ENVIRONMENTAL ISSUES, CLIMATE CHANGES, AND ENERGY SECURITY IN DEVELOPING ASIA

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NO. 399

June 2014

ADB ECONOMICS WORKING PAPER SERIES

ASIAN DEVELOPMENT BANK

ADB

ADB Economics Working Paper Series

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No. 399 | 2014

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ASIAN DEVELOPMENT BANK

Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org

June 2014
ISSN 1655-5252
Publication Stock No. WPS146535

Note: In this publication, "$" refers to US dollars.

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ABSTRACT

Four environmental dimensions of energy security—climate change, air pollution, water availability and quality, and land-use change—and the environmental impact of 13 energy systems on each are discussed in this paper. Climate change threatens more land, people, and economies in Asia and small Pacific island states than any other part of the planet. Air pollution takes a substantial toll on national health-care expenditures and economies in general. Of the 18 megacities worldwide with severe levels of total suspended particulate matter emissions, 10 are in Asia. Regarding water availability and quality, hydropower, nuclear power, and thermal power account for 10% to 15% of global water consumption, and the volume of water evaporated from reservoirs exceeds the combined freshwater needs of industry and domestic consumption. In the domain of climate change, rising sea levels could contaminate freshwater aquifers possibly reducing potable water supplies by 45%. Changes in land use for fuelwood collection and biofuel production in Southeast Asia have resulted in deforestation at 5 times the global average and 10 times the average for the rest of Asia. Policymakers must begin to incorporate the cost of these negative consequences into energy prices.

Keywords: environment, water policy, climate change, energy security, Asia-Pacific

JEL: Q40, Q43, Q51

I. INTRODUCTION

This study explores the intersection of environmental constraints, climate change, and energy security in Asia and the Pacific. Although environmental sustainability has only recently emerged as an energy policy issue, the magnitude of energy impacts on environmental systems suggests strong links to energy security. The unchecked growth in fossil energy consumption and the ensuing acceleration of global climate change as well as related air and water pollution act as "threat multipliers" impinging on national security globally. These environmental dimensions are just a subset of a larger array of environmental concerns that threaten energy security including land pollution, forestry, and biodiversity loss.[1] Table 1 summarizes the four environmental dimensions of energy security in Asia and the Pacific discussed in this chapter: climate change, air pollution, water availability and quality, and land-use change.

Table 1: Environmental Dimensions of Energy Security in Asia and the Pacific

Dimension	Link To Energy Security	Energy Contribution To The Problem
Climate Change	• Climate change is a "threat multiplier" in terms of energy security. • Mass migrations of refugees seeking asylum from ecological disasters could destabilize regions of the world threatening energy as well as national security.	A total of 66.5% of global carbon dioxide emissions come from energy supply and transport.
Air Pollution	• Deterioration of environmental conditions can negatively impact human and ecological health with significant numbers of premature deaths related to indoor and outdoor air pollution and significant expenditures lost in terms of lost productivity and healthcare.	About 80% of global sulfur dioxide emissions, 80% of particulate matter emissions, and 70% of nitrogen oxide emissions come from the energy and transport sectors.
Water Availability and Quality	• Lack of available safe drinking water can destabilize the security of a region. • Because fossil, hydro, and nuclear power plants consume large quantities of freshwater, shrinking supplies of water could threaten the ability to provide electricity and the ability of nations to feed themselves.	In all, 25% of global water supply is lost due to evaporation from reservoirs and another 10%–15% of global freshwater is used in thermoelectric power plants.
Land-Use Change	• Deforestation can cause social dislocation, increase the cost of fuelwood, destroy biodiversity, and conflict with agriculture and the preservation of nature reserves.	At least 15% of land-use change is caused by the direct clearing of forests for fuelwood and the expansion of plantations for energy crops.

Source: Modified from Brown and Dworkin (2011).

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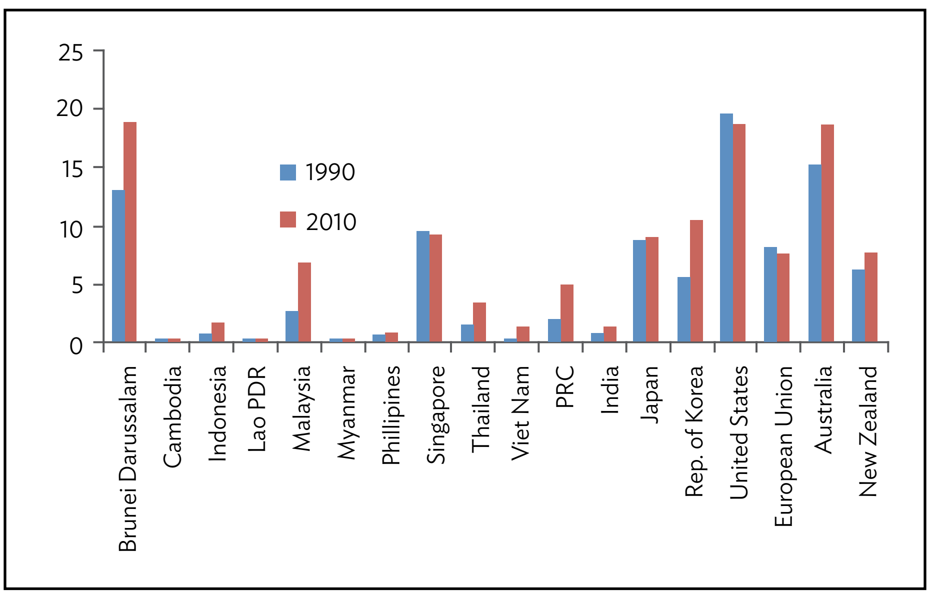
1 Brown and Dworkin 2011.

II. CLIMATE CHANGE

Climate change is a substantial energy security concern not only because direct flooding and natural disasters can damage power plants and transmission lines, disrupt the delivery of imported energy fuels, and destroy crops for biofuels but also because it has severe impacts on food security, health, and environmental refugees that can all lower the income base of Asian countries and add to government debt further complicating attempts at sound energy policy making. Though climate change is certainly a global phenomenon, in many ways it is becoming an Asian problem. Figure 1 shows annual tons of carbon dioxide (CO_2) emissions from fuel combustion divided by the total national population for selected Asian countries. It indicates that emissions more than doubled from 1990 to 2010 in the People's Republic of China (PRC), Indonesia, Malaysia, Thailand, and Viet Nam.

