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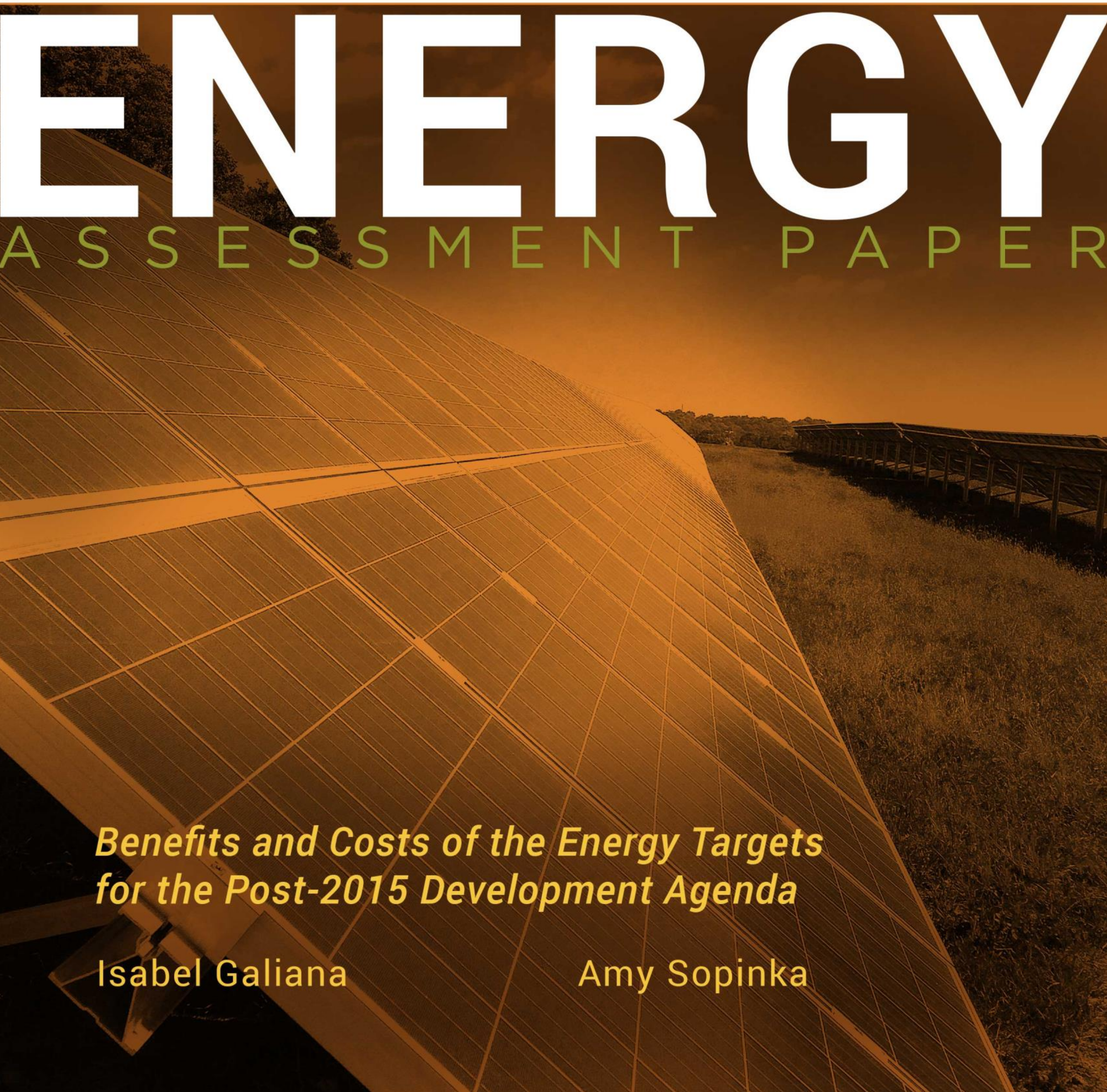

Benefits and Costs of the Energy Targets for the Post-2015 Development Agenda

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Post-2015 Consensus

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Working Paper as of 23 September, 2014

Highlights

Within Energy, the targets that have the highest benefit-cost ratio are:

- Provide Access to Modern Cooking Fuels to 30% of the Population which has a benefit-cost ratio of >>4.8-23.9. The reduction of indoor air pollution from burning wood, dung, coal and other solid fuels-has massive benefits. The estimated benefit cost presented here is quite conservative given the potential to radically improve the lives of the world's poorest.

- Double Research, Development and Demonstration (RD&D) in Energy Technologies has a benefit-cost ratio of 2 - 30. All energy targets depend on further technological developments in storage, transmission and distribution, transportation, efficiency etc. Actively seeking these technologies through targeted RD&D programs will expedite the global energy transformation required to provide sustainable energy access for all.

- Phasing out Fossil Fuel Energy Subsidies a benefit-cost ratio >>15. This target yields particularly high benefits for developing countries if revenues are appropriately recycled.

Valuable targets are:

- Double the Rate of Energy Efficiency Improvement Globally with a benefit-cost ratio of 2.4 – 3. Improvements in efficiency reduced energy prices through lesser demand ease infrastructure needs and frequency of temporary power shortfalls as well as improve industrial competitiveness.

- Universal energy access, electrification and access to modern cooking facilities with a benefit-cost ratio of 4.3-7.8, 4.6-10.2 and 2.9—14.7 respectively. These are all valuable targets but the universality of the target implies increasing costs at the limit and thus suggests a more restrained target would result in greater benefit-cost ratios.

The following targets are relatively ineffective or there is large uncertainty regarding the benefit-cost ratio:

- Double the Share of Renewable Energy in the Global Energy Mix with a benefit-cost ratio of 0.72 - 0.92. Until the issues of intermittency and storage are resolved through RD&D, this target is excessively costly

Introduction

The global energy system is undergoing a rapid and significant transformation both from a demand and supply perspective. The former is due in large part to emerging economies growth and rapid urbanization both of which are extremely energy intensive. The latter is due primarily to the 'shale gas revolution', the disaster at Fukushima and the push for renewables. Governments' are defining policies regulating all aspects of energy systems, including extraction, transportation, distribution, accessibility, fuel mix, transmission, etc.

The World Energy Council's definition of energy sustainability is based on three core dimensions - energy security[1], social/economic equity, and environmental sustainability. Policy objectives should strive to address these three dimensions although at times they are conflicting. Take for example, the historically strong correlation between GDP per capita and energy access. Improving energy access is a fundamental objective in many developing countries; however achieving this objective is often associated with increased levels of pollution, water depletion and global climate deterioration.

Further confounding the complexity of establishing targets that address the three core dimensions of sustainability are the following facts: there are currently ~1.3 billion people are without electricity and 2.6 billion people in developing countries that rely on traditional biomass for cooking and heating; energy demand expected to double by 2050; and there is a strong international desire to reduce greenhouse gas emissions by half to keep global temperature increase below 2 degrees Celsius. Energy planning must be linked to goals and priorities in other sectors including environmental, health, education, infrastructure planning etc.

Regional difference abound, with regions least able to finance an energy shift are most in need of one. Energy poverty[2] in Africa in particular is a priority as less than 30% of the population has access to electricity Sub-Saharan Africa. In Asia 700 million people still have no access to electricity and almost 2 billion people still burn wood, dung, and crop waste to cook and to heat their homes (Asian Development Bank, 2014). As described by the energy ladder, lack of access to modern form of energy results in the use of more polluting both in terms of climate and indoor air pollution, less sustainable forms of fuel, including biomass.

In this report we examine 6 potential targets for a Post-2015 development agenda.

1. The zero target of increasing access to modern forms of energy to 100% of the population.

    a. Universal provision of electrification

[1] Energy security in this context relates to reducing volatility in energy supply and prices.

[2] Definitions abound for energy poverty; here we define energy poverty as a lack of access, financial or physical, to sufficient modern energy to meet basic needs of cooking, lighting, and heating

   b. Universal provision of modern cooking facilities

2. Doubling the rate of energy efficiency improvement globally.
3. Double the share of renewable energy in the global energy mix.
4. Phasing out fossil fuel energy subsidies.
5. Providing access to modern cooking fuels to 30% of the population.
6. Increasing investment in R&D in energy technologies.

PART 1

Existing global energy programs

The UNFCCC climate negotiation failures of 2009 in Copenhagen served to draw attention to the importance of energy and its conflicting contributions to human development and environmental degradation. Copenhagen's failure was in large part due to the rapid growth of emerging economies and their justified unwillingness to compromise economic development for climate/energy mitigation. At the UN General Assembly in 2010 a resolution was passed designating 2012 as the International Year of Sustainable Energy for All. In 2011 the Sustainable Energy for All initiative was launched based on the recommendations of the Secretary-General's Advisory Group on Energy and Climate Change (AGECC). The Sustainable Energy for All (SE4ALL) focuses on drawing attention and financing to three objectives. First, ensuring universal access to modern energy services by 2030. Second, to double the rate of improvements in energy efficiency by 2030. Third, to double the share of renewable energy to 30% of the global energy mix by 2030.

Access to modern energy services is critical to providing the basic necessities for subsistence as well as a catalyst for social and economic development. Although energy was not explicitly targeted in UN's Millennium Development Goals (MDGs), its importance in achieving the eight targets was widely recognized. Numerous reports highlight the issue of energy services in achieving the MDGs (Modi, McDade et al. 2005, UN 2005). The designation of 2012 as the International Year of Sustainable Energy for All was in part an appeal to governments to support the MDGs through energy policy.

In June of 2014 Secretary-General Ban Ki-moon declared the decade from 2014-2024 as the United Nations Decade of Sustainable Energy for All (DSEA). The DSEA was launched within the SE4ALL program and highlights the importance of energy in developing the post-2015 development agenda. It is hoped that with the backing of both the UN and the World Bank, SE4ALL will be successful in mobilizing action at the local, regional and global scale. The inclusion of an energy goal within the Post-2015 development agenda would draw further attention to the aspiration for global sustainable energy access.

Energy - The Basics

Modern forms of energy such as electricity, natural gas, clean cooking fuels, and mechanical power are necessary to increase the productivity of agriculture and labor, improve the health of the population, lower transaction and transport costs. Energy services, such as lighting, heating, cooling, power for transport, mechanical power etc. are of much more interest to consumers than energy in and of itself. Energy policy targets tend to focus on consumption through efficiency or production through energy portfolio preferences. Efficiency measures are driven by both environmental concerns though reduced damages associated with lower total energy consumption[3] and economic growth ambitions as reduced energy use per unit produced lowers costs. Production targets focus on the energy mix or the quality of energy services within an economy often though renewable targets and/or increased distribution. The quality of energy services is often described with the "energy ladder" hypothesis which states that as incomes rises a household's energy choice moves from traditional fuels, such as wood, first to transitional fuels, like kerosene, and then to modern fuels, such as electricity from the grid. Higher quality energy is portrayed as more productive, environmentally less damaging, and more flexible. The energy ladder hypothesis was studied by Burke (2013) based on data from 134 countries for the period 1960–2010. He shows that economic development results in an overall substitution from the use of biomass to energy sourced from fossil fuels, and then increasingly towards primary electricity from nuclear power and certain low-carbon modern renewables such as wind power. An important consideration will be to the possibility of skipping rungs on the ladder…for example jumping from biomass to 'clean' electricity skipping the fossil fuel rung. Unfortunately, there is no clear answer regarding the welfare enhancing potential and cost-effectiveness of this option. Lastly with respect to production objectives, energy life cycle impacts must be examined; extraction, transformation, transportation distribution and consumption of energy of governed by unyielding laws of physics that constrain possibilities.

Current Trends in Energy Production and Use

According to the International Energy Outlook 2013 (EIA 2013) world energy consumption is projected to grow 56% between 2010 and 2040. Figure 1 illustrates the growth over the last two decades and projections for total world energy use to rise from 524 quadrillion Btu[4] in 2010 to 630 quadrillion Btu in 2020 and to 820 quadrillion Btu in 2040. It is clear from Figure 1 that the trend seen in the past decade of rapid growth in non-OECD countries continues out to 2040 due to strong economic growth. In fact, energy use in non-OECD countries increases by 90 percent whereas in OECD countries, the increase is only 17 percent.

