Access in BS (Million)		People with Access in UAS (Million)		Incremental Access in UAS (Million)		Population without Access in BS (%)			Population without Access (%) in UAS
	2009	2015	2030	2009	2015	2030	2015	2030	2015	2030	2015	2030	2009	2015	2030	2015
Bangladesh	162	175	203	148	155	160	20	44	67	203	46	160	91.4	88.4	78.5	61.9
Cambodia	15	16	20	14	14	15	2.1	5.4	6.4	20	4.3	15	92.5	87.4	73.3	61.2
China	1,331	1,396	1,462	804	747	532	649	930	873	1,462	224	532	60.4	53.5	36.4	37.5
India	1,171	1,294	1,485	855	863	780	431	705	690	1,485	259	780	73.0	66.7	52.5	46.7
Indonesia	243	244	271	126	127	117	117	155	155	271	38	117	51.7	52.0	42.9	36.4
Malaysia	28	30	35	0.9	0.9	0.8	29	34	29	35	0.28	0.84	3.2	3.1	2.4	2.2
Mongolia	2.7	2.9	3.2	2.1	2.2	1.9	0.70	1.32	1.3	3.2	0.65	1.9	76.4	75.4	59.1	52.8
Nepal	29	33	41	25	26	23	6.9	18	15	41	7.7	23	86.1	78.8	56.0	55.2
Papua New Guinea	6.6	7.7	10.1	5.8	6.1	5.4	1.6	4.7	3.4	10	1.8	5.4	88.1	79.1	53.6	55.4
Philippines	92	102	124	46	49	43	53	81	68	124	15	43	50.4	47.7	34.6	33.4
Solomon Islands	0.50	0.60	0.79	0.48	0.50	0.45	0.10	0.34	0.25	0.79	0.15	0.45	96.2	83.9	56.6	58.7
Sri Lanka	21	21	22	16	17	15	4.0	7.0	9.2	22	5.1	15	80.1	81.0	68.6	56.7
Thailand	68	70	73	25	26	23	44	50	51	73	7.9	23	37.3	37.7	31.9	26.4
Tonga	0.10	0.10	0.12	0.04	0.05	0.04	0.06	0.08	0.07	0.12	0.01	0.04	43.2	43.0	34.7	30.1
Vanuatu	0.20	0.28	0.37	0.20	0.21	0.19	0.06	0.18	0.13	0.37	0.06	0.19	98.7	76.8	51.1	53.8
Viet Nam	87	94	105	58	61	63	33	43	51	105	18	63	66.9	65.1	59.6	45.6
Asia-Pacific	3,622	3,895	4,363	2,403	2,383	2,064	1512	2299	2,227	4,363	715	2,064	66.3	61.2	47.3	42.8
Sub-Saharan Africa	836	970	1,308	653	741	918	229	390	468	1,308	239	918	78.1	76.4	70.2	51.8
World	6,810	7,302	8,309	3,145	3,213	3,065	4090	5244	5,090	8,309	1,000	3,065	46.2	44.0	36.9	30.3

Source: Author's estimates based on IEA 2010a, UN Data 2010, #PRB 2010, #UNPD 2009

Table 36: Proposed modern fuels/technologies for universal energy access (modern fuels for cooking)