Figure 2 indicates that when changes in land use are included, four of the top 10 emitters of greenhouse gases (GHGs)—the PRC, Indonesia, India, and Japan—are in Asia. CO_2 emissions from the electricity supply sector in the PRC—mainly coal-fired power plants—make up almost half of the total emissions generated by the country .[2] In 1987, only 12% of emissions were due to industrial production, but that figure rose to 21% in 2002 and to 33% in 2005.[3] In Taipei,China emissions jumped from 160.5 million metric tons of CO_2 equivalent in 1990 to 271.6 million in 2000, an increase of 5.3%.[4] One international assessment of the carbon footprints in 12 major metropolitan areas throughout the world in 2010 found that only four cities were below the world average and that many major ones such as Seoul, Singapore, and Tokyo were already well above it.[5]

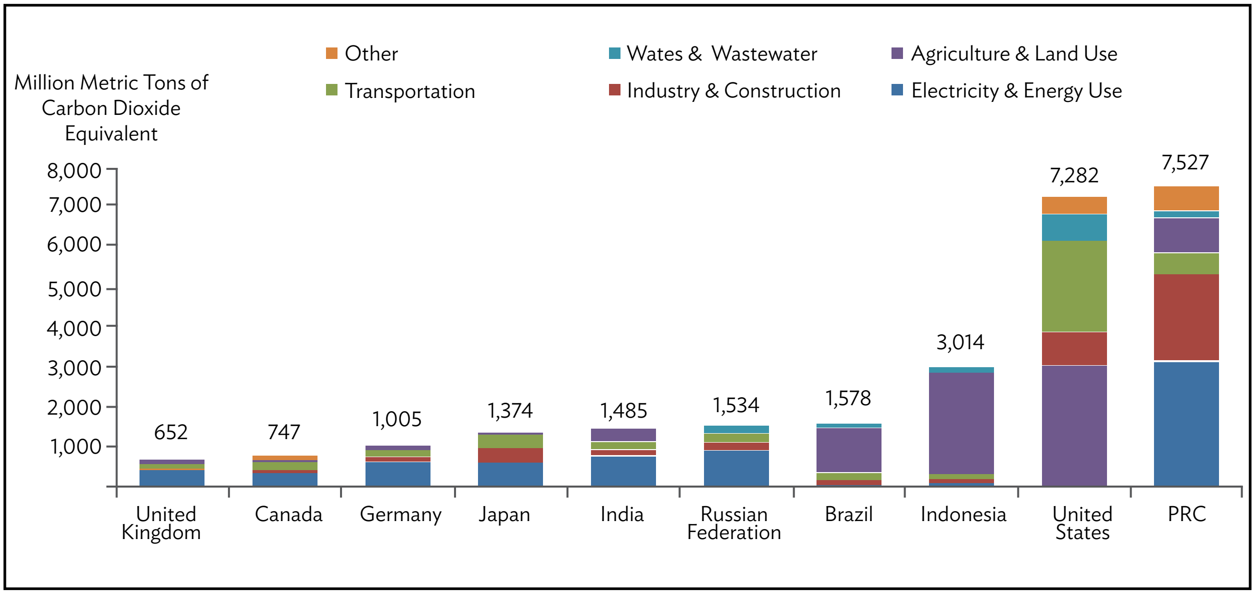
Figure 1: Per Capita Energy-Related Carbon Dioxide Emissions, 1990 and 2010 (metric tons)



Lao PDR=Lao People's Democratic Republic, PRC=People's Republic of China.
Source: Sovacool et al. 2011.

[2] Liu et al 2011.
[3] Weber et al 2008.
[4] Tsai and Chou 2005.
[5] Global carbon footprint of 1.19 computed by dividing global emissions (28.1 billion tons of carbon dioxide) by the world population (6.4 billion) and again by 3.67 to convert carbon dioxide to carbon. Footprints include direct and responsible emissions from transport, buildings and industry, agriculture (when applicable), and waste (when applicable). See Sovacool and Brown 2010.

Figure 2: Share of Greenhouse Gas Emissions in Top Ten Countries, 2010



PRC=People's Republic of China.
Source: Brown and Sovacool 2011.

Unfortunately from a climate standpoint, the GHGs already emitted will threaten Asia with a staggering list of negative consequences. Because of their unique geography and climatology, low per capita incomes, and changing patterns of urbanization, Indonesia, the Philippines, Thailand, and Viet Nam are expected to lose 6.7% of combined gross domestic product (GDP) by 2100 if temperatures change as the Intergovernmental Panel on Climate Change predicts, which is more than twice the rate of global average losses.[6] Even uniform changes in climate will not affect Asia equally as Cambodia, the Lao People's Democratic Republic (Lao PDR), the Mekong River Delta, the Philippines, central Thailand, and Sumatra and Java in Indonesia are more at risk than wealthier countries such as Brunei Darussalam or Singapore.[7]

The PRC and India, for instance, could exhaust between 1% and 12% of their annual GDPs coping with climate refugees, changing disease vectors, and failing crops.[8] One study forecasts a 37% reduction in national crop yields by 2050 in the PRC if current climate trends continue.[9] Some states in India such as Maharashtra are projected to suffer greater drought that will likely wipe out 30% of food production inducing $7 billion in damages among 15 million small and marginal farmers.[10] In India as a whole, farmers and fishers will have to migrate from coastal areas as sea levels rise and as they confront heat waves lowering crop output, and they will have to manage declining water tables from saltwater intrusion.[11]

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6 Asian Development Bank (ADB) 2009.
7 Yusuf and Francisco 2009, Government of Singapore 2008.
8 Economics of Climate Adaptation Working Group (ECA) 2009, Mackenzie and King 2009, and, Center for Naval Analyses (CAN) 2009.
9 McMichael 2007.
10 ECA 2009.
11 CNA 2009.

One wide-ranging survey of climate impacts in Asia and the Pacific from the United States Agency for International Development predicted the following, among other things:

- accelerated river bank erosion, saltwater intrusion, crop losses, and floods in Bangladesh that will displace at least 8 million people and destroy up to 5 million hectares of crops;
- more frequent and intense droughts in Sri Lanka crippling tea yields and reducing national foreign exchange and lowering incomes for low-wage workers;
- higher sea levels inundating half of the agricultural lands on the Mekong Delta causing food insecurity throughout Cambodia, the Lao PDR, and Viet Nam;
- increased ocean flooding and storm surges inundating 130,000 hectares of farmland in the Philippines affecting the livelihoods of 2 million people;
- intensified floods in Thailand placing more than 5 million people at risk and causing $39 billion to $1.1 trillion in economic damages by 2050.[12]

That study concluded that Asia and the Pacific will have more land threatened, more people damaged, and more economic damage from rising sea levels than any other part of the planet. Already, the region accounted for 85% of deaths and 38% of global economic losses due to natural disasters from 1980 to 2009.[13]