[3] An exception may be particular cases of total rebound (discussed in more detail in target 2)
[4] British thermal units

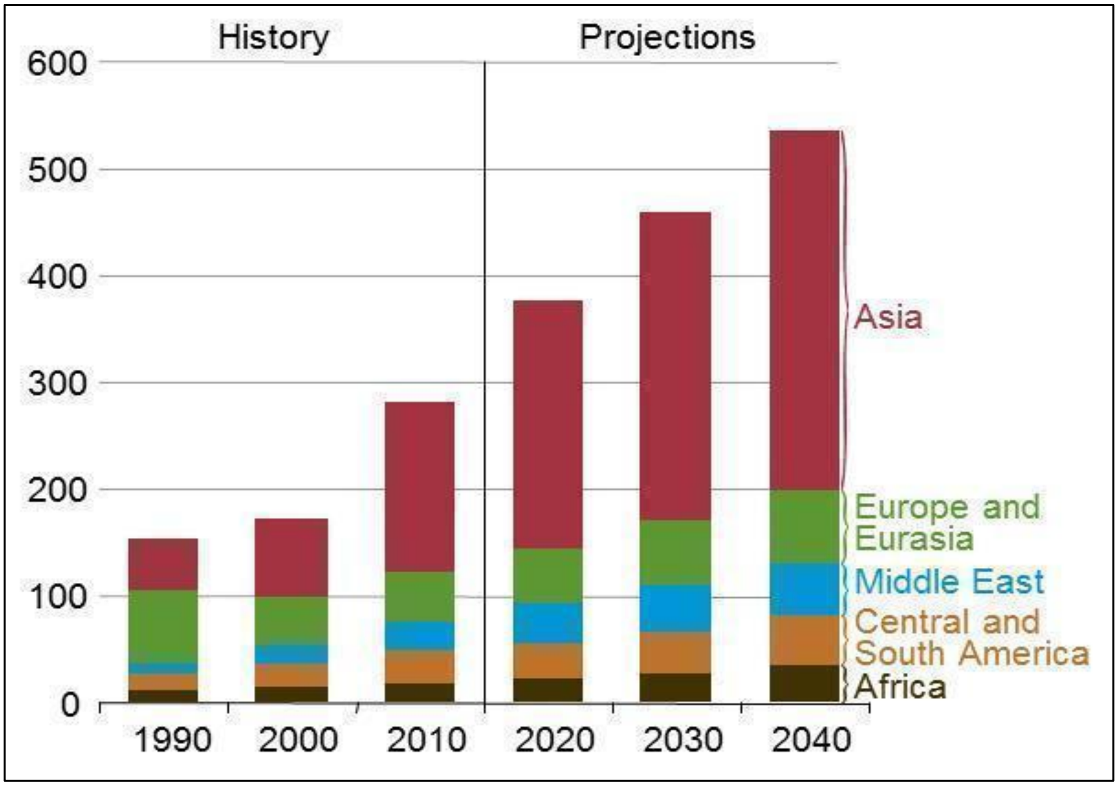

FIGURE 1: NON-OECD ENERGY CONSUMPTION (QUADRILLION BTU) BY COUNTRY GROUPING (SOURCE: EIA 2013a)

The lack of significant growth in Africa is of concern given the severe energy poverty of Sub-Saharan Africa where less than 30% of the population has access to electricity in 2012. Clearly the forecasts do not predict a forthcoming solution to this situation and action is needed.

Figure 2 looks at the fuel mix of energy demand from 1990 to 2010 with projections out to 2040. Renewable energy and nuclear power are the world's fastest-growing energy sources to 2035, both increasing by 2.7 percent per year. Fossil fuels continue to dominate supply almost 80 percent of world energy use through 2040 and growth of ~1.4% per annum. Natural gas, supported increasing supplies of tight gas, shale gas, and coalbed methane, is the fastest-growing fossil fuel by increasing by 1.7 percent per year. Coal use continues to grow although at a lesser rate than the past decade mostly because of China's electricity generation needs. Despite an expected increase in the share of renewables and nuclear, fossil fuels continue to increase and dominate largely due to their wide availability, low costs and integration in existing infrastructure (lock-in).

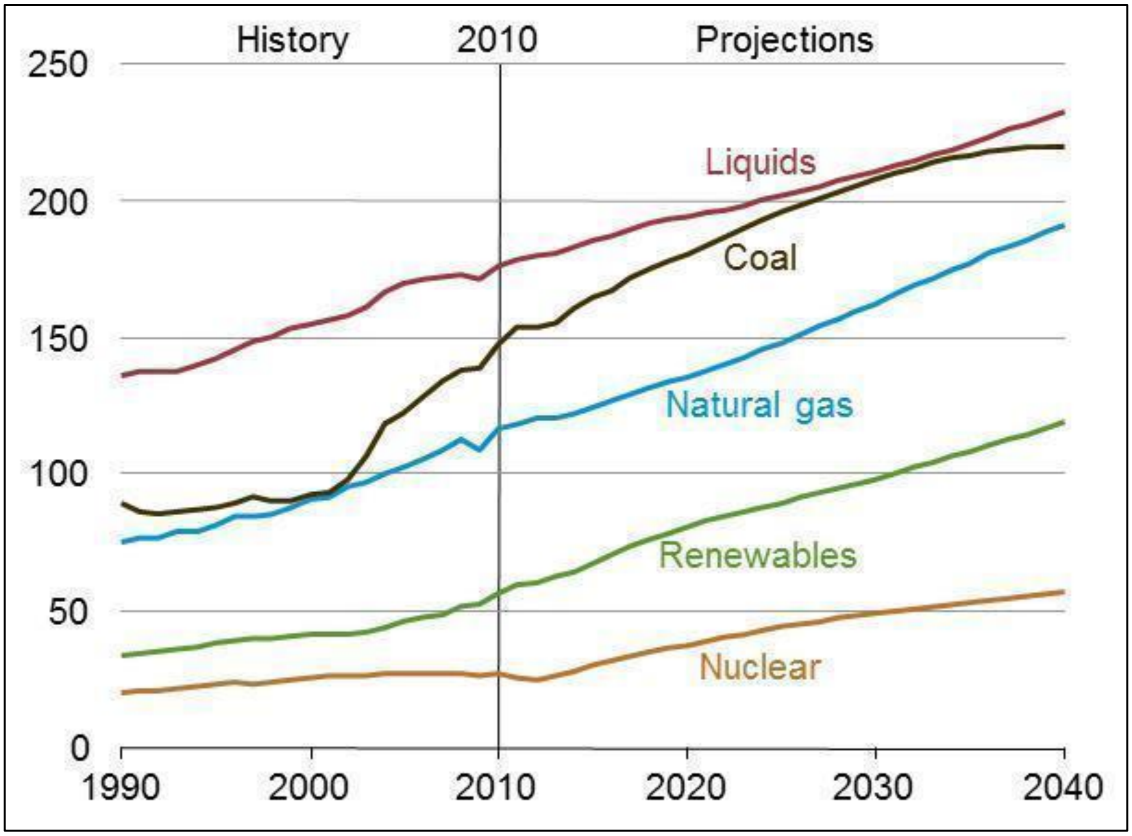

FIGURE 2: WORLD ENERGY DEMAND (SOURCE: EIA, 2013a)

Csereklyei, Varas et al. (2014) find evidence for the following five stylized facts on energy and economic growth[5] that have implications for the development of suitable energy policy objectives. First elasticity of energy with respect to income is stable and less than unity. CVS1 has a number of important implications. Energy use per capita increases over time as an income grows. Some countries have experience a decoupling of energy and GDP but they are not typical of development patterns. Consequently accelerating development implies a growth in energy demand. The elasticity of global energy intensity with respect to income is around -0.3. The growth rate of energy intensity is negatively correlated with the growth rate of income, thus rapid growth implies rapid improvements in energy efficiency. The second CVS stylized fact is that both global energy intensity and the energy to capital ratio are converging across countries. Third, elasticity of the energy to capital ratio with respect to income is around -0.4 implying that the decline in energy intensity is driven mainly by energy efficiency improvements rather than structural change. Noteworthy for the purposes of this study are the countertrends in Africa and South America where there are examples of increasing energy/capital ratios. This is not unusual in the earlier phases of development as energy intensive capital is added to the economy. Fourth, based on data from the US, the UK and Sweden, the cost share of energy declines over time. Fifth, energy quality increases with income.

[5] The stylized facts will be referred to as CVS1-CVS5

According to the EIA (2013a) the industrial sector currently account for the largest share of delivered energy consumption and continues to consume over half of global energy in 2040. From an environmental perspective, assuming current climate are respected, worldwide energy-related CO2 emissions rise 46% from ~31 billion metric tons in to 45 billion metric tons in 2040. This would suggest that sectoral policies targeting efficiency may merit consideration. Targeting both efficiency and processes can have significant result in terms of emission reductions[6].

The World Energy Outlook provides a series of scenarios under different policy and cost projections in order to assess various potential futures. The New Policies Scenario takes into account policy commitments and plans that have been announced by countries. These policies include climate targets and plans to phase out fossil-energy subsidies that have not been implemented but rather only announced and consequently are extremely optimistic. This scenario serves as the IEA baseline scenario. The New Policies Scenario shows a gradual decline in the number of people without electricity, bringing this below 1 billion in 2030, but a much smaller net fall in those without clean cooking facilities.

There is often a focus on financing needs to achieve long-term targets while little attention is given to the needs to maintain the status quo in the energy system not to mention to supply growing demand. In fact, investments in energy supply have doubled since 2000 to over $1.6 trillion. Moreover, $130 billion went to improve energy efficiency and $250 billion to renewables. As expected, the extraction and transport of fossil fuels, oil refining and the construction of fossil fuel-fired power plants make up the largest share of investment at more than $1 trillion per year (World Energy Investment Outlook 2014). It will become increasingly difficult for developing and emerging economies to supply the massive investments in infrastructure needed to support booming electricity demand, brownouts and energy shortages are already seen across India, Brazil, and China, not too mention the African subcontinent.

IEA (2014a) projections under the New Policies Scenario show annual investment in energy supply rising to $2 trillion in 2035, with expenditures on energy efficiency expands to $550 billion. Within this New Policies Scenario where all currently announced policies are implemented, low-carbon technologies account for almost three-quarters of energy supply investment with renewables at a cumulative $6 trillion and nuclear at $1 trillion over the 2012-2035 period. Given the strong expected growth, nearly two-thirds of energy-supply investment takes place in emerging economies, with investment spreading beyond the BRICS. The remaining third goes primarily to replacing ageing infrastructure and supporting climate policies in the OECD. Achieving the widely discussed climate target of 2 °C would require double the investments in the New Policies Scenario by 2035.

Shale Gas and the Growth of Liquefied Natural Gas

The availability of primary energy sources has never been greater as the past two decades

[6] For example the world steel association's approach. http://www.worldsteel.org/steel-by-topic/sustainable-steel/environmental/climate-change.html

have revealed an abundance of previously inaccessible energy, particularly in the developed countries where both technology and capital are plentiful. For the most part, the increased supply is due to the 'shale gas revolution' also known as 'the shale gale'. Shale gas, until recently was not economically feasible, but is now part of the energy lexicon as technological innovation has increased proven gas reserves to unprecedented levels. However, both government policy and export constraints interfere with the ability of resource-rich regions to move their product to high-valued external markets.

Hydraulic fracturing is a sixty year-old technology that releases trapped natural gas from sedimentary rock. The process, also known as 'fracking', requires fluid to be pumped down through a well causing the sedimentary rock to crack and the liquid, which contains a sand solution seeps into the fractures, keeping them open and allowing the natural gas to be released. The natural gas flows to the well and is processed and shipped for further distribution.

> The breakthrough that made large-scale commercial shale gas production possible was pioneered in the Texas Barnett Shale in the late 1990s when two differing technologies, horizontal drilling and multi-stage hydraulic fracturing were combined. In short, the gas well is drilled vertically from the surface and is bent or kicked at a certain depth to penetrate the shale gas layer horizontally or at a diagonal. This allows the wellbore to intersect a much greater part of the reservoir as well as a greater number of existing natural fractures. (Council of Canadian Academies, p.37)

Together, multi-stage hydraulic fracturing, horizontal drilling along with 3D seismic technologies have dramatically increased proven reserves; in 2013, the EIA recently estimated global technical recoverable shale gas resources of 7,299 trillion cubic feet (EIA, 2013a).

However, the process of fracing is controversial. Much of Europe and pockets of North America have banned the practice. Some of these regions are now looking at developing policies around the practice to mitigate environmental concerns to benefit from the inexpensive natural gas. Anti-fracking campaigns focus on seismicity resulting from deep fractures, chemical contamination of freshwater aquifers from surface seepage and sub-surface migration. The quantity of shale gas reserves have greenhouse gas implications through methane leakages and carbon emissions from combustion.

The shale revolution led to a massive increase in the supply of natural gas. However, without an equal size increase in demand, the price for the commodity is depressed in well-developed basins. In areas without natural gas or without the necessary pipeline capacity, natural gas is valuable, giving rise to a nascent global liquefied natural gas (LNG) industry. LNG is the result of refrigeration and liquefaction, the so-called "freeze and squeeze" that condenses natural gas into a liquefied state it can be transferred by tanker to overseas markets. Thus natural gas can replace higher cost input fuels such as coal, oil, or other petroleum products, even in areas without natural gas reserves. One of the uses of the low cost natural gas is as a primary fuel used in the generation of electricity and the shale gas revolution has reduced electricity prices across those jurisdictions with access to the natural gas.