Country	LPG Households in UAS (million)		Biogas Households in UAS (million)		Advanced biomass stoves Households in UAS (million)		Total (Million)		LPG requirement ('000 Tonne)
	2015	2030	2015	2030	2015	2030	2015	2030	2030
Bangladesh	19	64	7.0	24	21	72	46	160	1,813
Cambodia	1.7	5.9	0.6	2.2	1.9	6.6	4.3	15	167
China	90	213	34	80	101	239	224	532	6,655
India	104	312	39	117	117	351	259	780	9,142
Indonesia	15	47	5.7	17	17	52	38	117	1,361
Malaysia	0.11	0.34	0.04	0.13	0.13	0.38	0.28	0.84	10
Mongolia	0.26	0.76	0.10	0.29	0.29	0.86	0.65	1.91	23
Nepal	3.1	9.1	1.2	3.4	3.5	10	7.7	23	268
Papua New Guinea	0.7	2.2	0.3	0.8	0.8	2.4	1.8	5.4	63
Philippines	5.8	17	2.2	6.5	6.5	19	15	43	507
Solomon Islands	0.06	0.18	0.02	0.07	0.07	0.20	0.15	0.45	5
Sri Lanka	2.1	6.1	0.8	2.3	2.3	6.8	5.1	15	179
Thailand	3.2	9.4	1.2	3.5	3.6	10.5	7.9	23	276
Tonga	0.01	0.02	0.00	0.01	0.01	0.02	0.01	0.04	0.47
Vanuatu	0.03	0.08	0.01	0.03	0.03	0.08	0.06	0.19	2.2
Viet Nam	7.3	25	2.7	9.4	8.2	28	18	63	714
Asia-Pacific	286	826	107	310	322	929	715	2,064	24,455
Sub-Saharan Africa	95	367	36	138	107	413	239	918	10,178
World	400	1,226	150	460	450	1,379	1,000	3,065	35,773

Source: Author's estimates based on Table 35 and IEA (2010b), IEA 2010d

Table 37: Cost implications and carbon emissions of universal energy access (modern fuels for cooking)

Country	Capital Cost (Million US$)				CO_2 emissions ('000 tonne)
	LPG	Biogas	Advanced Biomass stoves	Total	2030
Bangladesh	1,236	3,090	1,043	5,370	5,604
Cambodia	114	285	96	496	517
China	4,538	11,344	3,829	19,711	20,572
India	6,233	15,584	5,259	27,076	28,259
Indonesia	928	2,320	783	4,030	4,206
Malaysia	6.7	17	5.7	29	31
Mongolia	15	38	13	67	70
Nepal	183	457	154	793	828
Papua New Guinea	43	108	37	188	196
Philippines	346	865	292	1,502	1,568
Solomon Islands	3.6	8.9	3.0	16	16
Sri Lanka	122	305	103	531	554
Thailand	188	470	159	817	853
Tonga	0.3	0.8	0.3	1.4	1.5
Vanuatu	1.5	3.8	1.3	6.6	6.9
Viet Nam	487	1,217	411	2,115	2,208
Asia-Pacific	16,674	41,684	14,068	72,426	75,589
Sub-Saharan Africa	6,940	17,349	5,855	30,144	31,460
World	24,391	60,977	20,580	105,948	110,575

Source: Author's estimates based on Table 36, Table 12 and IEA (2010b), IEA 2010d

8.2. Universal Energy Access – Implementation Mechanism

Universal energy access needs a robust implementation mechanism to achieve the time-bound targets. We have made some specific recommendations for designing of regulatory policies, programmes, institutions, financing and local delivery mechanisms, which may function as useful inputs for developing country-specific universal energy access programmes. These recommendations are based on ADB (2010b) and Balachandra (2011b).

Energy access Policy: Policies provide guidelines and plan of action for achieving the desired objectives. Clear political commitment for its promotion should be translated into supportive policies and regulations that work to create incentives and greater certainty for all participants. Energy access policies are targeted at the poor who are vulnerable and have serious issues with affordability. Thus, the proposed policy should encompass following:

- Account for universal service obligation
- Allow for lifeline energy consumption and affordable tariff design
- Flexible and affordable connection, disconnection and reconnection policies
- Enable the establishment of institutions for programme implementation and delivery of energy services.
- Enable the creation of dedicated energy access funds to support the programme implementation.

- Provision for establishing distributed energy generation systems and flexible access to the grid for the local institutions
- Provision for tax incentives for establishing off-grid and micro-grid power generation systems.
- Support capacity development through education, training and awareness programmes.