Although these vulnerabilities are great, perhaps the most severe climate change impacts will befall small developing island states. Small island countries in the Pacific are at the ever-present mercy of natural disasters, especially cyclones and storm-induced floods that can damage energy infrastructure and reduce national incomes. Since the 1950s, the quantity and magnitude of natural disasters throughout the Pacific have increased significantly, and many countries lie in the path of Pacific cyclones. Table 2 also illustrates that a selection of Pacific island countries has had no fewer than 257 disasters from 1950 to 2008 that have caused $6.8 billion in damages.[14] In the Solomon Islands, the Ministry of Environment, Conservation and Meteorology has warned that "energy production, utilization, conversion, and transportation" have been and will continue to be negatively affected by "droughts, floods, fires, storm surges, and cyclones."[15] In Samoa, the earthquake and tsunami in September 2009 greatly damaged the Electric Power Corporation (EPC) generation and distribution assets in the southern and eastern coastal areas of Upolu, Manono, and Savii. Damages included toppled power poles and fittings, cracked transformers, and destroyed hydroelectric dams.[16] With assets of only $163 million and a net operating profit of $2.1 million per year, the EPC has little revenue to draw from to address these types of damages. In Fiji, unexpected shortfalls in water have forced the country's hydroelectric dams to operate below full capacity increasing reliance on diesel imports and precipitating increases in electricity tariffs.[17]

[12] United States Agency for International Development (USAID) 2010.
[13] United Nations Economic and Social Commission for Asia and the Pacific 2012.
[14] See ADB 2005, World Bank 2009.
[15] Government of the Solomon Islands 2008.
[16] Government of Samoa, Electric Power Corporation 2011.
[17] Government of Fiji, Fiji Electricity Authority 2011.

Table 2: Estimated Economic and Social Impact of Disasters in Selected Pacific Island Economies, 1950–2008

	Disasters	*Loses ($ 2008)*	*Average Population Affected (%)*		*Average Impact on Gross Domestic Product (%)*	
Country			***Disaster Years***	***All Years***	***Disaster Years***	***All Years***
American Samoa	6	237,214,770	5.81	0.61	7.76	0.82
Cook Islands	9	47,169,811	5.13	0.63	3.48	0.43
Fiji	43	1,276,747,934	5.39	2.74	3.48	0.78
French Polynesia	6	78,723,404	0.53	0.04	0.31	0.02
Guam (United States)	10	3,294,869,936	1.97	0.28	10.13	1.42
Kiribati	4	0	29.19	1.54	0.00	0.00
Marshall Islands	3	0	6.40	0.22	0.00	0.00
New Caledonia	15	69,623,803	0.14	0.03	0.09	0.02
Micronesia, Federated States of	8	11,915,993	6.20	0.65	0.82	0.09
Niue	6	56,461,688	73.15	7.70	80.88	8.51
Papua New Guinea	58	271,050,690	0.69	0.36	0.14	0.07
Samoa	11	930,837,187	21.15	3.71	16.97	2.98
Solomon Islands	21	39,215,686	2.93	0.98	0.52	0.17
Tokelau	4	4,877,822	39.70	2.79		
Tonga	12	129,344,561	21.32	3.37	5.76	0.91
Tuvalu	5	0	3.19	0.28	0.00	0.00
Vanuatu	36	406,402,255	5.33	2.06	3.78	1.46

Source: World Bank 2009.

III. AIR POLLUTION

Air pollution is an energy security concern in at least two respects: outdoor air pollution degrades human health and increases hospital admissions, and indoor air pollution from using traditional and stoves for cooking and heating causes premature deaths in women and children. Outdoor air pollution is significantly caused by energy production and use as about 80% of sulfur dioxide emissions, 80% of particulate matter emissions, and 70% of nitrogen oxide emissions come from the energy and transport sectors.[18]

The International Energy Agency (IEA) notes that air quality has become a serious problem for hundreds of Asian cities and towns. Bangkok, Ho Chi Minh City, Jakarta, Kuala Lumpur, and Manila suffer from air pollution due to increased vehicle use, rapid rates of industrialization and urbanization, a reliance on coal, and industries operating in close proximity to residential areas.[19] The World Health Organization (WHO) estimates that 517,700 people in Asia die annually because of outdoor air pollution, 275,600 in the PRC alone. Of the 18 megacities worldwide with severe levels of total suspended particulate matter emissions, 10 are in Asia and 5 are in South Asia (Karachi, Osaka–Kobe, Dhaka, Beijing, Jakarta, Delhi, Shanghai, Kolkata, Mumbai, and Tokyo).[20]

18 World Resources Institute Earth Trends Database accessed January 2012.
19 Olz and Beerepoot 2010.
20 World Health Organization 2007.

Air pollution takes a substantial toll on national health-care expenditures and GDP. In the Philippines, particulate matter pollution has been estimated to cause $432 million in annual damages worth 0.6% of national GDP.[21] In Thailand, particulate matter pollution causes at least $825 million in damages worth 1.6% of GDP.[22] In the context of electricity prices, the cost of air pollution adds as much as $0.0417 per kilowatt to every unit of Thai electricity.[23] In the PRC, particulate matter pollution causes from $63 to $272 billion in damages or as much as 3.3% to 7.0% of national GDP.[24] These numbers will undoubtedly rise with the growth in demand for automobiles in the PRC. In India, "It is now understood that rural outdoor air pollution is a significant problem with average levels of pollution in the Ganga River Basin, for example, being substantially above Indian and WHO health-based norms."[25] In Cambodia, the rapid increases in vehicle operation have led to ambient concentrations of particulate matter that are "very high" with "likely severe impacts on the health of residents."[26]

Transportation is not the only cause of outdoor air pollution; burning coal for electricity and industrial uses contributes as well. The best example is the PRC. Coal is the most abundant and widely used fuel; the PRC already uses more of it than the European Union, Japan, and the United States (US) combined.[27] Coal meets more than 70% of the country's energy needs. The PRC is currently the world's biggest producer and consumer of coal producing 3.8 billion tons in 2011 (compared to 1.1 billion tons in the US) amounting to about half the world total.[28] Coal combustion provided 65% of the country's electricity in 1985 but that figure rose to more than 80% in 2006. From 2002 to 2007, demand for electricity grew by about 12%, and more than 70,000 megawatts (MW) of capacity were brought online to meet it,[29] a majority of which was coal fired. The PRC currently is constructing the equivalent of two 500 MW coal-fired plants per week—a capacity comparable to the entire power grid in the United Kingdom (UK) every year. More than half of the coal production is used in the non-electricity sector. It provides 60% of chemical feedstock and 55% of industrial fuel. Nearly 45% of the national railway capacity is devoted exclusively to the transport of coal.