Globally, liquefied natural gas is a growing market. The EIA expects world LNG production to double from about 10 trillion cubic feet in 2010 to around 20 trillion cubic feet in 2040. The liquefaction facilities are currently, or are expected to be located Australia, Qatar and North America (EIA, 2014). Canada has proposed six facilities on the west coast while another 13 are in the planning stages in the US; the total capacity should all 19 facilities move into production, will be 219 metric tonnes per annum (MTPA). More than 28 other countries have announced plans to build LNG facilities.

At present, natural gas development occurs within jurisdictions that have the physical and financial capital available to develop upstream production and capital-intensive LNG facilities. However, as technology evolves and disperses, significant opportunities will present themselves to regions that currently have poor access to energy supply, are without the necessary infrastructure and investment capital, but have technically recoverable shale gas. For example, the EIA (2014) estimates that China and Africa have some of the world's largest technically recoverable shale gas resources.

By 2020, the number of countries with import capacity could double. Although China has considerable shale gas reserves, its viability as a energy supply source is hampered by the water-intensity of the process and the lack of infrastructure required to transport it to the demand centres. Importing LNG by tanker to industry on the Chinese coast is the more cost effective option. India is also expected to be an important source of LNG demand as its economy continues to grow. At present, Japan is primarily dependent upon LNG imports from Qatar, however as LNG production facilities in North America and Australia are constructed, the range of supply options for Japan will grow.

Implications of Fukushima

Following World War II, Japan emerged as an economic giant with a growing industrial sector that included an energy-intensive steel segment. As an island economy, Japan imports most of its required raw materials such as metallurgical coal, ore and oil. Due to the country's dependence on expensive imports for both raw materials and primary energy sources, the investment in nuclear energy facilities represented a pragmatic choice for electricity generation. Nuclear power plants, although expensive to build, are relatively inexpensive to operate and can produce vast amounts of carbon-free energy at low cost. Prior to the earthquake in 2011, 30 percent of Japan's electricity came from its 40,000 MW nuclear generating facilities. However, following the incidents at Fukushima, Japan systematically shut down of the country's nuclear fleet, and at present Japan's energy needs are being met by coal, oil and liquefied natural gas.

As Japan's carbon-free nuclear energy was replaced with higher carbon sources, the country's carbon emissions have increased. While there appears to be trepidation from policy makers globally with respect to expanding the role of nuclear energy, the climate implications of switching from carbon-free to carbon-intensive sources is clear. Germany's Energiewende which supported the closure of nuclear facilities and the subsidization of renewable, but non-dispatchable, energy sources, has seen their emissions increase as base load coal facilities are required to offset the nuclear closures.

Whether or not Japan will be able to restart their shuttered nuclear energy facilities is still unclear. It is estimated that Japan's fuel import costs, as a result of the nuclear closures, were $250 billion in 2012. These skyrocketing primary energy expenditures might help to explain why in April 2014, Japan's Prime Minister Shinzo Abe approved the country's long-term energy plan that included nuclear energy as a key resource. In January 2014, ten of Japan's electric utilities consumed 5.66 million metric tons of coal, a record amount. Thus it is unsurprising, that while supporting the eventual use of nuclear energy, Abe has encouraged Japan's coal industry to expand it sales both domestically and internationally, competing with China and India for a larger market share.

The Rise of Coal in China and India

Setting aside Japan's newfound reliance, the use of coal is integral in electricity generation globally. In 2012, 41% of the world's electricity generation was coal-fired, although the distribution of coal, as a primary energy source in electricity production is not uniform. In 2012, the top three importers of coal for steam-fired electricity production were China, Japan and India. Japan's coal necessity is due to the closure of its nuclear facilities. For China and India, strong economic growth, which is closely tied to energy consumption, was responsible for the increase.

Between 1990 and 2010, the Chinese and Indian economies grew by an average of 10.4 and 6.4 percent per year (EIA, 2013b and 2013c). Since 2010, the growth rates in both those countries dipped slightly, however coal consumption continues to rise. EIA (2013b) estimates Chinese coal consumption tripled between 2000-2010 period and in 2011 China became the largest coal importer in the world although these imports represent only 5% of the country's total coal consumption. China alone consumed 47% of global coal in 2012 and accounted for 82% of the global incremental coal demand in that year.

The strong growth of India's economy is driving the consumption of coal as the country's primary energy source. In 2012, India ranked third in the world in both the production and the consumption of coal; 639.6 and 721.4 million short tons respectively. The electricity sector uses 70% of the coal. The ability of India to feed its coal appetite is aided by the fact that that country is home to the fifth largest coal reserves in the world (EIA, 2013c). The EIA forecasts that coal will remain the second largest energy source globally due to the significant increases in use in China and India and other non-OECD countries (EIA, 2013c).

Energy and Development

Economic development represents a qualitative change and restructuring of a country's economy in connection with technological and social progress indicated quantitatively through increasing GNP per capita (or GDP per capita). Economic growth is closely linked to economic development, as it represents a quantitative change or expansion in a country's economy measured as the annual percentage increase in gross domestic product (GDP). Csereklyei and Humer (2012) describe four theories that relate economic growth and energy consumption. Of the hypotheses outlined (Neutrality, Feedback, Conservation and Growth), only the Growth Hypothesis postulates a unidirectional relationship between energy consumption and GDP growth.

The importance of energy forms the core of the Growth theory; economic growth is driven by the use of more resources, which increases per capita GDP – as long as growth is not solely attributable to an increasing population (World Bank, 2005). Smil (2000) hypothesizes that "civilization's advances during the twentieth century are closely bound with an unprecedented rise of energy consumption" (p. 21). Statistics reveal that in the 20th century, there was a dramatic increase in fossil fuel consumption, rising by over 1300 % over the one hundred year period. Over that same period, population grew by almost 300%, allowing annual per capita energy consumption to more than quadruple.

The growth in fossil fuel consumption can be attributed to the expansion of three key sectors – electricity generation, transportation and residential end-use in developed countries. This theory is expounded by Smil (2000), who postulates that the cycle of energy consumption begins with increased energy consumption for industrial production, along with use by households, and finally, substantially larger amounts of energy are used by the transportation sector.

In contrast to the Growth theory, the Neutrality hypothesis asserts that there is no relationship between energy consumption and GDP, thus policies to encourage energy access would not impact economic growth or development. The Conservation hypothesis assumes a unidirectional relationship wherein GDP growth causes energy consumption. If the unidirectional causality exists it suggests that policies aimed at conserving energy will not impact GDP. The Feedback Hypothesis assumes bi-directional causality between energy access and economic development. When this feedback mechanism is known to occur, the relationship between GDP and energy should be considered, an a means of decoupling the two would allow for a reduction in energy consumption without a deleterious impact on economic growth.

Empirically, evidence can be found to support each of these hypotheses. Econometric analysis shows bi-directional causality in OECD countries supporting the Feedback theory (Belke et al., 2011). Unidirectional causality from GDP to energy for some OECD countries such as Italy and Germany is evidence of the Conservation hypothesis (Soytas and Sari, 2003; Erol and Yu, 1987). The Neutrality hypothesis of no relationship between energy and GDP growth is supported by the finding of no causality in European countries (Menegaki, 2011) and unidirectional causality, evidence of the Growth hypothesis, is found in US and Canada (Stern, 1993, Erol and Yu, 1987). Tests of Granger causality on the energy-growth nexus for the lowest income countries show a bidirectional causality (Kahsaia et al, 2011), while threshold cointegration methods used in Esso (2010), indicate no causality for Cameroon, Nigeria, Kenya and South Africa, bi-directional causality in the Ivory Coast, and a unidirectional relationship supporting the Feedback hypothesis in Congo and Ghana. Chen (2007) finds a bidirectional relationship between electricity and GDP, using an error correction model in seven Asian countries.

The only conclusion that is clear is that the relationship between energy or electricity and GDP growth is uncertain and can support any one of the four hypotheses. Each hypothesis justifies differing energy development paradigms, however as Smil (2005) suggests, the paucity of data at extremely low levels of income may reduce the power of the hypothesis testing rendering it difficult to make conclusive statements with respect to energy consumption and GDP growth for the least developed countries.

Energy and the Environment

Environmental and energy policies are fundamentally linked since all forms of energy have some degree of environmental damage associated with them. There is a strong push to reduce negative impacts associated with energy systems at all levels of government.

At the global level, energy and climate change are strongly related. Reducing GHG emissions from energy systems is urgently needed to limit global warming to less than 2oC above pre-industrial levels. It is also urgent to decrease indoor and outdoor air pollution from fuel combustion and its impacts on human health and ecosystems, as well as to reduce other adverse effects and ancillary risks associated with some energy systems. Menyah and Wolde-Rufael (2010) found for South Africa a unidirectional causality running from pollutant emissions to economic growth; from energy consumption to economic growth and from energy consumption to CO_2 emissions all without a feedback.

The burning of fossil fuels, currently the largest source of primary energy, contribute about 10 billion tons of CO_2 a year to the atmosphere, as well as significant amounts of ozone, sulphur dioxide, nitrogen dioxide and particulate matter. Coal in particular also releases mercury, arsenic and radioactive material.

Fossil fuel extraction causes significant damage at both the local and regional levels. Tailings from mining or oil shale recovery as well as leakage during transportation leach into waterways and soil contaminating entire watersheds.

Nuclear energy's main environmental impact is the disposal of spent fuel (although great progress has been made on reprocessing) and the risk of a nuclear catastrophe. Despite a NIMBY attitude towards nuclear, it is one of the most environmentally sound sources of base load energy[7].

Hydropower's environmental impacts are linked to the flooding of large areas and the alteration of natural river flows, disturbing wildlife. Flooding releases poisonous methyl mercury into the water and the greenhouse gas methane into the air. It is however one of the few means of electricity generation that does not depend on a non-renewable resource.

Renewables such as wind and solar have minimal environmental impacts however both require rare earth metals (REMs). REMs contain radioactive elements such as uranium and

[7] Base load energy – reliable, consistent source of power, ie not intermittent such as wind or solar

thorium, which can contaminate air, water, soil and groundwater. Metals such as arsenic, barium, copper, aluminum, lead and beryllium may be released during mining into the air or water, and can be toxic to human health. Moreover, the refinement process for rare earth metals uses toxic acids and results in polluted wastewater that must be properly disposed of. Moreover, REMs are, as the name implies, rare, non-renewable and currently mined ores of lesser and lesser quality.

All major forms of electricity generation save for wind require large amounts of water either for cooling in the case of nuclear, coal, NG, and solar thermal, or cleaning of solar panels. There is evidence that the needs of generating systems will conflict with irrigation and consumption needs as populations increase particularly in drought prone areas.

With respect to biofuels, decentralized traditional biomass such as wood or cow dung can lead to biodiversity loss and deforestation not to mention the adverse health effects of traditional three-stone cooking (for a more complete discussion see Target 5). Environmental concerns associated with modern biofuels, principally ethanol and biodiesel, include carbon emissions, deforestation and biodiversity loss, and the food versus fuel dilemma whereby croplands get diverted from food to fuel potentially causing food prices to spike.

Part 2

Target 1: Increase Access to Modern Forms of Energy to 100% of the Population (The 'Zero Target')

Modern energy access, defined as "household access to electricity and clean cooking facilities (e.g. fuels and stoves that do not cause air pollution in houses)" (IEA, 2014b). As postulated by the Growth Hypothesis and estimated empirically by numerous authors (DFID, 2014), modern energy access is considered by some to be a fundamental requirement for economic growth and development. Energy access is ubiquitous in the developed world while elsewhere in the world, its presence is sporadic.[8] There are currently 1.3 billion people without access to electricity and 2.6 billion are without access to modern forms of energy, most of whom live in rural areas of Africa and South-east Asia. In sub-Saharan Africa only thirty-one percent of the population has access to electricity, the lowest level in the world (Centurelli, 2011).

The target of providing universal modern energy access is imbued with four sub-requirements: access to electricity for rural populations, 100% access to the grid for rural populations, providing modern cooking facilities - liquefied petroleum gas (LPG) or advanced biomass -- to the rural poor and LPG stoves to urban populations. In the remainder of this section, the benefits and costs associated with achieving 100% modern energy access are described. The zero target is then disaggregated into two sub-targets: electrification and modern cooking facilities and the corresponding BCRs are derived.

[8] One needs only to look at the impacts of blackouts and the North American and European imperative for nearly 100% grid reliability in developed nations to ascertain the importance of electrification. The blackout in northeast US and Canada in August 2003 was estimated cost between $7 and $10 billion.

The World Energy Council (1999) stated that "for the poor, the priority is the satisfaction of such basic human needs as jobs, food, health services education, housing, clean water and sanitation. Energy plays an important role in ensuring delivery of these services". In less developed countries only half of school-aged children attend primary school; even fewer children in sub-Saharan Africa receive formal education. Electrification and modern cooking facilities provide lighting, mechanization and improved cooking efficiency which reduces time spent on household chores while increased productivity allows fewer adult labour hours to replace child labour thereby freeing up time for children to attend school (DFID, 2014).