National and regional institutions for programme implementation: Establishment of dedicated national and regional institutions for implementing programmes related to universal energy access is critical for the success. The role of national level institution is to design implementable programmes, support its actual implementation along with regional/state level institutions and many other stakeholders, and monitor its progress. For doing this, the national level institution is expected to establish the partnership of stakeholders and use its services for performing different activities, supervise and monitor the activities of the regional institutions, design and implement the capacity development programmes, transfer funds to the regional energy access funds. The regional institutions are the ones who would be implementing the programmes, conducting capacity development programmes, interacting with the entrepreneurs and NGOs, and providing incentives.

Multi-stakeholder partnerships: These kinds of innovative processes aiming at universalization of energy access have to pass through a number of hurdles. These barriers are created by various stakeholders of energy systems and their involvement is absolutely necessary to overcome them. Government/policy makers, energy organizations/utilities, technical institutions and R&D organizations, industries, entrepreneurs, financial institutions, donor agencies, NGOs and poor households need to join together to achieve the objective of universal rural energy access. The role of the individual stakeholders in the partnership would be based on their competencies and it could be related to financing, advising, expressing needs, information dissemination, technology provision, training and capacity building, management and monitoring, etc.

Dedicated energy access funds: Obtaining the required financial support for programme implementation is crucial. It is proposed to establish dedicated energy access funds (EAFs) at the national as well as regional or state levels. The energy access funds would be made up of contributions from national budgets, government grants, redeployed energy subsidies, contributions from multilateral agencies and international donors. All the financial support dedicated to universal energy access need to be routed through these energy access funds. In addition, low cost bank finance from multilateral, bilateral and local financial institutions to support investment requirements needs to be tapped.

Support from carbon markets: The global climate change mitigation imperatives have created many market mechanisms created through international protocols which allow the avoided GHG emissions to be traded in the carbon market. This is the new revenue stream for climate change mitigation projects. The Clean Development Mechanism (CDM) is one such mechanism, which is set up under the Kyoto Protocol. The low-carbon pathway adopted for expanding energy access would have large potential for certified emission reductions (CERs) through avoided GHG emissions and these could be traded in the international carbon markets under CDM or similar carbon trading mechanisms. CDM in its present form is not exactly suitable for the universal energy access programme envisaged in this study. In its current form it is too restrictive and preference is always for large scale and easy to implement GHG mitigation projects. Though on paper, sustainable development and conforming to national priorities are listed as critical factors for approval of a CDM project, these are not strictly adhered to in practice. Projects catering to the needs of poor and with a dominant objective of maximizing social wellbeing hardly attract attention of CDM market. These limitations of the CDM programme have been recognized and few remedial measures are being taken to overcome these. One such measure is allowing bundling of small scale CDM projects. Other one is allowing for CDM credits from programmes of activities.

Institutions for local delivery of energy services: The success of the programmes related to providing access to the poor depends mainly on the existence, effectiveness and efficiency of the local institutions responsible delivering the energy carriers or services. This institution could be a private small scale enterprise, an NGO, a government agency or a community organization. The local institution needs to be empowered with capacity to create and maintain the local energy infrastructure and make provisions for energy production and distribution, repair and maintenance, new connections, billing and collection, monitoring and reporting, and other related activities. Thus, the final delivery of energy services to rural households can be performed by the micro-enterprises specially established for this purpose and they can function with the objective of earning profits (private benefits). For example, the large scale rural electrification programme being implemented in India (Box 2) uses the services of local entrepreneurs as franchisees to manage the local delivery of electricity in villages.

Capacity development: As proposed in the study, multiple stakeholders at different levels are involved in implementation of this universal energy access programme. There are stakeholders at the national, regional/state and local government levels, belonging to public sector organizations, financial institutions, Energy service companies (ESCOs), private sector, small-scale industries, NGOs and the households. The awareness and knowledge levels, educational qualifications, professional experiences and commitment levels are varied across the strata of individuals associated with these entities. Successful implementation of the programme to a large extent depends on empowerment of these individuals through effective capacity development programmes. The capacity development programmes could be in the form of information dissemination, awareness campaigns, sensitization programmes, training programmes and course programmes depending on the type of individuals.