IV. WATER QUALITY AND AVAILABILITY

The United Nations (UN) reports that overall, agriculture is the largest user of freshwater but that the energy sector comes second with hydropower, nuclear power, and thermal power generation accounting for about 10% to 15% of global water consumption.[30] In addition, the UN estimates that the volume of water evaporated from reservoirs exceeds the combined freshwater needs of industry and domestic consumption which represent about 25% of global water use. As the UN concluded, hydroelectric dams therefore "greatly contribute to water losses around the world, especially in hot, tropical regions."[31]

The energy sector consumes and contaminates water sources imposing costs on all water users from households and commercial enterprises to farmers and recreational users as well as on fish and marine mammals. Thermoelectric power plants—those relying on coal, oil, natural gas, biomass/waste, or uranium in nuclear reactors—take water from rivers, lakes, and streams to cool equipment before

[21] World Bank 2002a.
[22] World Bank 2002b.
[23] Sakulniyomporn, Kubaha, and Chullabodhi 2011.
[24] Deng 2006, McMichael 2007.
[25] Venkataraman et al 2010.
[26] ADB 2006.
[27] Sovacool and Khuong 2011; Government of the United States, Energy Information Administration 2010.
[28] Biswas and Kirchherr 2012.
[29] Khuong and Sovacool 2010.
[30] United Nations Environment Programme (UNEP) 2008.
[31] UNEP 2008.

returning it to its source, and they consume it through evaporative loss. As Table 3 shows, the average power plant uses about 25 gallons (95 liters) of water for every kilowatt-hour generated.[32] This means that the power consumed in 1 day in the average US home requires 775 gallons of water. Given that the world consumed about 17,000 terawatt-hours of electricity in 2007, power plants ostensibly used 425 trillion gallons (1.61 quadrillion liters) of water that year. The water use of individual power plants is even more striking. A conventional 500 MW coal plant, for instance, consumes about 7,000 gallons (26,498 liters) of water per minute or the equivalent of 17 Olympic-sized swimming pools every day.[33]

Table 3: Water Use (Consumption and Withdrawals) for Selected Power Plants (gallons per kilowatt-hour)

	Withdrawals	Consumption	Withdrawals	Consumption	Total
	(Combustion/Downstream)		(Production/Upstream)		
Nuclear	43	0.4	0	0.11	43.5
Coal (mining)	35	0.3	0.17	0.045	35.5
Coal (slurry)	35	0.3	0	0.05	35.3
Biomass/Waste	35	0.3	0.03	0.03	35.3
Natural gas	13.75	0.1	0	0.01	13.9
Solar thermal	4.5	4.6	0	0	9.1
Hydroelectric	0	0	0	4.5	4.5
Geothermal (steam)	2	1.4	0	0	3.4
Solar photovoltaic	0	0	0	0.3	0.3
Wind	0	0	0	0.2	0.2
Energy efficiency	0	0	0	0	0

Source: Sovacool and Sovacool 2009b.

Deficiencies in water supply and water quality already cause about 4,500 deaths throughout the world every day or 1.7 million deaths a year, 90% of which are to young children. More than 1 billion people lack access to clean water, and 2.6 billion do not have access to improved sanitation facilities.[34] Some rivers, aquifers, lakes, and other water sources are so polluted that it is more profitable for residents to remove plastic bottles and trash from them for recycling than it is to fish. The US Central Intelligence Agency believes that more than 3 billion people will be living in water-stressed regions around the world by 2015 (with a majority concentrated in North Africa and the PRC). Water tables for major grain producing areas in northern PRC are dropping at a rate of 5 feet per year, and per capita water availability in India is expected to drop by 50% to 75% over the next decade.[35]

Complicating this picture is climate change which is slowly but steadily altering precipitation and water patterns. For instance, if global warming induces the rise in sea levels that many climatologists and scientists expect, the intrusion of salt water could contaminate freshwater aquifers possibly reducing potable water supplies by 45%.[36] Warmer temperatures resulting from global climate change will also increase energy demands in urban areas and require more intensive air-conditioning loads in turn raising the water needs for power plants. Hotter weather also increases the evaporation rates for lakes, rivers,

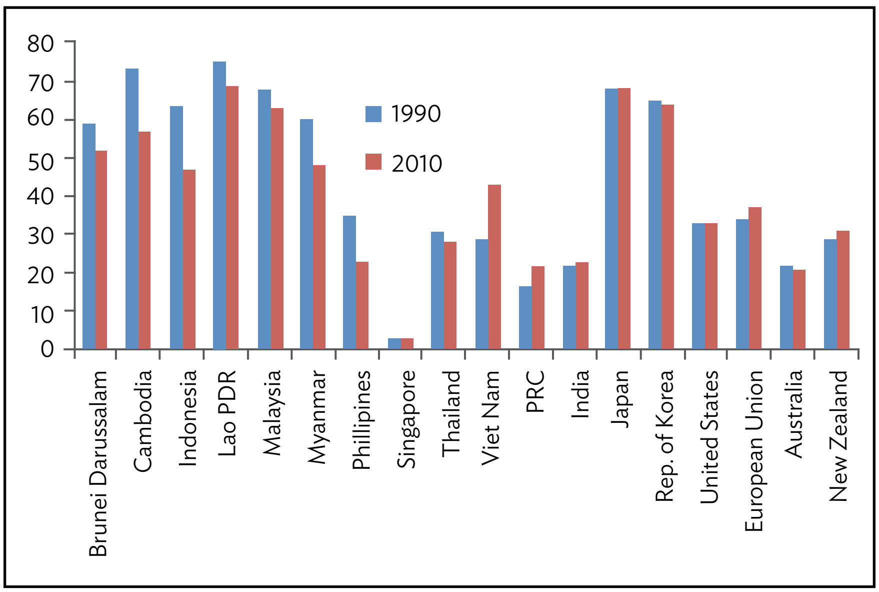
[32] Sovacool and Sovacool 2009a.
[33] Sovacool and Sovacool 2009b.
[34] Schaefer 2008.
[35] Pope and Lomborg 2005.
[36] Smith and Ibakari 2007.

and streams and thus accelerates the depletion of reservoirs and causes more intense and longer-lasting droughts as well as more wildfires that in turn need vast quantities of water to control.[37]

V. LAND-USE CHANGE

As with climate change, air pollution, and water, the link between energy security and land-use change is complex. Energy production can affect land in many ways from converting forests into plantations for energy crops to access roads for dams and oil and gas facilities that open up areas to deforestation. One incredibly conservative estimate suggests that 15% of land-use changes are caused by clearing forests for fuelwood and for energy crop plantations.[38] Figure 3 shows that most Asian countries saw a decline in their forest areas from 1990 to 2010 with significant decreases in Cambodia, Indonesia, Myanmar, and the Philippines.[39]

Figure 3: Forest Area as a Percent of Land Area in Selected Countries, 1990 and 2010 (%)



Lao PDR=Lao People's Democratic Republic, PRC = People's Republic of China.
Source: Sovacool et al. 2011.