Modern energy access improves health in a number of ways. First, the use of clean cooking fuels reduces the morbidity and mortality associated with indoor air pollution (IAP). Mechanical power can increase productivity in the agricultural sector, reducing the impacts of malnutrition; pumping systems reduce the frequency with which waterborne bacteria are introduced into water systems, decreasing infection rates. Refrigeration, another aspect of electrification, allows for the storage of vaccines and other medicine. In some countries up to 57% health care facilities do not have access to electricity; on average, 26% of health facilities in sub-Saharan Africa are without electricity (Adair-Rohani et al., 2013).

Mechanical power and cooking fuels, both of which are part of modern energy services create time savings by reducing or eliminating fuel gathering. Women, who traditionally are responsible for gathering cooking fuel, can use the time instead to become involved in income generating activities, leading to greater gender equality. The time savings can be substantial -- one study estimated that 2-6 hours and 4-8 km of travel per day was required per household to collect an average of 10 kg of biomass (Bloom and Zaidi, 2002). An additional benefit of modern fuel access and the reduced dependence on firewood, is that the rate of deforestation is slowed as biomass combustion replaced with cleaner cooking fuels.

Universal Electrification

Bazilian et al. (2010) undertake a comprehensive study and summarize the costs and assumptions associated with universal electrification. The annual per capita costs of achieving universal electrification from 12 different studies. The results are shown in Fig 3.

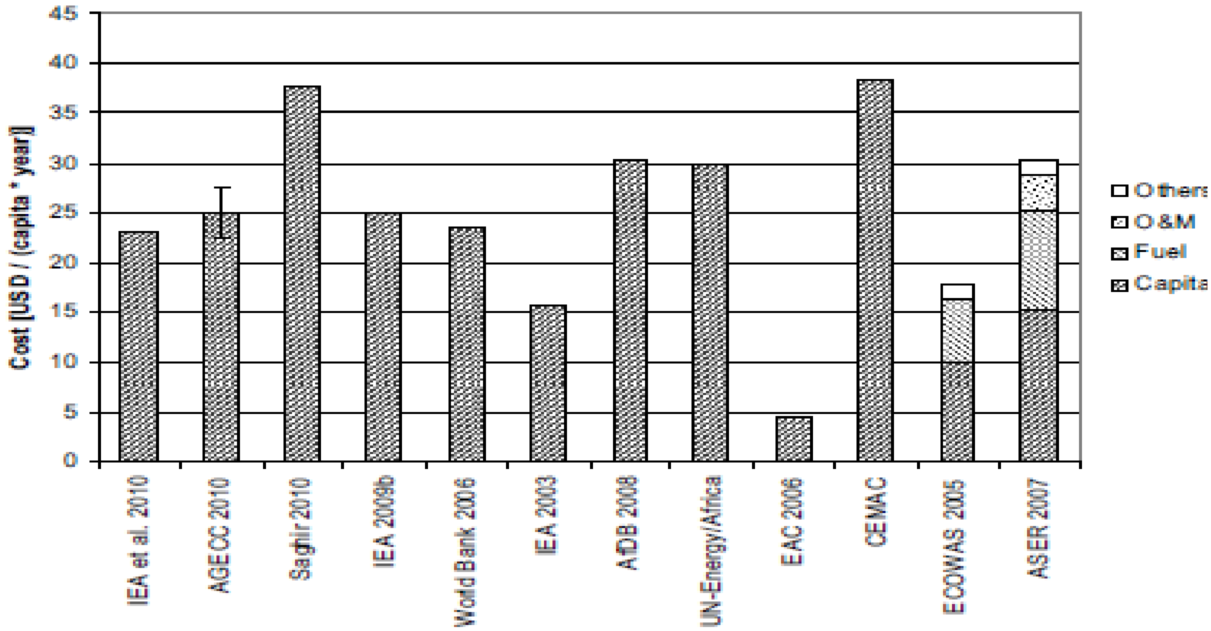

FIGURE 3: ESTIMATES OF UNIVERSAL ELECTRIFICATION COSTS (BAZILIAN ET AL., 2010)

In each case the total costs are disassembled into fuel, O&M, capital and others. From the chart it is clear that only two of the studies include expenses other than capital, which would suggest a gross underestimation of the costs of universal electrification. In assessing the electrification studies Bazilian et al. (2010) authors found other gaps in the methodology such as the omission of recurrent O&M and fuel costs in both the electrification and cooking fuels studies. They rectify the issues by creating an algorithm that utilizes levelized costs to incorporate capital, fuel, and O&M costs associated with various generating technologies. Transmission and distribution is not explicitly modeled but is included in the total cost estimates based on the IEA assumption that these costs are roughly equivalent to the capital costs associated with providing the universal electrification.

Looking solely at the cost of achieving universal electrification, Bazilian et al. (2010) estimate a range of $14 to $134 billion per year, and explain that $100 billion per year would be the best approximation of cost.

Given the population without electricity and the kWh targets proposed by the IEA, Bazilian et al. (2010) estimate that 950 TWh of incremental energy would be required by 2030, generated from an additional 250 GW of capacity. The welfare gain associated with household lighting alone could be $0.15-$0.65 per kWh (IEG, 2013) in rural areas. Applying this range to the total electricity requirement of 950 TWh results in benefits ranging from $142.5 to $617.5 billion. A more recent study found that the willingness to pay for electricity in Ghana was in the $0.2734/kWh (Twerefou, 2014). Using this more modest value, the benefits attributable to universal electrification are $259.7 billion per year once the target has been met.

Access to Modern Cooking Fuels

Table 1 shows the estimated capital and fuel costs enumerated by Bazilian et al. (2010) for those studies that estimated the costs of providing modern cooking fuels, clearly the costs associated with the provision of modern cooking facilities range widely.

TABLE 1: COST ESTIMATES FOR GLOBAL MODERN COOKING FACILITIES

Capital ($US billion)	Fuel ($US billion)	Source
1.0		IEA et al. 2010
0.9		AGECC 2010
0.6		EAC 2006
1.3	8.3	ECOW AS 2005
5.0	18.1	IIASA

From Bazilian et al. (2010)

The variability in costs is the result of the assumptions used to derive the estimates. For example, the IEA 2010 paper includes the capital costs associated with LPG stoves and fuel canisters, as well as biogas digesters but does not include the infrastructure investment, distribution and fuel costs. Both the ECOW and IIASA studies explicitly include fuel costs resulting in a higher overall cost estimates.

More recently, Pauchuri et al (2013) estimate the cost of achieving global access to modern cooking facilities. The authors' find that the cost in 2005 dollars for universal modern energy access with fuel prices supports and microfinancing is cumulatively estimated to be $1,210.92 billion in 2010 dollars or $60.6 billion per year and includes fuel price support with grants for low-cost financing for stove purchases.

The health benefits from modern fuel access results from the avoided morbidity and mortality that are currently attributable to indoor air pollution (IAP). 4.3 million people die each year from IAP. We assume each death corresponds to about 32 DALYS. Using a low estimate of $1,000 and a high estimate of $5,000 for DALYS[9] the added health benefit of modern cooking access ranges from $137.6 - $688 billion per year. In terms of avoided morbidity benefits, WHO (2009) estimates that 41 million DALYS are attributable to negative health impacts of indoor air pollution. Using a low estimate of $1,000 and a high value of $5,000, the avoided health costs are $41- $205 billion per year.

[9] DALYS are disability adjusted life years--" One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability" http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

Universal Energy Access

Providing global electrification and access to modern cooking fuels allows encompasses the benefits of achieving to the two goals individually. The morbidity and mortality associated with indoor air pollution from solid fuel use would be eliminated. The welfare benefits that result from electrification would also be achieved.

Goal	Cost	Benefits	BCR
Universal Electrification	$14 - $134 Billion (Bazilian et al., 2010)	Welfare: $142.5 - $617.5 billion (Bazilian et al, 2010)	4.6-10.2
Modern cooking fuels	$60.6 BILLION (Pauchuri et al, 2013)	avoided morbidity: $41-$205 billion avoided mortality: $137.6-$688 billion total health benefits: $178.6-$893	2.9-14.7
Universal energy Access	$74.6 - $194.6 billion	welfare and health benefits: $321.1 - $1,510.5 BILLION	4.3-7.8

Target 2: Double the Rate of Energy Efficiency Improvement Globally.

Energy intensity is the ratio of energy use to GDP whereas energy efficiency is the ratio of GDP to energy. Energy efficiency (EE) is a popular policy tool presented as cost-saving, job creating and environmentally friendly. One of the three pillars of the EUs 20-20-20 targets includes a 20% improvement in the EU's energy efficiency by 2020. It is expected to generate financial savings of up to €1000 per household every year and create of up to 2 million jobs by increasing industrial competitiveness with. In the United States, the American Recovery and Reinvestment Act of 2009 included more than $70 billion in direct spending and tax credits for clean energy and energy conservation initiatives. A 2012 Deutsche Bank report on the market size of energy efficiency retrofits for buildings in the United States estimated that for every $1 invested it could yield a return of more than $310. China's 12th Five-Year Plan concentrates on energy efficiency with a target to cut energy consumption per unit GDP by 16 percent by 2015 and the 13th Five Year Plan is expected to place energy efficiency as a priority[11].

Benefits of improvements in energy efficiency are numerous and span the three core dimensions of energy sustainability - energy security, social/economic equity, and environmental sustainability. EE can improve the security of energy systems by increasing fuel availability, accessibility, affordability, and reduce a country's dependence on fossil fuels (APERC, 2007; Kruyt et al., 2009). Economically, EE reduced energy prices, through

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[10] Deutsche Bank Climate Change Advisers and The Rockefeller Foundation, *United States Building Energy Efficiency Retrofits Market Sizing and Financing Model* (March 2012).

[11] http://www.scmp.com/comment/article/1548648/clean-energy-takes-stage-china-national-interests-evolve

lesser demand, eases infrastructure needs and frequency of temporary power shortfalls as well as improving industrial competitiveness through reduced operating costs. The 'negawatt' argument, whereby conservation (the 'negawatt') is much cheaper than expanding energy production capacity, cannot be overstated. Moreover, through reductions in energy consumed, EE can conserve natural resources; reduce environmental pollution and carbon emissions. Ultimately, EE programs are seen as "no regrets" policies that provide multiple benefits for the government, energy consumers and the environment. In addition, energy efficiency policies can be put in place rapidly, produce results much more quickly than other measures and is often cited as one of the best near-term options to reduce energy demand and greenhouse gas emissions.

In the context of developing countries, energy efficiency is especially important as it can accelerate productivity growth and lead to further economic development. In addition, developing countries that are endowed with abundant energy resources have been shown to be relatively inefficiency in their domestic energy use. Moreover electricity generation efficiency in developing countries tends to be low and consequently improvements can be made at moderate expense. For example, generation efficiency in Africa is on average 20–40% lower than in developed countries and transmission losses can be up to 20% (UN-Energy/Africa 2009).

In least developed countries energy access naturally takes priority over energy efficiency measures. However, according to Koskimäki (2012) African countries also have very distinctive motives to focus on energy efficiency. First for those with energy access, EE can expand access to energy services to a greater number of people as demand levels are lower and the energy system may serve more customers. Moreover, efficiency at the domestic level reduces energy bills, alleviating poverty and freeing up resources for other uses. As discussed in detail in target 5, biomass use for cooking is of great concern in most SSA countries. More efficient cooking devices also reduce health impacts of poor cooking devices, and provide social benefit, not to mention saving forest. Lastly, the rapid rate of urbanization is associated with greater energy, and in particular electricity consumption. This is both a cost in terms of building new infrastructure but also an opportunity to set the stage for efficient networks in generation, transmission and distribution of electricity as well as transportation.

The average rate of energy efficiency (EE) improvement has been ~1.2% for the period from 2000-2012(EIA 2013). Figure 5 illustrates the IEA reference case[12] energy intensity forecasts for certain key regions as well as the world. Energy efficiency is expected to improve at a rate of 2.04% per annum to 2040. A doubling of the rate of energy efficiency improvements thus implies reaching a 2.4% decline in energy intensity by 2040, or an increase of ~0.4% from the IEA reference scenario.

Csereklyei, Varas et al. (2014) analyses a global data set from 1971-2010 and find the geometric mean energy intensity decrease is 0.40% per annum and the arithmetic average

[12] IEA reference case: Recall this is the optimistic future in which all currently announced policies are successfully implemented.

world energy intensity decreases 1.07% per annum. They also find no general improvement in energy intensity that is common to all countries whether they are growing or not. A doubling of this longer-term energy efficiency improvement estimate may be more technologically feasible given the accelerated rate of energy intensity decline associated with China over the last decade. Moreover given the evidence of convergence in EE discussed above, an important issue will be the physical limits to energy intensity.

Figure 4 is consistent with Csereklyei, Varas et al. (2014) second stylized fact that global energy intensity is converging across countries.