9. Energy Outlook for the Industrial Sector

According to the forecast provided in the Energy Outlook for Asia and the Pacific by the Asian Development Bank (ADB, 2009b), the industrial sector in the region is expected to continue to have a dominant share in the final energy demand even in the future. As per the estimates, the industrial sector accounted for about 35% of the total final energy demand in 2006, which is expected remain same in 2015 and marginally reduce to 33% in 2030. In 2030, out of a total final energy demand of 4,635 MTOE, the industrial sector is expected to account for 1,526 MTOE. The energy related CO_2 emissions is forecast to grow from 10,749 million tonne to 17,763 million tonne and increase of 65%. With majority of the developing countries in the region striving hard to attain high economic growths and sustain them in the long run these increases are bound to happen. Such high economic growths are essential for these countries considering that still a large section of the population is poor. However, with the climate change threats looming large and need for urgent actions towards mitigating these threats, the developing countries of region cannot escape from the responsibilities. The global communities want their participation, mainly of the large developing countries like China, India and Indonesia. Thus, there are pressures internal as well as international to alter the path of development by adopting low-carbon pathways. The industrial sector too required to be part of such initiatives. According to the International Energy Agency's World Energy

Outlook 2010, the countries of the non-OECD Asia, consisting of all the developing countries of Asia excluding the Pacific region, required to make significant contributions to climate change mitigation (IEA, 2010a). As per the estimates, according to the reference energy scenario, which assumes the current policies to continue, the industrial sector energy demand is likely to be 1793 MTOE in 2030. However, the 450 ppm climate change stabilization scenario requires this demand to reduce to 1526 MTOE in 2030, a reduction of 267 MTOE. In fact, the reduction in the fossil fuel based energy carriers under 450 ppm scenario by 2030 is estimated at 288 MTOE and the difference of 21 MTOE is expected to be made up through increase in the contribution from biomass and waste energy. Coal with about 158 MTOE contributes mainly to the reduction of 288 MTOE by 2030. Other major contributors are electricity 95 MTOE and oil 20 MTOE. All these reductions are to be achieved mainly through implementation of energy efficiency measures across industries (IEA, 2010a). According to this report, energy efficiency is expected account for about 67% of the total energy related CO_2 emissions abated in 2020 in relation to current policies or reference scenario but its share declines to 45% by 2035. These indicate the significance energy efficiency in achieving the goals set for 450 ppm scenario.

The expectations are that the large reductions in energy consumptions and associated GHG emission reductions will result partly from a shift to low-carbon economic structure (IEA 2009). These are also linked to the expectation that as the industrial production increases sharply, these countries will take advantage of the much greater potential that exists to improve energy efficiency and reduce carbon intensity. To achieve these savings, however, large-scale deployment of efficient and best available energy technologies will be necessary (IEA 2009). According to this report, within the industrial sector, the iron and steel sector is expected to contribute the most in curbing the energy consumption accounting for about 40% of the reductions in industry emissions in the 450 scenario compared to the reference scenario. Most of the critical measures in the industrial sector are expected to be initiated in the region are in China and India (IEA 2010a):

- Rebalancing of the economy and efficiency improvements in iron, steel, cement and others in China with an abatement potential of 348 million tonne of CO_2 emission by 2020.
- Rebalancing of the economy, increasing use of CCS and efficiency improvements in China resulting in CO_2 emissions abatement of 2,237 million tonne by 2035.
- Efficiency improvements in iron, steel, cement and others due to international offset projects in India contributing to a CO_2 emissions reduction of 76 million tonne in 2020.
- Efficiency improvements in iron, steel, cement and others increasing use of CCS due to offset projects in India resulting in CO_2 emissions abatement of 421 million tonne by 2035.

Globally, the incremental investments required to achieve the objectives of 450 ppm scenario is estimated at US$ 18 trillion to be incurred over a period of 2010 to 2035.Out this, the industrial sector needs an investment of US$ 2 trillion during this period, which is relatively less compared its expected contribution to mitigation efforts (IEA 2010a). Some of the policy proposals for the industrial sector to achieve the 450 ppm scenario are –

- Cap-and-trade systems in the power and industry sectors.