Forests can be a sink for GHG emissions but also a source depending on how they are managed. It is helpful to view forests through the lens of stocks and flows. The total stock of carbon in all tropical forests equals about 300 billion tons; through deforestation, about 1.5 billion tons are converted into 6 billion tons of CO2 that is emitted into the atmosphere.[40] In other words, tropical forests alone contribute about 20% of overall anthropogenic CO2 emissions per year[41] making them the largest emitter of carbon in the world after the energy sector. This amount is equivalent to the total emissions of the PRC or the US, and it is more than the emissions produced by every car, truck, plane, ship, and train on earth.

37 Sovacool and Sovacool 2009a.
38 Dale, Efroymson, and Kline 2011.
39 Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.
40 Boucher 2009.
41 Houghton 2003.

Forestry is thus unique in its ability to fight climate change, but its benefits are reversible. A ton of carbon sequestered in a forest is not permanent and is a benefit to the atmosphere only if it remains stored. If a tree is felled or a forest is cleared, carbon is released and the temporary benefit reversed. Partly because of this aspect of forestry, tropical deforestation was excluded from the Kyoto Protocol as an eligible project class. Acknowledging that forests are decreasing at an alarming rate, the Copenhagen Accord produced (but not adopted) at the Fifteenth Conference of the Parties to the UN Framework Convention on Climate Change meeting in 2009 does, "...recognize the crucial role of reducing emissions from deforestation and forest degradation."[42] Yet the rate of deforestation worldwide averaged 13 million hectares a year between 1990 and 2005 (out of a total forest coverage of about 4 billion hectares).[43] Indonesia and Brazil accounted for about half the emissions from deforestation which also explains why they are (respectively) the third and fourth largest emitters of GHGs overall behind the PRC and the US. Table 4 shows that just nine countries, four of them in Asia, accounted for more than 80% of all GHG emissions from deforestation.[44]

Table 4: Global Leaders in Carbon Dioxide Equivalent Emissions from Deforestation

Country	Share of Emissions from Deforestation (%)
Indonesia	33.7
Brazil	18.0
Malaysia	9.2
Myanmar	5.6
Congo, Democratic Republic of the	4.2
Zambia	3.1
Nigeria	2.6
Peru	2.5
Papua New Guinea	1.9
Total	80.8

Source: Boucher 2008.

At least two main energy sources contribute to deforestation: fuelwood collection and energy plantations for biofuels. Indonesia, Malaysia, and Thailand are the largest producers of palm oil in the world. The land-use changes taking place there involve converting peat lands, some of the richest carbon sinks in the world, to palm oil plantations. Some scholars and global institutions concerned with bioenergy recognize the environmental dilemmas that the large-scale production of palm oil can present by encroaching on protected areas, affecting water systems, displacing food production, and harboring unsustainable land-use practices that cannot only cancel GHG emissions for decades but can also lead to widespread ecological despoliation.[45]

As a result of the twin pressures of fuelwood collection and biofuel production, in Southeast Asia as a whole deforestation have been 5 times the global average and 10 times the average for the rest of Asia.[46] Indonesia alone is being deforested at a rate of 1.4 million hectares (3.5 million acres) a year with only 53

42 United Nations Framework on Climate Change 2009.
43 Food and Agricultural Organization 2006.
44 Boucher 2008.
45 Keam and McCormick 2008, World Bank 2008a and 2008b, Markevicius et al 2010, Havlik et al. 2011, Comte et al. 2012.
46 ASEAN Secretariat 2000.

million hectares (131 million acres) of total forest area left.[47] Deforestation has helped promote the forest fires and peat land degradation that have made the country such a large emitter of GHGs.[48] Roughly 98% of the forest cover on Borneo and Sumatra will be "severely degraded" by 2012 and "completely gone" by 2022.[49] Illegal logging is difficult to control: 75% of timber is extracted illegally and illegal harvesting has been documented in 37 out of Indonesia's 41 national parks. [50] Milling capacity exceeds legal limits by as much as a factor of five.

VI. ENVIRONMENTAL IMPACT OF ENERGY TECHNOLOGY OPTIONS

Though admittedly qualitative, this section briefly assesses the environmental impacts of 13 energy systems on climate change, air pollution, water availability and quality, and land-use change. Table 5 summarizes them.

Table 5: Impacts of Energy Systems on Climate Change, Air Pollution, Water Availability and Quality, and Land-Use Change

Energy System	Climate Change	Air Pollution	Water	Land Use
Energy efficiency	Minimal	Minimal	Minimal	Minimal
Nuclear power	Moderate	Minimal	Severe	Severe
Shale gas	Severe	Severe	Severe	Severe
Conventional coal	Severe	Severe	Severe	Severe
Clean coal	Moderate	Severe	Severe	Severe
Oil and gas	Severe	Severe	Severe	Severe
Hydroelectricity	Minimal	Minimal	Severe	Moderate
Wind energy	Minimal	Minimal	Minimal	Moderate
Solar photovoltaics	Minimal	Minimal	Minimal	Moderate
Solar thermal	Minimal	Minimal	Moderate	Moderate
Geothermal	Minimal	Minimal	Moderate	Moderate
Biomass	Minimal	Moderate	Moderate	Moderate
Biofuels	Minimal	Moderate	Severe	Severe

Source: Author.

A. Energy Efficiency

Energy efficiency and demand-side management—doing more with less, reducing energy consumption by substituting fuels and technologies and altering consumer behavior—is clearly the most environmentally benign way to address increases in demand for energy services. Energy efficiency can include practices as diverse as switching from conventional coal power plants to combined heat and power units, lowering thermostats, better maintaining industrial boilers, and walking or cycling instead of driving. These actions not only involve very little damage to the environment, they can be cost effective as well as long as they are strategically implemented to avoid the rebound effect. On a global scale, the IEA reviewed large-scale energy efficiency programs and found that they saved electricity at an average cost of $0.032 per kilowatt-hour, well below the cost of supplying electricity from any source.[51]

[47] Indonesian Working Group on Underlying Causes of Deforestation and Forest Degradation 1999.
[48] Speth 2008.
[49] Nelleman et al. 2007.
[50] United Nations Environment Program. 2007.
[51] Geller and Attali 2005.