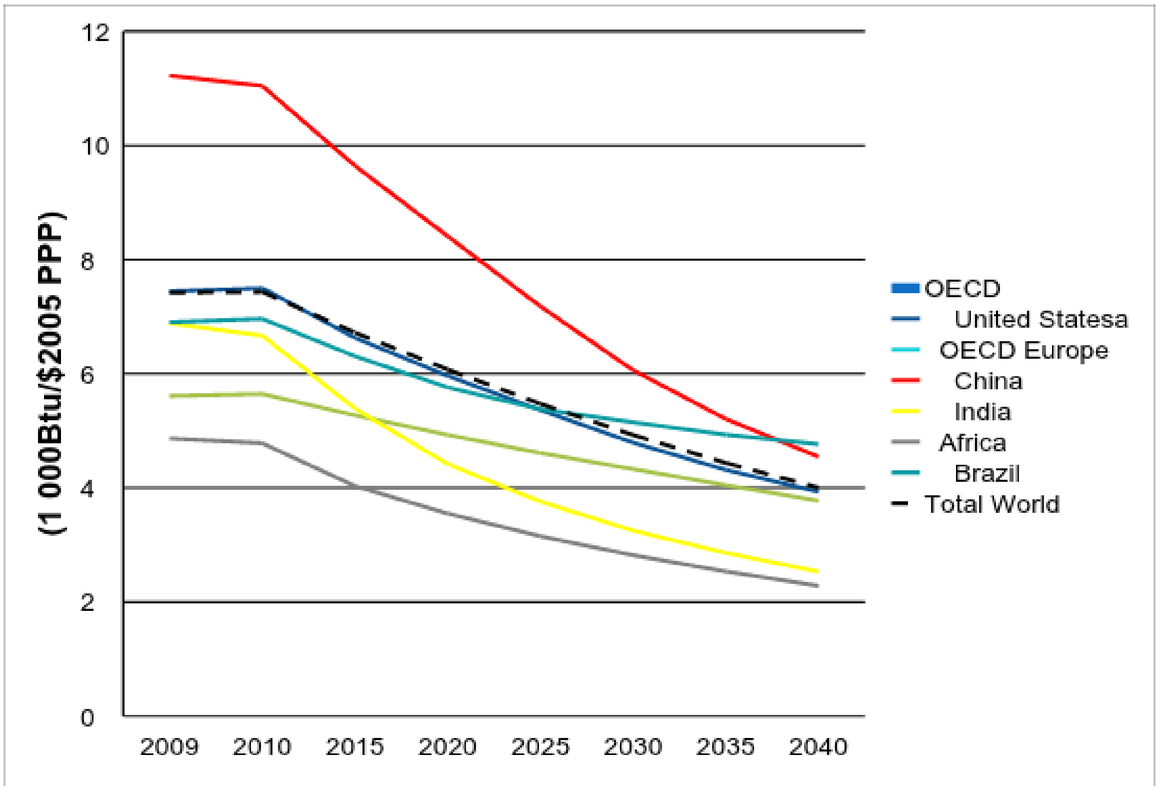

Figure 4: ENERGY EFFICIENCY OUTLOOK (SOURCE: IEA 2013 REFERENCE CASE)

Linares and Labandeira (2010) present a review of the literature associated with two 'paradoxes' that influence energy efficiency policies, the rebound effect and the energy-efficiency gap. The rebound effect describes a situation in which an improvement in energy efficiency does not bring about a proportional reduction in energy demand. Rebound is measured using the elasticity of energy demand with respect to energy efficiency. Thus an elasticity of -1 indicates that demand for energy is perfectly elastic with respect to efficiency and that the increase in efficiency will generate the proportional decrease in the demand for energy. If, on the other hand elasticity is between -1 and 0 there will be a less than one proportional decrease in energy demand, although still a decrease from the no EE improvement state. Lastly, an elasticity that is positive would yield what is referred to as backfire; a situation where energy demand increases with improvements in EE due to a net increase in demand. Only in this last case is there no conservation of energy. This rebound is a 'paradox' only in the context of climate change or other environmental policies looking for energy conservation. From a developmental perspective rebound is in fact something that can be capitalized on to spur growth objectives since energy efficiency gains can increase consumption. From a social welfare perspective, it is will be optimal for governments, in particular of emerging or developing countries, to give greater attention to economic growth, job creation or industrial productivity than energy conservation.

The energy efficiency gap coined in 1990 by Hirst and Brown (1990) describes the discrepancy between actual levels of cost-effective investment in energy efficiency and observed levels. The energy efficiency gap is the unexploited economic potential for energy efficiency, the low-hanging fruit that doesn't get picked. There are numerous studies looking to understand the market failures that prevent technologically feasible EE improvements from being adopted. A difficulty in assessing the energy efficiency gap as well as potential costs and benefits from EE policies is that the opportunities for efficiency improvements are fragmented and found at all scales (light bulb to generating plant). Another market failure that distorts energy use is underpricing of energy by regulators exacerbated by energy subsidies. Sudhakara Reddy (2013) classifies the barriers to energy efficiency as one of eight types; imperfect information, consumer attitudes, limited access to capital, and cost disincentives, misplaced incentives, product life cycles, high consumer discount rates, electricity rate distortions and regulatory uncertainty, externalities. Tackling the energy efficiency gap between potential and real investment will be a key element of realizing EE targets post-2015.

The International Energy Agency (IEA) first Energy Efficiency Market Report, estimates total global investment in energy efficiency measures in 2011 was between $147 and $300 billion (OECD/IEA 2013). The World Energy Investment Outlook (IEA 2014a) finds current energy efficiency investment for 2012 to be $130 billion, equivalent to 13% of fossil fuel investment and compares to $240 billion in renewable energy sources.

In the New Policies Scenario, EE investment quadruples to $550 billion towards 2035 with 62% being spent in the transport sector, 29% in buildings and 9% in industry. Figure 6 shows forecasts for annual spending on energy efficiency for EE investments by sector, the vast majority being at the various levels of the fossil fuel energy supply chain.

In the IEA 450 scenario with rapid decarbonisation of the energy sectors, energy efficiency investment increase to $1.1 trillion in 2035, eight times current levels. This cumulative investment of $14 trillion in efficiency reduces energy consumption by almost 15% in 2035 relative to the reference scenario. It is unlikely this type of investment will materialize given current economic trends and objectives.

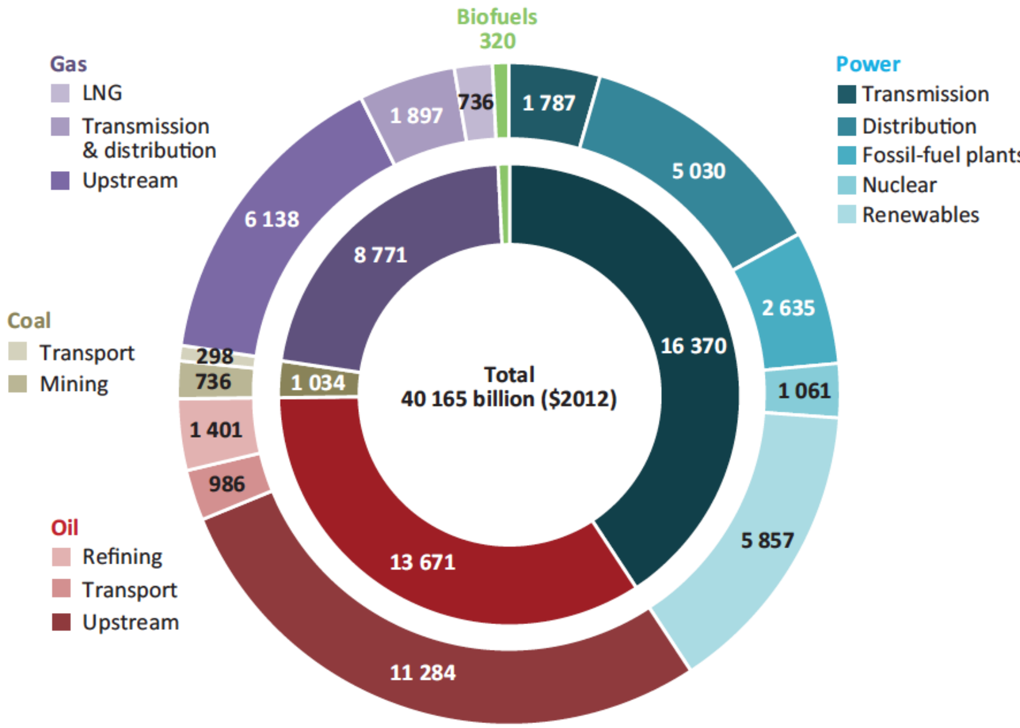

FIGURE 5: CUMULATIVE GLOBAL ENERGY EFFICIENCY INVESTMENT BY END-USE SECTOR IN THE NEW POLICIES SCENARIO 2014-2035 (SOURCE: (IEA 2014a)

There are two main linkages between energy efficiency and GDP: increased investment and increased consumption. A study by Vivid_Economics (2013) finds evidence from OECD countries for a 0.1 GDP growth elasticity of energy efficiency. That is to say a 1 per cent increase in the level of energy efficiency causes a 0.1 percentage point increase in the growth rate of GDP per capita per annum. A Cambridge Econometrics study confirmed this estimate for the UK finding the impact the UK's energy efficiency policies between 2000 and 2010 increased real annual GDP (i.e. annual GDP that is adjusted for inflation) by 0.1 percent (Barker and Foxon 2008). This evidence of rebound (GDP growth resulting from energy efficiency ~ 1%) suggests energy efficiency should be considered as part of mainstream economic policy rather than an energy or environmental issue only (Ryan and Campbell 2012).

Given the estimate for GDP rebound, if energy efficiency levels are increasing each year by 1 additional percentage point, combined GDP for the OECD countries considered would be 612 billion US$ larger in 2030 than currently projected, representing a 1.78 per cent increase. If energy efficiency improves at an additional percentage point from 2012 through to 2030 (almost double its current rate), it would reach 20% above the projected baseline by 2030. (Vivid_Economics 2013).

In Serbia and Montenegro, where energy intensity is three times higher than the rest of Europe, a UN study (UNDP, 2004) identified that energy efficiency measures could boost the GDP growth rate to 5% to 7% a year by improving households' ability to participate more productively in society. The potential for high energy-intensity regions to benefit economically from efficiency policies is recurring and important in developing objectives.

According to one McKinsey report, energy efficiency measures are able to save, over a period of years, more than US$1.2 trillion at an investment cost of less than half this savings, while reducing projected 2020 energy demand in the US by 23 %(Dobbs, Oppenheim et al. 2011).

It has been shown that Germany's Energy-efficient Construction and Refurbishment program yielded €5 in tax revenue for every €1 of public funds spent on the program in 2010. In fact, the program produced €5.4 billion in direct tax revenue in 2010 from companies and employees in 2010 and created 340,000 jobs, reducing government spending on unemployment welfare payments and saving a further €1.8 billion. The Energy-efficient Construction and Refurbishment program also offered €8.9 billion in loans, attracted private sector investments worth €21.5 billion in 2010. Ultimately the program achieved returns of 12.5 percent on investments[13] excluding environmental benefits.

The IEA's World Energy Outlook 2006 estimates that an investment of US$3.2 trillion will be required worldwide to double the rate of energy efficiency improvement, US$2.3 trillion of which will be invested by the G8 countries. These efficiency investments avoid new supply investments of US$3 trillion worldwide, and result in a net incremental investment of US$200 billion worldwide. These relatively small net efficiency investments generate significant additional benefits in improved business productivity and reduced consumer energy bills worth approximately US$500 billion annually by 2030. This implies a BCR of greater than 1 within three to five years, rising thereafter, for the efficiency investments needed to reach the target of doubling the rate of energy efficiency improvements.

If G8 countries pledge to double their historical rate of energy efficiency improvement to ~2.5% and maintain it to 2030, it would reduce their energy demand by about 20 percent in 2030 and avoid the consumption of 55 exajoules (EJ) of primary energy in the G812—avoiding about 2,000 coal-fired power stations or the equivalent of 80 percent of future demand projected to be met by coal power. Accomplishing a 2.5 percent efficiency improvement on a worldwide basis would save 97 EJ and return energy consumption to 2004 levels by 2030.[14]

At the industrial level, according to the IEA, investments of ~US$360 billion in energy efficient technology will be needed and lifetime savings in energy costs are estimated to be more than US$900 billion (IEA 2006). In order to meet growing energy demand to 2030, China and India are forecast to spend an additional US$4 trillion on capacity. In order to

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[13] KfW Bankengruppe (2011) KfW Programmes: Energy-efficient Construction and Refurbishment. Public budgets benefit up to fivefold from "promotional euros". Press Release No. 092. See http://www.kfw.de/kfw/en/KfW_Group/Press/Latest_News/PressArchiv/PDF/2011/092_E_Juelich- Studie.pdf

[14] The calculation assumes the Reference Case of the IEA World Energy Outlook 2006 (IEA, 2006c) as the baseline scenario.

ensure this is done with the most energy-efficient plants is estimated to add about US$30 per kW to the cost of a plant not too mention fewer plants would be needed to meet the expected demand (MIT 2007). This is expected generate capital expenditure savings of save more than US$24 billion in Europe and US$270 billion worldwide along with fuel savings of almost US$0.001 per kWh that would offset the capital cost in only four years (MIT, 2007). The imposition of efficiency standards for coal-fired plants could save OECD countries US$5 billion per year and reduce CO2 emissions by almost 1.8 billion tonnes per year in 2030. Moreover, a 60% efficiency standard in natural gas generation would reduce total OECD power generation costs by almost US$60 billion in 2030, and would cut carbon emissions by 400 million tonnes per annum. If replicated globally, this policy would reduce projected CO2 emissions in 2030 by 5 billion tonnes per year (Moss, Chandler et al. 2007).