- International sectoral agreements for the iron and steel, and the cement industries.
- The complete phase-out of fossil-fuel consumption subsidies.

10. Summary and Conclusion

Energy drives development, economic as well as human, with advanced technologies as means to achieve the ultimate goals. The deprivations in energy in terms of quantity as well as quality causes lack of development thereby poverty and human sufferings. Further, indiscriminate exploitation of the nature for energy resources and their use for economic growth has negative implications in the form of environmental degradation including climate change. Thus, energy inadequacy as well as abundance has consequences to the human development. By this, we understand that energy, poverty and climate change are closely interlinked and have implications for each other. This technical paper is an attempt at delving deeper into these aspects with a focus on the developing countries of the Asia and the Pacific region. Thus, as stated earlier, the overall objective of this technical paper is to develop an evidence-based research paper analyzing issues, challenges and solutions related to energy-poverty nexus and their linkages with climate change from the human development perspective, focusing on the developing countries of Asia-Pacific.

The technical paper begins with emphasizing the issue of securing energy needs of the poor and climate change mitigation emerging as conflicting challenges and significance of these challenges in the developing countries of the Asia-Pacific region in the global context. These challenges are extremely critical in the region because it has the highest energy deprivation among the poor at present and it is fast moving towards emerging as the biggest emitter of CO_2 in the future. Energy deprivations measured in terms of lack of access to electricity and modern fuels/technologies for cooking and heating are found to be critical in the region. In the total world rural population deprived with modern energy access, about 63% without access to modern fuels and 55% lacking electricity access live in the developing countries of the Asia-Pacific. The poor in the region mostly rely on solid fuels like wood, coal, cattle dung and agro-waste for most of their energy needs. Solid fuels accounts for about 63% of the total household energy consumption with significant contributions to both CO_2e as well as black carbon emissions. Further, the energy consumption patterns in the industrial sector of the region are analysed. The role played by the industrial sector is crucial in terms of contributing to economic growth and eradication of poverty, and thus the extent of industrial energy development determines its success. Coal and electricity are the dominant industrial energy carriers together accounting for about 71% of the total consumption. The region accounts for about 41% of the global energy related CO_2e emissions from the industrial sector. Further, the linkages between energy, poverty, sustainable development and climate change are analysed by developing different sets of indicators and the results suggested relatively strong association among these. A composite development index is developed integrating the indicators of economic, energy, environmental and human development and the selected developing countries of the region are compared against this index for empowerment and resilience. Malaysia emerged as the most empowered and resilient country followed by Bhutan in the second place. The lessons learnt is an important input for designing effective policies and towards this an assessment of policies targeting expansion of energy access and the associated good practices across the region is performed. Finally, the possibility of providing universal access to modern energy carriers for the households of the Asia-Pacific is explored by adopting a low-carbon pathway, the implications are analysed and an integrated implementation mechanism is proposed.

Overall, the technical paper covers issues related to energy for livelihood as well as productive needs by targeting the household and the industrial sectors of developing countries of the Asia-Pacific region. Expanding access to modern energy carriers to all in the region is the first step towards eradicating poverty and achieving human development. The analysis showed that it is possible to adopt a low-carbon pathway for universalizing access to modern energy carriers. The proposal entails a total incremental investment of US$ 113 billion over the next 20 years for providing electricity access to about 734 million people and access to modern fuels to about 2,779 million people. This is equal to a per capita investment of US$55 for providing access to electricity and US$ 26 for access to modern fuels. The GHG emissions due to universal energy access is minimal, a total incremental CO_2 emission of 101 million tonne per year in 2030. This is equal to a per capita annual emission of 35 $kgCO_2$ for electricity access and 27$kgCO_2$ for modern fuel access. This is negligible comparing with the current (2007) average per capita CO_2 emissions of 2.7 tonne in the Asia-Pacific region. Overall, it appears a win-win proposition for all the stakeholders.

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