B. Nuclear Power

Nuclear power has minimal air pollution impacts as it is a combustion-free source of energy, but it does have moderate impacts on climate change and severe impacts for water and land use. In terms of climate change, reprocessing and enriching uranium requires a substantial amount of electricity that is often generated from fossil fuel–fired power plants. Uranium milling, mining, and leaching; plant construction; and decommissioning all produce substantial amounts of GHGs. An assessment of 103 life-cycle studies of GHG-equivalent emissions for nuclear power plants found that the average CO2 emissions over the typical lifetime of a plant in 2005 were about 66 grams for every kilowatt-hour or the equivalent of some 183 million metric tons of CO2.[52] A second, follow-up, peer-reviewed study found that the best performing reactors had associated life-cycle emissions of 8 to 58 grams of CO2 per kilowatt-hour but that other reactors emitted more than 110 grams.[53]

In terms of land use, nuclear power's most significant impacts arise from uranium mining and the storage of nuclear waste. Uranium is mined in three different ways—underground, open pit, and in-situ leaching—but uranium mining is very wasteful, regardless of the technique. To produce the 25 tons of uranium needed to operate a typical rector for a year, 500,000 tons of waste rock and 100,000 tons of mill tailings toxic for hundreds of thousands of years will be created along with an extra 144 tons of solid waste and 1,343 cubic meters of liquid waste.[54]

In terms of water, the nuclear industry has serious consequences both for human consumption and for the environment. Apart from the water-related impacts of uranium mining, three other stages of the nuclear fuel cycle—plant construction, plant operation, and nuclear waste storage—consume, withdraw, and contaminate water supplies. Moreover, a team of Indian scientists studying heated water discharges from the Madras Atomic Power Station noted that substantial additions of sodium hypochlorite to seawater decreased viable counts of bacteria and plankton by 50% around the reactor site.[55] A team of Korean marine biologists and scientists studied satellite thermal infrared images of the Younggwang Nuclear Power Plant and found that the thermal pollution plume extended more than 100 kilometers southward.[56] The researchers documented that the power plant directly decreased the dissolved oxygen content of the water, fragmented ecosystem habitats, reduced fish populations, and induced eutrophication.

C. Shale Gas

Shale gas refers to natural gas extracted from gas shales, i.e., porous rocks that hold gas in pockets. Shale gas is captured by hydraulic fracturing or fracking, a process that shatters rocks by injecting water to release the gas. Shale gas has severe climate change, air, water, and land-use impacts.

New evidence has surfaced that the life cycle of shale gas is more carbon intensive than previously thought.[57] Prior estimates of the carbon footprint of shale gas did not account for losses in processing and distribution, but the US Environmental Protection Agency took a nonpartisan look at the life cycle of natural gas and its carbon equivalent emissions and doubled its previous estimate when it accounted for methane leaks from loose pipe fittings and methane vented from gas wells. When included, these losses make gas as little as 25% cleaner than coal from a carbon standpoint. Billions of cubic feet of natural gas are lost in the US each year—equivalent to the emissions from 35 million automobiles—seeping from loose pipe valves or venting from production facilities.[58]

52 Sovacool 2008.
53 Beerten et al. 2009.
54 Sovacool 2011.
55 Saravanan et al. 2008.
56 Ahn et al. 2006.
57 Jaramillo, Grifin, and Matthews 2007.
58 Government of the United States, Environmental Protection Agency 2010.

Furthermore, Nature cautions that 0.6% to 3.2% of the methane captured during hydrofracking can escape directly into the airshed.[59] Other studies have noted that 3.6% to 7.9% of methane from shale gas production escapes into the atmosphere in venting and leaks which make methane emissions from shale gas between 30% and 100% greater than conventional natural gas.[60] These studies have noted, for example, that fugitive methane emissions are vented during the completion of wells, especially during the drill-out stage of new reserves. Venting and equipment leaks of methane are common, too, as the typical well has 55 to 150 different connections to equipment including heaters, meters, dehydrators, and compressors as well as vapor recovery systems that all can fail and leak. Processing to remove hydrocarbons and impurities such as sulfur is energy and carbon intensive, and shale gas needs more extensive processing to make it ready for existing pipelines. Shale gas is also prone to all of the environmental impacts of ordinary oil and natural gas production.

D. Conventional Coal

The extraction of coal poses serious problems for communities and ecosystems near mining sites. Coal mining can remove mountaintops by clearing forests and topsoil before using explosives to break up rocks, pushing mine spoils into adjacent streams and valleys. This can cause acid drainage into river systems, destroy ecosystems, blight landscapes, and diminish water quality.[61] One global assessment of the coal mining industry noted that common, "direct" impacts include

> ... fugitive dust from coal handling plants and fly ash storage areas; pollution of local water streams, rivers, and groundwater from effluent discharges and percolation of hazardous materials from the stored fly ash; degradation of land used for storing fly ash; and noise pollution during operation [in addition to] impacts on the health, safety, and well-being of coal miners; accidents and fatalities resulting from coal transportation; significant disruption to human life, especially in the absence of well-functioning resettlement policies; and impacts on the environment such as degradation and destruction of land, water, forests, habitats, and ecosystems.[62]

Another recent survey of global mining practices concluded that "a serious history of mining accidents" exists due largely to "widespread neglect of environmental safety and human security issues" and "sub-standard management activities"; it also noted an increase in trans-boundary pollution associated with mining and mineral prospecting and that more mines are opening in states with weak regulatory and governance regimes.[63] A similar Word Bank study of mining practices noted that they "often have substantial environmental impacts" and have negative impacts on food security and the collection of clean water and on the health and time burdens of women.[64]

E. Clean Coal

Clean coal has moderate climate impacts but like conventional coal, severe impacts on air, water, and land use. In terms of climate change, power plants with carbon capture and storage (CCS) can sequester much of their affiliated carbon underground; however, they can also "...increase [GHG] emissions and air pollutants per unit of net delivered power and will increase all ecological, land-use, air-pollution, and

[59] Lovett 2011.
[60] Howarth, Santoro, and Ingraffea 2011.
[61] Bernhardt and Palmer 2001, Palmer et al 2010.
[62] Chikkatur, Chaudhary, and Sagar 2011.
[63] United Nations Environment Programme, United Nations Development Programme, Organisation for Security and Co-Operation, and North AtlanticTreaty Organization 2005
[64] Eftimie, Heller, and Strongman 2009.