SUMMARY

Cost of Double the Rate of Energy Efficiency Improvement Globally: US$3.2 trillion.

Benefits Double the Rate of Energy Efficiency Improvement Globally:

1. US$3 trillion in avoided new supply investments
2. Improved business productivity and reduced consumer energy bills worth approximately US$500 billion annually by 2030
3. CO2 reductions – increasing linearly to 25 US$ billion (5$/ton CO2) – 250 US$ billion (50$/ton CO2) annually in 2030

BCR: 2.4 - 3.0

Target 3: Double the Share of Renewable Energy in the Global Energy Mix

The growth in the use of renewable energy technologies is aimed at decreasing global carbon emissions from electricity production. At the same time, these technologies, such as wind and solar photovoltaic (PV), have the potential to be deployed at a small scale in remote areas. This type of distributed generation, rather than the North American model of centralized generation, is suitable for rural and urban areas lacking infrastructure and could achieve both access to electricity and displace some traditional solid fuel use.

Renewable energy technologies, other than large-scale storage hydro, are dependent on variable fuel sources such as the sun and wind. This results in the production of intermittent energy that requires an alternate energy source to be available to firm up electricity supply thus ensuring reliability. For both wind and solar technologies, the optimal location of the facilities tend to be remote from the demand centres and requires more transmission infrastructure. Both the backstop energy and the transmission requirements increase the cost of producing renewable energy particularly when compared to a highly efficient natural gas-fired generation. Moreover, when the firming energy is provided by natural gas or coal-fired generation, the net carbon benefit associated with renewable energy technologies is ambiguous.

In theory, doubling renewable energy in the global energy mix has the potential of meeting multiple goals including the mitigation of carbon emissions, the economic benefits from changes in GDP and health outcomes as a result of the increased low and zero-carbon energy.

Subsidies, and other inducements such as feed-in-tariffs (FITs) and renewable portfolio standards (RPSs), have been shown to be extremely cost ineffective and have not impacted emissions as hoped. In the US, under RPSs, utilities are being forced into adopting complex systems in order to deal with the intermittent, non-dispatchable energies, primarily solar and wind that they are required to take on. The case for FITs in Europe looks no better. The UK based Renewable Energy Foundation finds the cost of abatement under FITs to be between £174 and £800 per tonne of CO2 (Constable 2011). In Spain, FITs have led to a record deficit of US$8.3 billion for a total 5-year deficit of about US$20 billion[15]. Marcantonini and Ellerman (2013), find the effective marginal abatement costs of European wind and solar policies to be an order of magnitude greater than ETS prices. There are many justifications beyond current carbon abatement for increasing the share of renewables including energy security and reduced imports, issues of technological change and path dependence. Of course, one can still argue that they may be too generous (Fischer, Newell and Preonas 2014), but they should be evaluated with these other benefits in mind. For example, van Benthem, Gillingham, and Sweeney (2008) find that California's solar subsidies are economically justified by learning spillovers, although the environmental benefits alone fall short of the costs.

The European Union has set a goal of 27% share of renewables in energy consumption by 2030; currently it is approximately 14%. Globally, renewables excluding large hydro accounted for 8.5 percent of global electricity generation in 2013. Krozer (2013) looks at the case of Europe's renewables policies between 2002 and 2011 and considers benefits in terms of reductions of CO2 emissions and fossil-fuel imports. He finds that benefits have been higher than the FIT costs for on-shore wind and small hydro during periods of high oil prices. However, the costs of solar photovoltaics have been significantly higher than the benefits and slightly higher in the case of solar thermoelectric (Krozer 2013).

Del Río and Gual (2007) look at the costs of public support for the Spanish RES-E (electricity from renewable energy sources) deployment granted through the feed-in-tariff system (FIT). They find that the total RES-E support costs outweigh the external costs avoided by RES-E deployment for all technologies (Del Río and Gual 2007).

Fundamentally, goals that target the share of renewables have potential at the local level but are limited globally. A co-benefit of increasing global renewable production may be lower costs for developing and emerging economies. CBAs could be quite high for select regions, but globally poor without significant technological breakthroughs to deal with the intermittency and non-dispatchability of renewables.[16]

The European 20-20-20 targets are a combination of emission reductions (20% below

[15] http://www.economist.com/node/21524449
[16] This of course does not apply to storage hydro but rather solar and wind.

1990 levels) and share of renewables (20%) by the year 2020. Tol (2012) finds that these targets are unlikely to pass a benefit-cost test], costing twice as much as necessary. He finds a benefit cost ratio of 1/30 with a 3% discount rate and finds that only a 0% discount rate would justify the target (Tol 2012).

The potential to meet the target of increasing global renewable energy production was studied by the International Renewable Energy Agency (IRENA). In the most recent study, the agency found that doubling renewable energy from its current share of 18% to 36% in 2030 was feasible. The reference case, estimates renewable energy production under a business-as-usual scenario, with current and planned renewable energy policies. The reference case estimates that globally 93 exajoules (EJ) of final renewable energy would be produced worldwide.

There are significant limitations associated with the IRENA study. This includes a limited number of countries achieving very high levels of renewable penetration, assumption that fossil fuel energy will be displaced, incremental energy is not created which does not improve the energy access situation in developing countries. Moreover, the assumptions on the benefits (too high) and the costs (too low) are suspect.

In the basic scenario, final renewable energy use increases to 132 EJ but relies heavily on biomass that represents 61% of renewable energy.[17] The net increase is 39 EJ of renewable energy. Although, in theory, additional clean and renewable energy sources could benefit the least developed countries, for a large part, developing countries are not accounted for in the study. Additional benefits would accrue if much of Africa and many of the Asia Pacific nations were the beneficiaries of the additional energy through improved energy access. [18]

The REmap study costs include capital, O&M, and technical details including capacity factors and conversion efficiencies, all measured in real 2010 USD. To achieve the goal of doubling the renewable energy share, worldwide incremental energy system costs are estimated to be $93 billion annually until 2030, while average incremental investment needs are $200 billion annually to 2030 (IRENA, 2014b).

The study results reveal that the annual net incremental investment required to achieve the goal of doubling renewable energy share is US$265 billion until 2030, however, when fuel costs savings are incorporated into the estimate, the yearly costs fall to US$133 billion. To incentivize the substitution towards renewable energy, an estimated US$315 billion per year in subsidies is required. Thus the total annual cost of achieving the doubling the share of renewable energy is in the range of $448 billion to US$580 billion (IRENA, 2014b).

[17] Biomass is somewhat controversial as a low-carbon renewable energy source. Over shorter time horizons, biomass combustion produces almost as much carbon as coal.

[18] REmap analysis covers 75% of projected global total final energy consumption (TFEC) in 2030, with analysis of the following 26 countries: 2 Australia, Brazil, Canada, China, Denmark, Ecuador, France, Germany, India, Indonesia, Italy, Japan, Malaysia, Mexico, Morocco, Nigeria, Russia, Saudi Arabia, South Africa, South Korea, Tonga, Turkey, Ukraine, the United Arab Emirates (UAE), the United Kingdom (UK) and the United States (p.3)

Relative to the reference case, the REmap option shows that additional deployment of renewable energy can yield 8.6 gigatonnes (Gt) of CO2 reductions by 2030. The IRENA author's estimate that the value of the CO2 mitigation ranges from $165 - $640 billion per year (IRENA, 2014b). The benefits associated with the removing both outdoor and indoor air pollution include improved health outcomes and fewer deaths. The benefits associated with displacing some coal and biomass combustion through a savings of $200 billion per year.

The authors of the study also note the trend in rising fossil fuel subsidies, reaching a peak of $544 billion in 2012. Fossil fuel subsidies would be reduced through the displacement of high carbon energy with renewable energy. Thus the maximum fossil fuel subsidy would $544 billion (IRENA, 2014a) and would presumably decline as more renewable energy displaces fossil fuel-fired generation.[19] However, the ability for renewables to displace fossil fuel fired generation in the countries that are part of the study, is suspect.

> As variable energy resources, such as wind, run-of-river, and solar penetrate the grid, they require additional firm generation to backstop their intermittency. According to the North American Electric Reliability Corporation (NERC), the increase in VER [variable energy resources] necessitates additional transmission to smooth the intermittent output across a broader region and to deliver ramping capability and ancillary services In a grid without transmission constraints, the location of these firming resources can be geographically disperse (Sopinka and Pitt, 2013).

Expecting that renewable energy to fully-displace fossil fuel, as is assumed in the IRENA study, overstates the capacity of VER and understates the importance placed on grid reliability. For these reasons, our assessment of the benefits associated with doubling renewable energy will not include the substantial reduction in fossil fuel subsidies valued at $544 billion. In addition, the cost savings attributed to CO2 mitigation amount to approximately $75/tCO2, which is 50% higher than the typical estimate for carbon emissions reductions. At $50/tCO2 and expecting only half the carbon emissions reductions, the environmental benefit of doubling renewable energy would be a maximum of $215 billion.

SUMMARY

Total Costs of Doubling Renewable Energy: $448-$580 billion per year.

Total Benefits of Doubling Renewvale Energy: $415 billion per year.

BCR: 0.72 - 0.92

[19] Increasing renewable energy through variable energy sources such as wind and solar technologies does not decrease firm energy (likely produced with fossil fuels as a primary energy input) one-for-one, as additional energy is required to backstop any intermittency and deliver other necessary ancillary services that variable sources cannot provide.

Target 4: Phasing Out Fossil Fuel Energy Subsidies

At the Pittsburgh G20 summit of September 2009, Canadian and other G20 leaders agreed to "phase out and rationalize over the medium term inefficient fossil fuel subsidies while providing targeted support for the poorest[20]." In the G20 summits since Pittsburgh 2009, leaders have reiterated their intent to phase out inefficient fossil fuel subsidies. The 2010 Toronto Declaration encourages the continued and full implementation of country-specific strategies to phase out fossil fuel subsidies. The November 2010 Seoul Summit Leader's Declaration added the concept of mitigating excessive fossil fuel price volatility. Most recently the Saint Petersburg Declaration states:

> We reaffirm our commitment to rationalise and phase out inefficient fossil fuel subsidies that encourage wasteful consumption over the medium term while being conscious of necessity to provide targeted support for the poorest. We welcome the efforts underway in some G20 countries as described in the country progress reports. We welcome the development of a methodology for a voluntary peer review process and the initiation of country-owned peer reviews and we encourage broad voluntary participation in reviews as a valuable means of enhanced transparency and accountability. We ask Finance Ministers to report back by the next Summit on outcomes from the first rounds of voluntary peer reviews.

As a member of the G20, Canada has officially recognized that efforts to deal with climate change, wasteful energy consumption, market distortions and barriers to clean energy investment are undermined by fossil fuel subsidies. Despite the commitment to phase-out inefficient fossil fuel subsidies, the 2013 IEA World Energy Report estimates that worldwide fossil fuel subsidies rose to 544 billion $US in 2012 up from 523bn in 2011 and approximately 400bn in 2010. Most of the increase has been tied to energy price increases as well as the global economic crisis during which governments have increased support to industry. If the G20 initiative is having any effect, the two aforementioned countervailing pressures have been dominating.

Multilateral cooperation to back fossil-fuel subsidy reform has continued to develop. This commitment was reinforced in 2010 by a leaders' statement from 21 Asia-Pacific Economic Cooperation (APEC) countries. The Friends of Fossil Fuel Subsidy Reform, a group of eight non-G20 countries[21], was established to encourage the transparent rationalisation and phase-out of inefficient subsidies. Four years have now passed since leaders of the G-20 and Asia-Pacific Economic Cooperation forum (APEC) committed to phase out inefficient fossil-fuel subsidies that encourage wasteful consumption. G-20 countries have begun undertaking voluntary peer reviews of each other's subsidies and reform efforts. The high-level panel reporting to the United Nations Secretary General has recommended that a goal of achieving sustainable energy be included in the post-2015 Development Agenda, which will succeed the Millennium Development Goals, and this objective should encompass the phasing out of fossil fuel subsidies.