water-pollution impacts from coal mining, transport, and processing, because the CCS system requires 25% more energy, thus 25% more coal combustion, than does a system without CCS."[65] Globally, coal mining activities have taken their toll on local environments and communities. Exploration involves drilling, clearing vegetation, trench blasting, and geophysical surveying that can result in habitat loss, sedimentation, and deforestation due to road development. Site preparation has been shown to fragment ecosystems, increase demand for water resources, change predation rates, and accelerate the chemical contamination of land. Mining operations require supporting infrastructure such as roads, electricity, processing facilities, and ports. Once closed, abandoned mines pose dangers in the form of physical injury, persistent contaminants in surface and groundwater, and acid drainage affecting hundreds of thousands of streams.[66] Again, CCS requires more coal to produce each unit of electricity exacerbating all of these downstream impacts.[67]

F. Oil and Natural Gas

Many stages of the oil and gas fuel chain—exploration, onshore and offshore drilling, refining—pose serious environmental risks. Exploration necessitates heavy equipment and can be quite invasive as it involves "discovering" oil and gas deposits in sedimentary rock through various seismic techniques such as controlled underground explosions, special air guns, and exploratory drilling.[68] The construction of access roads, drilling platforms, and their associated infrastructure frequently has environmental impacts beyond the immediate effects of clearing land as they open up remote regions to loggers and wildlife poachers. About 465 to 2,428 hectares of land (1,000 to 6,000 acres) are deforested for every 1 kilometer of new oil and gas roads built through forested areas around the world.[69]

The production and extraction of oil and gas—which are themselves toxic as both contain significant quantities of hydrogen sulfide which is potentially fatal and extremely corrosive to equipment such as drills and pipelines—is even more hazardous. Drilling for oil and gas involves bringing large quantities of rock fragments, called "cuttings," to the surface. These cuttings are coated with drilling fluids called "drilling muds" that operators use to lubricate drill bits and stabilize pressure in oil and gas wells. The quantity of toxic cuttings and mud released for each facility is gargantuan ranging between 60,000 and 300,000 gallons per day. In addition to cuttings and drilling muds, vast quantities of water contaminated with suspended and dissolved solids are also brought to the surface creating what geologists refer to as "produced water."[70] Produced water contains lead, zinc, mercury, benzene, and toluene making it highly toxic often requiring operators to treat it with chemicals that increase its salinity and make it fatal to many types of plants before releasing it into the environment. The ratio of waste to extracted oil is staggering: Every gallon of oil brought to the surface yields 8 gallons of contaminated water, cuttings, and drilling muds.[71]

The next stage, refining, involves boiling, vaporizing, and treating extracted crude oil and gas with solvents to improve their quality. The average refinery processes 3.8 million gallons of oil per day, and about 11,000 gallons of its product (0.3% of production) escapes directly into the local environment where it can contaminate land and pollute water.[72]

65 Government of the United Kingdom 2010.
66 Miranda et al 2003.
67 Boute 2008.
68 Waskow and Welch 2005.
69 Waskow and Welch 2005.
70 Waskow and Welch 2005.
71 Waskow and Welch 2005.
72 Waskow and Welch 2005.

Natural gas also has some environmental impacts unique to its fuel cycle. When not separated from oil deposits, it is often burned off at the well site, flared (combusted into CO_2 and water vapor), or vented directly to the atmosphere. In all, 5% of world natural gas production—150 billion cubic meters of natural gas, more than 2 billion tons of CO_2 equivalent—is lost to flaring and venting each year making the gas industry responsible for roughly 10% of annual global methane emissions.[73] Methane is a GHG 21 to 23 times more potent than CO_2 on a 100-year timeframe, and its half-life is only 12 years meaning its instantaneous impact is much larger on the climate system. Methane is already the second largest contributor to anthropogenic GHG emissions after CO_2 accounting for 16% of the total on a CO_2-equivalent basis.[74] Researchers at the International Association of Oil and Gas Producers and the Society of Petroleum Engineers have calculated that the global average emission ratio for gas production is about 130 to 140 tons of CO_2 equivalent for every 1,000 tons of production which is more than any other electricity fuel except oil and coal.[75]

G. Hydroelectricity

Hydroelectricity poses severe water impacts but only moderate land-use impacts and minimal climate change and air pollution impacts. For hydroelectric dams, the most extensively debated and complex environmental problems relate to habitat and ecosystem destruction, emissions from reservoirs, water quality, and sedimentation.[76] All these concerns arise because a dam is a physical barrier interrupting water flows for lakes, rivers, and streams. Consequently, dams can drastically disrupt the movement of species and change upstream and downstream habitats. They also result in modified habitats with environments more conducive to invasive plant, fish, snail, insect, and animal species all of which may overwhelm local ecosystems. To maintain an adequate supply of energy resources in reserve, most dams impound water in extensive reservoirs; however, these reservoirs can also emit GHGs from rotting vegetation.[77]

All forms of hydroelectric generation combust no fuel so they produce little to no air pollution in comparison with fossil fuel plants. One life-cycle assessment of hydroelectric facilities focused on the activities related to building dams, dikes, and power stations; decaying biomass from flooded land (where plant decomposition produces methane and CO_2); and the thermal backup power needed when seasonal changes cause hydroelectric plants to run at partial capacity. It found that typical emissions of GHGs for hydropower were still 30 to 60 times less than those from fossil-fueled stations of the same size.[78]

H. Wind Energy

Wind energy has moderate land-use impacts and minimal environmental impacts across the other three dimensions. Perhaps the most visible land-use concern associated with wind energy relates to the death of birds that collide with wind turbine blades which is termed “avian mortality.” Onshore and offshore wind turbines present direct and indirect hazards to birds and to other avian species. Birds can smash into a turbine blade when they are fixated on perching or hunting and pass through its rotor plane; they can strike its support structure; they can hit part of its tower; or they can collide with its associated transmission lines. These risks are exacerbated when turbines are placed on ridges and upwind slopes; close to migration routes; and in fog, rain storms, and at night. Indirectly, wind farms can physically alter

[73] Kirchgessner et al 1997, Robison 2006.
[74] International Petroleum Industry Environmental Conservation Association 2006.
[75] Campbell and Bennett 2006.
[76] World Commission on Dams 2000.
[77] Gagnon and van de Vate 1997.
[78] Gagnon and van de Vate 1997.

natural habitats, the quantity and quality of prey, and the availability of nesting sites.[79] Moreover, large, effective wind farms are sometimes highly land intensive. Large-scale utility wind turbines usually require 1 acre of land per turbine.[80] When these big machines are built in densely forested areas or ecosystems rich in flora and fauna, they can fragment large tracts of habitat.

I. Solar Photovoltaics

This form of solar energy has moderate land-use impacts and minimal environmental impacts across the other three areas. The land-use impacts center on the use of hazardous materials such as silicon which must be mined and can contaminate land when systems break down or are destroyed during hurricanes and tornados.[81] Chemical pollution has also occurred manufacturing solar cells and modules, and when not integrated into buildings, solar power plants need comparatively larger amounts of land than conventional energy sources.[82]

J. Solar Thermal

Solar thermal, or concentrated solar power, has many of the same climate and air benefits of solar photovoltaic systems. However, thermal and concentrated systems consume much more water and withdraw similar amounts as a natural gas–combined cycle power plant and also require amounts of land similar to solar photovoltaic power plants.

K. Geothermal

Geothermal facilities have moderate water impacts but minimal environmental impacts in the other areas. Geothermal plants can emit small amounts of hydrogen sulfide and CO_2 along with toxic sludge containing sulfur, silica compounds, arsenic, and mercury (depending on the type of plant), though these can be controlled with pollution control equipment.[83] More significantly, geothermal systems require water during drilling and fracturing and are ill-suited for deserts or arid regions.[84] Extra land may also be required to dispose of waste salts from geothermal brines, and contamination of groundwater and freshwater can occur if plants are poorly designed.[85]

L. Biomass

Biomass energy has minimal climate change impacts but moderate environmental impacts on air pollution, water, and land use. While biomass combustion has the advantage of not releasing any net CO2 into the atmosphere (and thus contributes little to the global inventory of GHGs), it releases measurable levels of a wide variety of pollutants into air, land, and water.[86] The air pollution issues parallel aesthetic concerns about land use, smell, and traffic congestion. The combustion of biomass has been noted to release foul odors near some plants, and biomass fuel can contribute to traffic congestion when large amounts must be delivered by trucks.87 When harvested improperly, generating electricity with agricultural wastes, forest residues, and energy crops such as sugar, legumes, and vineyard grain can strip local ecosystems of needed nutrients and minerals.

[79] Sovacool 2009; Fielding, Whitfield, and McLeod 2006; Barclay, Baerwald, and Gruver 2007; Kunz et al 2007a and 2007b.
[80] Government of the United States, Department of Energy 2004.
[81] Fthenakis and Alsema 2006; Fthenakis and Kim 2007; Fthenakis, Kim, and Alsema 2008.
[82] Fthenakis 2001.
[83] Berinstein 2001.
[84] Green and Nix 2006.
[85] Duffield and Sass 2003.
[86] Pimentel et al 1994.
[87] Karmis et al 2005.

M. Biofuels

Biofuels raise severe climate, water, and land concerns but only moderately contribute to air pollution. As noted previously, the widespread use of biofuel crops can contribute to habitat destruction and deforestation.[88] Biofuel production, like that for oil and gas, also involves a large amount of water. Furthermore, some GHGs such as nitrogen oxide, methane, and CO_2 are emitted from nitrification and de-nitrification through the use of fertilizers, soil transformation, poorly drained soils, and motorized equipment; however, life-cycle GHG emissions are much lower for sugarcane ethanol than for gasoline with ethanol releasing 0.6 kilograms of CO_2 per liter compared to 1 kilogram for gasoline.[89] One significant benefit, however, is air pollution. Although the combustion of ethanol in automobile engines is not benign—ethanol is a significant source of aldehyde emissions (similar to formaldehyde from gasoline) and peroxyacetyl nitrate pollution (an irritant to plants)—every kilometer fueled by ethanol releases less particulate matter, volatile organic compounds, lead, Benzene (a carcinogen), 1-3 butadiene, sulfur oxide, and carbon monoxide than gasoline.[90]

VII. CONCLUSIONS

1. No energy source is free of some type of environmental impact, though energy efficiency practices properly implemented are the most environmentally friendly. While renewable energy sources such as wind and solar have clear environmental benefits compared to conventional sources, they are not free of consequences. Even with the use of renewable resources, every kilowatt-hour of electricity generated, every barrel of oil produced, every ton of uranium mined or cubic foot of natural gas manufactured produces a laundry list of environmental damage that may include radioactive waste and abandoned uranium mines and mills, acid rain and its damage to fisheries and crops, water degradation and excessive consumption, particulate pollution, and cumulative environmental damage to ecosystems and biodiversity through species loss and habitat destruction. In monetary terms, the social and environmental damage from just one type of energy—worldwide electricity generation—amounted to roughly $2.6 trillion in 2010.[91] This means that continuing along the business-as-usual path could result in an increased cost burden to governments as they become saddled with heavy public health-care and environmental costs and the negative effects on economic competitiveness through loss of workforce productivity.[92] Put another way, if the increasing energy demands for the Asian Century scenario are met by the traditional mix of energy supply with current technologies, then the implications for the environment in terms of GHG emissions, green growth, global warming, and prices of fossil fuels would not be sustainable.

2. Policy makers must incorporate the cost of some of these negative environmental consequences of energy production and use into prices. At a bare minimum they should place a price on carbon and preferably other things like sulfur dioxide, nitrogen oxide, particulate matter, and water. A preponderance of evidence suggests that pricing energy more accurately will greatly improve the efficiency of the electricity industry, provide customers with proper price signals, reduce wasteful energy use, and most importantly, improve household incomes since they no longer have to waste as much time and money dealing with debilitating health issues caused by pollution.[93]

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[88] Mahapatra and Mitchell 1999

[89] de Cerqueira Leite et al 2009.

[90] Goldemberg, Coelho, and Guardabassi 2008

[91] Brown and Sovacool 2011.

[92] Buckeridge et al 2002, von Klot et al 2002.

[93] Sovacool 2009.

3. If policy makers desire to truly promote cleaner forms of energy, feed-in tariffs seem the best method to rapidly accelerate their adoption. One study analyzed renewable portfolio standards, green power programs, public research and development expenditures, system benefit charges, investment tax credits, production tax credits, tendering, and feed-in tariffs, and found that only feed-in tariffs met the criteria for a truly effective policy tool.[94]

In the end, we must accept that current patterns of energy production and use have widespread and widely known negative impacts on the environment. As President Jimmy Carter once remarked when addressing the US Congress in 1976, to avoid a cycle of energy and climate crises: "We must face the prospect of changing our basic ways of living. This change will either be made on our own initiative in a planned way or forced on us with chaos and suffering by the inexorable laws of nature." It would be far better to implement carbon taxes, to incorporate the cost of negative environmental consequences into energy prices, to pass feed-in tariffs, and to harness the powers of energy efficiency now in a proactive way rather than a few decades from now when forced to by crises.

94 Sovacool 2010.

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Environmental Issues, Climate Changes, and Energy Security in Developing Asia

This paper examines four environmental dimensions of energy security—climate change, air pollution, water availability and quality, and land-use change—and the environmental impact of various energy systems. Since all energy sources have an environmental impact, policymakers must begin to incorporate the cost of these negative consequences into energy prices.

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