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[20] http://www.g20.org/documents/?query=leaders+declaration&extended_mode=0

[21] Costa Rica, Denmark, Ethiopia, Finland, New Zealand, Norway, Sweden and Switzerland

It has been well documented that some EU countries subsidize fossil fuel energy production and distribution, although some efforts are being made across the EU to phase them out. In March 2012 EU Climate Commissioner Connie Hedegaard joined a long line of individuals and institutions calling for the phase out of such subsidies ahead of the June 2012 Rio+20 Summit. Artificially low energy prices are a key driver for inaction on energy efficiency since they inherently weaken the economic case for investment. They also undermine the prices signals that carbon prices are meant to deliver to the market.

The benefits of eliminating fossil fuel subsidies are numerous: simplification of tax system, efficiency gains, reducing trade distortions, and meeting environmental goals. Depending on the number of countries that participate, the speed at which they remove their subsidies, subsidy reform could lead to a predictable source of governmental funding, from a few billion to many billion dollars a year. Subsidy expenditures aggravate fiscal deficits, and have been shown to crowd out both public spending in other crucial areas as well as private investment, including in the energy sector. For energy exporters, subsidies quicken the depletion of resources and can thereby reduce export earnings over the long term. For net energy importing countries, subsidies can also impose a significant fiscal burden on state budgets, exert pressure on the balance of payments through higher energy consumption, and also promote smuggling to neighbors with higher domestic prices. As higher-income households capture most subsidy benefits, energy subsidies have important distributive consequences that are often not fully understood.

Globally, subsidies have been shown to encourage wasteful consumption, exacerbate energy-price volatility by blurring market signals, incentivize black market fuel, and undermine the competitiveness of renewables and more efficient energy technologies. Under-priced fossil fuel energy distorts resource allocation by encouraging excessive fossil energy consumption, artificially promotes capital-intensive industries, reduces incentives for investment in renewable energy, and accelerates the depletion of natural resources. From a consumption perspective; fossil fuel subsidies undermine international efforts to avert dangerous climate change and negatively affect air quality. Combustion of fossil fuels contributes to more than 3 million premature deaths a year worldwide, with costs of about 1% and 4% of GDP for the United States and China respectively.

While at the production level, the extraction of fossil fuels can contribute to the pollution of soils and waterways. By acting as an indirect barrier to private investment in energy efficiency and clean energy, fossil fuel subsidies are a significant obstacle to the mobilization of finance to cleaner sectors.

The International Energy Agency (IEA) identifies phasing out fossil fuel subsidies as one of four policies to keep the world on course for the 2-degree global warming target. Similarly, the World Energy Outlook Special Report: Redrawing the Energy-Climate Map, published in June 2013 identified reforming fossil-fuel subsidies as one of the measures that could halt the increase in emissions by 2020 without harming economic growth. Removing fossil fuel subsidies in a number of non-OECD countries could reduce world Greenhouse Gas (GHG) emissions by 10% in 2050. In the short term, a multilateral phase out approach over the years 2013-2020 could increase global trade by 0.1%. In the long term, assuming that the subsidies are efficiently reallocated, the shift would actually raise global GDP by 0.5% by 2050. Accelerated action towards a partial phase-out of fossil-fuel subsidies would reduce CO2 emissions by 360 Mt in 2020 (IEA 2013). Redirecting subsidies away from fossil fuels, collecting adequate royalties on their extraction and taxing activities that emit GHGs could fight climate change and finance green alternatives all at the same time.

The International Monetary Fund has documented that eliminating fossil fuel subsidies together with imposing carbon taxes would immediately reduce worldwide carbon dioxide (CO2) emissions by 13 per cent. If solely the fossil fuel subsidies in certain developing countries were eliminated, GHG emissions would be reduced by more than 10 per cent by 2050, compared to the baseline (OECD 2013). Global fossil-fuel subsidies, which jumped to $523 billion in 2011, are providing an incentive to emit CO2 that is equivalent to $110 per ton (OECD/IEA 2013) for the sectors covered in third world countries.

European Union

In 2009 the EU's influence on energy issues increased with the adoption of the Treaty of Lisbon within which energy is identified as shared competence between the EU and Member States. Consequently, in Europe both the European Commission and individual states have legal authority to set energy objectives and legislation.

In March of 2009 the European Commission enacted binding legislation within its climate and energy package in order to achieve the '20-20-20' targets. These targets include a 20% reduction in EU greenhouse gas emissions from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20%; and a 20% improvement in the EU's energy efficiency.

Subsequently, in 2010, the EU Council Decision 2010/787/EU stipulated the phase-out of subsidies for the production of coal from uncompetitive mines by end of 2018. Europe's growth strategy for the decade from 2010-2020, Europe 2020, includes a call to Member States "to phase out environmentally harmful subsidies (EHS), limiting exceptions to people with social needs".

Germany

Germany is a G20 and EU member as well as net energy importer. The production of hard coal in Germany has traditionally attracted government support for geological, historical and political reasons. The total, nominal value of estimated financial assistance for hard coal amounted was reduced from EUR 5 billion in 1999 to EUR 2.27 billion in 2011. In accordance with the EU Council decision, Germany plans to discontinue subsidized coal mining in a socially acceptable manner by the end of 2018. The catalyst for this reform however may be that the production of hard coal in Germany remains fundamentally uneconomic[22]. After 2019, subsidized coal will no longer be produced in Germany. (OECD 2013)

[22] German production costs are on average four times the price of imported coal

According to a Cambridge Econometrics report (2013) to the European Commission Germany, removal of three subsidies[23] to producers would result in a very small increase in GDP (up to 0.03% for all three subsides combined) compared to the baseline and a 0.1% fall in energy consumption and CO_2 emissions.

Germany also has numerous exemptions from its energy taxes primarily aimed to address concerns over international competitiveness in industrial sectors. This in part reflects the unique structure of the German economy, with its reliance on producing high-quality manufactured goods for export. These subsidies are not deemed 'inefficient' by the German government and are currently not being considered for phase-out.

United Kingdom

The UK G20 and EU member and became a net energy importer in 2004 after 25 years as an exporter. The UK has significant producer and consumer subsidies that are in the process of reforms. The main type of producer subsidy remaining in the UK is in the oil and gas sector and relates to tax allowances to partially offset the petroleum revenue tax (PRT). In 2011 The United Kingdom gave £280 million in tax credits to the oil and gas sector. Domestic support, the largest subsidy for fossil fuels in the UK, is the lower VAT rate of 5% for domestic energy supplies (compared to 20% for the economy as a whole). Reductions in producer support have been accompanied by increased support to consumers through reduced VAT to fuel and power to offset the price increases over the last few years. The UK also imposes a climate change levy (CCL), end-user carbon tax, however discounts are offered for eligible energy intensive users. Exemptions from the CCL are considered a subsidy within the OECD and IMF methods of identifying subsidies.

A Cambridge Econometrics report (2013) to the European Commission, finds that phasing out the UK VAT exemption on heating fuels would have small net impacts at the macroeconomic and sectoral level. GDP is almost unchanged by 2020, with a very slight increase.

Sweden

Sweden is a G20, EU and Friends of Fossil Fuel Reform member. Sweden's fossil fuel subsidies are limited to exemptions and reductions from energy and CO_2-taxes that benefit particular users and uses of fossil fuels. Sweden has extremely ambitious environmental and climate policies as exemplified by their energy tax, a CO_2 tax, NO_x and a sulphur tax (Swedish National Audit Office, 2012). Sweden has announced plans to increase the reduced rates on many fuels and uses, therefore further reducing their tax expenditures in the coming years.

Until the end of 2010, greenhouses and the agricultural sector were granted a full energy-tax rebate for fossil fuels used for heating. In 2011, the energy-tax exemption was replaced by a 30% reduction in the standard tax rate on heating fuels. Since its introduction in 1991

[23] Energy-tax breaks for agriculture and manufacturing, peak equalisation scheme, and the tax relief for energy- intensive processes.

the exemptions from the carbon tax have evolved and been reformed. Sweden has reformed the exemption/subsidies related to its carbon tax twice in recent years. The first reform, in 2008, tackled the double taxation faced by industries covered by both the carbon tax and the EU ETS, and the second, wider reform in 2009 brought about a more general reduction of the tax exemptions and sought to convert the carbon tax into a more universal instrument. In 2011, natural gas and LPG exemption were reduced from 41% and 48% respectively to 30%. Also in 2011, heating fuels in agriculture and forestry exemption were reduced while the mining industry relieved and increase in its energy tax exemption from 84% to 86%. The Swedish government has outlined objectives to phase out all energy and CO2 tax exemptions. The Swedish experience shows that worries about competitiveness and carbon leakage can be mitigated through gradually declining tax exemptions for affected sectors.

A Cambridge Econometrics report (2013) to the European Commission, finds that phasing out Swedish fossil fuel subsidies would lead to modest reductions in energy consumption and emissions, at no economic cost (i.e. no reduction in GDP). If the consequent revenues are used in an efficient manner, then a small economic benefit might be possible, largely due to reduced imports of fossil fuels.

Norway

Norway is a member of the Friends of Fossil-Fuel Subsidy Reform, a global leader in sustainable development, highly transparent and the third-leading exporter of oil and natural gas in the world, after Russia and Saudi Arabia. Subsidies in the Norwegian oil and gas industry are limited to a faster rate of capital depreciation in the oil and gas sector for tax purposes compared to other industries, the funding of petroleum research and funding of seismic exploration. Norway has a tax on CO2 and SO2 and NOx with numerous exemptions for industries hardest hit by the measures. Petroleum producers are required to pay these emissions taxes, a special resource tax and regular corporate income tax. Norway uses the taxing of fossil fuels and to pay for the R&D and exploration subsidies. There are nine subsidies that are offered to the oil and gas sector, totalling around $4 billion per year in 2009, although these are forecast to be declining over time (GSI 2012).

Many African countries need to subsidize energy so that their citizens can afford the energy services, often provided by imported energy. Subsidies are targeted at the poor but may miss their original target and energy price subsidies are a heavy burden on the public purse. The progressive elimination of subsidies and redirection of public support towards energy efficiency and other mitigation measures, mean that government resources may be more efficiently allocated (Koskimäki 2012).

The IEA's latest estimates indicate that fossil-fuel consumption subsidies worldwide amounted to $544 billion in 2012, slightly up from 2011 as moderately higher international prices[24] and increased consumption offset some notable progress that is being made to rein in subsidies. Subsidies to oil products represented over half of the total (IEA 2013).

[24] Higher international prices amplify local macroeconomic volatility by increasing subsidies (expenditures) for fossil fuel producing countries.

Studies show the benefits of eliminating fossil fuel subsidies are numerous: simplification of tax system, efficiency gains, reducing trade distortions, and meeting environmental goals. Fossil fuel subsidies in developing and emerging economies target end-users and result in under priced electricity and the consumption of additional coal, oil and natural gas. In 2011, fossil fuel consumer subsidies in developing and emerging economies were estimated at USD 523 billion (IEA 2012), up to six times that of OECD countries. The benefits of reform that are of particular significance to developing countries include additional revenues for public health and education, reduced smuggling, reduced budgetary deficits, improved energy efficiency and various bottom quintile endeavours. Unfortunately, the case for reform in developing countries is less clear particularly because of the potentially regressive welfare effects. Despite the fact that the wealthiest 20% generally benefit the most from energy subsidies, the poorest 20% would be hardest hit by reforms (IMF 2013). Yemtsov (2010) summarizes the effects of various energy subsidy reforms on the poorest 20% in 9 developing countries and finds a negative effect on real income ranging from 1.8 to 16%. However, the very poor without access to modern energy derive no benefit from subsidies and so reform would certainly benefit them with appropriately recycled revenues. The IMF (2013) study, Case Studies on Energy Subsidy Reform, highlights the difficulties of protecting those at the lower ends of the economic spectrum from higher fuel prices resulting from subsidy reform.

Some regional studies of the impacts of fossil fuel reform in developing countries find negative outcomes for GDP in the short to medium run. For example, Lin and Jiang (2011) examine the impacts of energy subsidy reform in China and find lowered energy demand and emissions but also reduced welfare, GDP and employment (− 2.03%, − 1.56% and − 1.41%, respectively). If one considers the non-priced benefits such as the social cost of carbon, the impacts on welfare may be improved. In the 2014 IMF report 'Getting Energy Prices Right' the potential revenue from correcting energy prices (subsidy removal and appropriate taxation for externalities) is equivalent to 2.6% of GDP globally. In addition, they find a reduction of carbon emissions of up to 23% and a reduction of mortality due to outdoor air pollution of 63%. The benefit of these reforms will depend heavily on the manner in which the revenue is recycled but if done with the intention of minimizing the impacts to the poor they will be extremely large and equitably distributed. The OECD 2011 working paper, "The Trade Effects of Phasing Out Fossil-Fuel Consumption Subsidies" finds that multilateral subsidy removal results in a slight increase in global real income but is not specific about the value. With only non-OECD subsidy reform they find regional welfare improvements ranging form 0.4%-4% by 2050 (greater than for global reform). This suggests that developing countries would benefit from taking the lead on this target.

Recycling of revenues to energy efficiency measures, electrification, health and education along with the benefits of reduced emissions is thought to yield overall positive benefit-cost ratios for reform but the data is limited. Notwithstanding the potential distributional and welfare risks associated with reform, there have been significant developments in non-OECD countries. For example in 2013, Ghana completely removed subsidies to gasoline, diesel and LPG; in Indonesia, the price of gasoline, diesel, and electricity were raised 44%, 22% and 15% respectively; Pakistan raised electricity rates by 30%; and India reduced its budget for petroleum subsidies by 30% relative to 2012. It is imperative that fossil fuel subsidy reform in developing countries be accompanied by offsetting measures to the hardest hit.

SUMMARY

The difficulties in defining and identifying fossil fuel subsidies make accurate estimates about costs and benefits of their removal at an aggregate level impractical. However, all evidence suggests that the benefits in terms of government savings, reduced energy demand, improved health and reduced emissions would largely exceed the transitional costs. In particular if reform were undertaken simultaneously across the world to minimize competitiveness and trade effects, the potential damages would be limited.

Total Benefits: ~$600-$750 billion/year + health benefits + emission reductions.

Total Costs: Administrative costs and distributional impacts to the poorest but these can be mitigated through appropriate revenue recycling.

BCR: Likely >>15 with proper revenue recycling

Target 5: Provide Access to Modern Cooking Fuels to 30% of the Population currently using Traditional Fuels

The first target of universal energy access is momentous across both scale and scope. Although the prime facie assessment is that those benefits will outweigh the potential costs, the complexity of achieving the goal may lead to its undoing. A less ambitious but potentially more fruitful avenue is to concentrate funding and efforts on first providing modern cooking fuels to 30% of the population who currently rely, and will continue to rely, on traditional solid fuels

It is estimated that by 2030, 2.6 billion people will rely on solid fuels (e.g., wood, coal and other solid fuels such as animal waste) and this fuel use pattern is the cause of 4.3 million deaths due to exposure to IAP during cooking, which disproportionately affect women and small children. In addition, solid fuels induce a variety of negative socio-economic impacts countries reliant on their use including inefficiencies in fuel gathering, cooking times, and emissions. Times savings from collecting and/or preparing the solid fuels for cooking detracts from the time that could be spent engaging in more productive economic activities.

Although the problem of solid fuel use and inefficient cooking apparatus is widespread, there is evidence that a targeted approach would yield higher benefit-cost ratios when compared to the goal of universal access. Jeuland and Pattanayak (2012) find that the best options for a household are fuel switching from traditional wood-burning stoves to kerosene or LPG, or from traditional to improved charcoal burning stoves.

The elevated private net benefit is one that the UN explored in entering into a public-private partnership with the World Liquefied Petroleum Gas Association (WLPGA).The purpose of the partnership was to address the lack of energy globally and to aid in the achievement of the Millennium Development Goals.

Pauchuri et al. develop cost curves for providing modern cooking energy carriers and stoves under different levels of fuel price support and microfinance loans (Fig. 6).

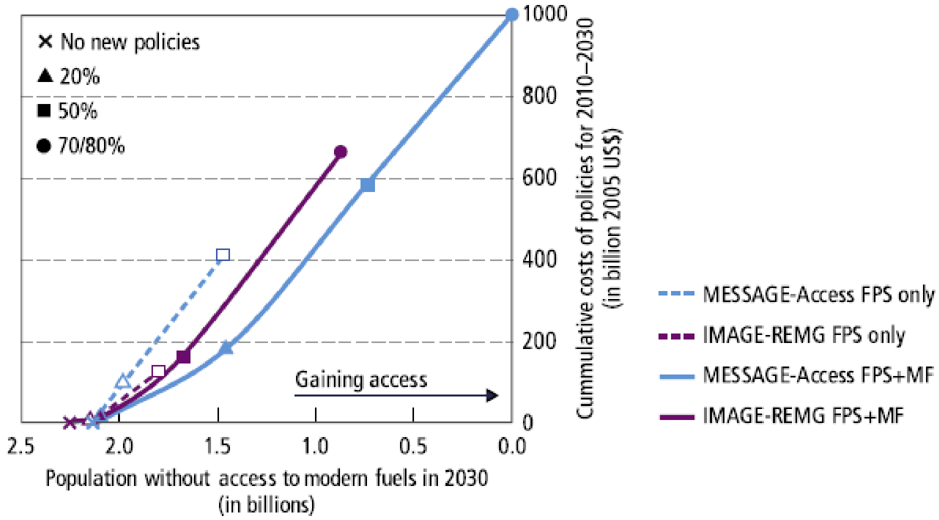

FIGURE 6: COST CURVES OF IMPROVING ACCESS TO MODERN COOKING FUELS UNDER DIFFERING LEVELS OF FUEL PRICE SUPPORT AND MICROFINANCE LOANS.

Providing access to the 30% of the population without access to modern fuels in 2030 would reduce the total number of people without access by about 780,000. This improvement could be achieved at a cumulative cost of less than $200 billion in US2005 dollars, or about 2010US $223.3. In annual terms this amounts to $11.2 billion over the 20 year period.

Using the same assumptions from Target 1 (death from IAP = 32 DALYS lost, $1,000 to $5,000 per DALY) access to modern cooking facilities provide $41.3 - $206.4 billion in benefits (from avoided deaths) when 30% of the population is served. The improved health benefits are estimated by valuing 30% of the annual DALYs associated with IAP. Thirty percent of the 41 million DALYS currently attributed to IAP, results in 12.3 million DALYS avoided. Applying a low estimate of $1,000 and a high estimate of $5,000, creates an additional health benefit of $12.3 - $61.5 billion.

Costs of Achieving 30% Access to Modern Cooking Fuels: <$11.2 Billion Per Year.

Benefits of Achieving 30% Access to Modern Cooking Fuels: $53.6-$267.9 Billion Per Year.

BCR: >4.8-23.9

Target 6: Doubling Investment in R&D in Energy Technologies

There is little disagreement that research, development and demonstration (RD&D) of advanced technologies will be crucial to meeting future energy challenges. Margolis and Kammen (1999) wrote a seminal paper on the low levels of energy D&D in the US and globally. The concern of underinvestment in energy RD&D has been supported by Sagar and Van der Zwaan (2006), Nemet and Kammen (2007), Popp and Newell (2012), Sterlacchini (2012) among others (Margolis and Kammen 1999, Nemet and Kammen 2007, Galiana and Green 2009, Nemet 2009, Galiana and Green 2010, Prins, Galiana et al. 2010, Hoffert 2011, Galiana and Green 2012, Leng Wong, Chia et al. 2013, Prins, Caine et al. 2013). Total investments in R&D as a share of GDP are around 2.5% for the Americas, 1.9% for Asia and Europe and 0.9% for the rest of the world. Although energy R&D is forecast to increase 4.8% to $22 billion globally for 2014, equivalent to approximately 1.4% of total global R&D and 0.02% of gross world product. From a developing country perspective RD&D at the regional and local levels will be key to developing appropriate technologies to meet the needs of each region. The benefits of research and development have largely been considered as long-term investments in future energy improvements. Innovations in extraction, transportation, distribution, fuel sources, efficiency and energy use are but examples of potential cost saving or productivity enhancing benefits. Focus areas include smart grids, storage, clean coal, solar, wind, advanced nuclear, hydrogen and fuel cell technologies among others. The effect of increased R&D expenditure may lead to better energy efficiency and renewable technologies that may also benefit environmental sustainability. It is unfortunate that estimates of these benefits are extremely imprecise due to long-time frames, discounting and complex counterfactual forecasts of technological development.

R&D has been traditionally focused on the development of individual technologies but systems approaches are coming of age as an awareness of the benefits of evaluating energy systems as a whole becomes clear. Holmes (2013) discusses the benefits of energy system R&D and shows that the benefit-to-cost ratio of R&D systems research can be substantially higher than for individual technology development. Since systems approaches are still in the early phases there is potential for significant results in the short term, another example of cost-effective low-hanging fruit.

Leng Wong, Chia et al. (2013) look at the impacts of economics growth and renewable energy R&D on fossil fuel consumption. There are several main findings in this study. With respect to energy R&D they find an indirect effect of higher economic growth on fossil fuel consumption that works through renewable energy R&D. Higher economic growth promotes renewable energy R&D and renewable energy R&D in turn reduces fossil fuel consumption as renewable energy R&D has negative and significant effect on fossil fuel consumption. They provide a novel view of the short term benefits of energy R&D showing that output is dependent not only on energy consumption but also on energy R&D.. They show that in countries that remain highly dependent on fossil fuels, fossil fuel R&D is found to be more important for economic growth than fossil fuel consumption. The impact of fossil fuel R&D reduces manufacturing costs with improved efficiency to fossil fuel usage. Renewable energy R&D is shown to cause positive and significant effects (1 – 1.4%) on economic growth within the countries without oil reserves. The contribution of energy R&D to economic growth is confirmed in both their estimations. If output is in fact more responsive to changes in fossil fuel R&D than fossil fuel consumption this may suggest increasing energy R&D could be a powerful policy instrument in developing countries.

Energy R&D has numerous potential co-benefits, beyond GDP growth, including spillovers into other sectors, employment and environmental benefits in the short run (2030) as well as the expectation of technological breakthroughs to address the long-term issues (2050-2100) (Galiana and Green 2010).

Galiana and Green (2009, 2010 and 2012) have shown BCAs of increasing clean energy RD&D can be expected to be anywhere from 2 – 30 depending on expectations of success and discount rates. The results from Wong, Chang et al. (2013) alone virtually guarantee a BCA of greater than 1, add to that the co-benefits, breakthroughs and environmental and welfare gains and it is easy to see the benefit of such a policy. Moreover, the transfer of current subsidies to fossil fuels towards energy R&D could cover the costs of the policy.

PART 3

Target Recommendations for Post-2015.

The Post-2015 development agenda should provide ambitious goals founded in a realistic understanding of trends, key players, interests and issues. What is clear from an energy perspective is that all considered targets have positive BCAs. The 'zero target' is the least positive as providing access to the last percentiles will exhibit increasing marginal costs with constant marginal benefits. Our analyses suggest that target 5 Provide Access to Modern Cooking Fuels to ~30% of the Population and Target 6: Doubling Investment in R&D in Energy Technologies should be the top priorities for a Post-2015 development agenda.

Table 2: Benefit-Cost Summary

	BCR (range)	Comments
Target 1: Universal Energy Access.	***4.3.-7.8***	Aspirational goal but BCR can be improved by redefining as a subset (global electrification, universal modern cooking) of the original target.
Target 1a: Universal electrification.	***4.6-10.2***	
Target 1b: Universal modern cooking facilities.	2.9-14.7	
Target 2: Double the Rate of Energy Efficiency Improvement Globally.	2.4 – 3.0	Much higher for specific regional programs particularly in inefficient rapidly growing regions. BCAs up to ~15-20
Target 3: Double the Share of Renewable Energy Globally	0.72-0.92	Difficult due to intermittency and storage issues.

Target 4: Phasing Out Fossil Fuel Energy Subsidies	>>15	Policies must be put in place to protect the most vulnerable. Namely appropriate revenue recycling.
Target 5: Provide Access to Modern Cooking Fuels to 30% of the Population	>4.8-23.9	
Target 6: Double RD&D in Energy Tech.	2-30	RD&D in energy technologies will be essential to achieving global sustainable energy access.

Universal electrification, energy access and access to modern cooking facilities are all valuable targets but the universality implies increasing costs at the limit and thus suggests a more restrained target would result in greater benefit-cost ratios. As ambitions and hopes for the future they are all valid but they are primarily limited by the lack of technological readiness to achieve them. Technological innovations will be required to improve benefit cost ratios of energy targets and subsidizing RD&D, although not he only route, appears to be the most likely to accelerate the appearance of these innovations. Energy is essential to development and as such any target that stimulates greater energy access will yield positive benefit cost ratios. Moreover, if inequality is considered, energy access becomes the most important target. It is unfortunate that current technologies require a trade-off between sustainability and full energy access. Until the low-carbon energy sources solve the issues of intermittency and storage, energy access will be shaped primarily by fossil fuels. The benefits of appropriately pricing energy, in particular fossil energy, through subsidy and taxation reform will be all the more important until alternative low-carbon energies can be reliably delivered.

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This paper was written by Isabel Galiana, Lecturer in Department of Economics at McGill University and Amy Sopinka, Senior Research Analyst at Institute for Integrated Energy Systems at University of Victoria. The project brings together more than 50 top economists, NGOs, international agencies and businesses to identify the goals with the greatest benefit-to-cost ratio for the next set of UN development goals.

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