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Reassessing Renewable Energy

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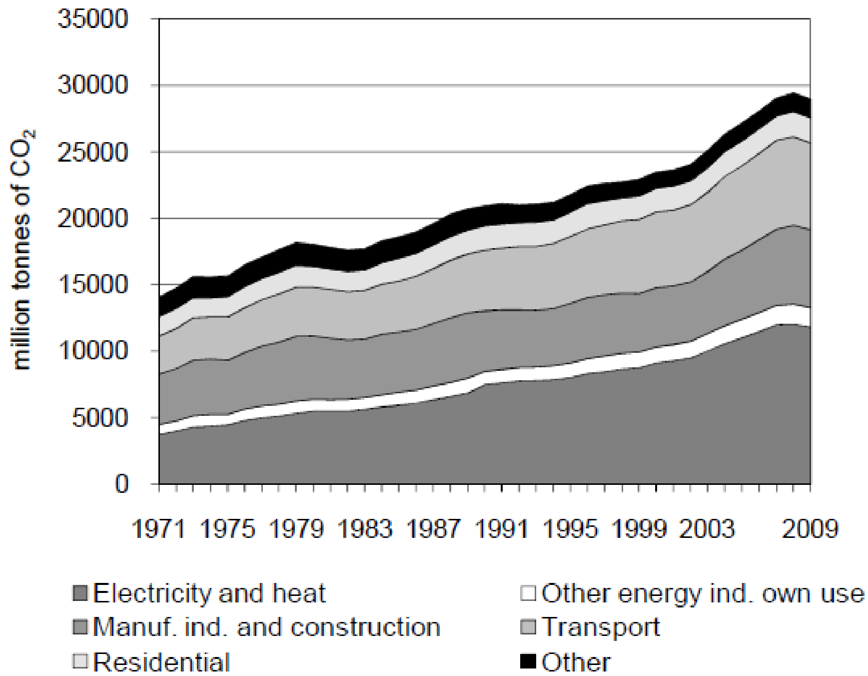
Reassessing Renewable Energy[1]

Renewable energy contributes not only to mitigate climate change and reduce other environmental problems, it also contributes to diversify the energy mix and may support local economic development. Replacing fossil fuels with renewable energies and other low-carbon energy sources will reduce greenhouse gas emissions (GHG) and curb global warming. To achieve ambitious climate stabilization goals, renewable energy technologies (hydro power, bioenergy, biomass, solar, wind, and geothermal) as well as low-carbon energy sources (nuclear and power plants equipped with carbon capture and storage (CCS)) are expected to play an important and increasing role.

Most of the anthropogenic GHG emissions come from the combustion of fossil fuels in cars, industries and power generation. In 2004, fossil fuel combustion accounted for around 57 % of all anthropogenic GHG emissions (Rogner et al. 2007). The electricity and heat generation is the single largest source of emissions, accounting for more than 40 % of the global carbon dioxide (CO_2) emissions from fossil fuel consumption. Currently, two thirds of the global electricity are generated from fossil fuels. Thus, CO_2 emissions and electricity generation are intertwined. Policies to reduce GHG to avoid dangerous climate change have to target the electricity sector, because both the magnitude and the share of emissions are crucial for a low-carbon pathway (Figure 1).

Figure 1:
Global CO_2 emissions by sector



Source: **OECD (2011a).**

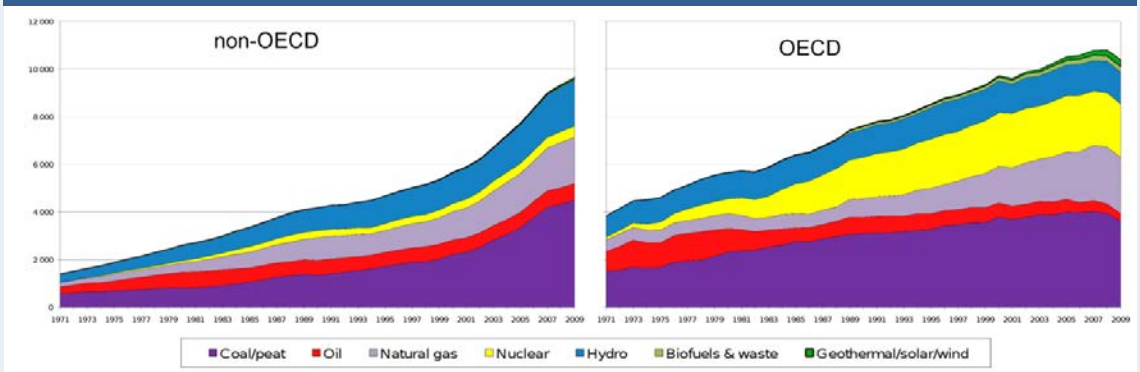
[1] The Policy Brief serves as a background paper for a session of the 2012 Global Economic Symposium in Rio de Janeiro.

This policy brief presents a long term assessment of low-carbon energies including renewables, nuclear and fossil energy with CCS. It targets the electricity sector from a global to a regional perspective and from centralized to decentralized energy systems. The policy brief aims at finding answers to the following questions: What role can and should renewable energy play in the next decades on the way to a low-carbon energy future? What is the optimal electricity mix (now and in the future)? What are the implications of the optimal mix regarding renewable energy investment and policy? What framework would be needed to enhance international coordination?

Challenges in the electricity sector

The global demand for energy and specifically for electricity is likely to continue its current rise. The rapid economic development in emerging economies is a key factor driving up energy demand. In fact, even though electricity generation in OECD countries has more than doubled since 1975, today about half of world's electricity is generated in non-OECD countries (Figure 2). China and India contributed most to this development. Moreover, both countries produce their electricity from coal-intensive utilities, which are a major source of CO_2 emissions and several air pollutants including sulphur dioxide, oxides of nitrogen and particulate matter. Generation from coal is now larger outside OECD countries than in OECD countries. Population growth, rising per capita incomes as well as changing consumption patterns especially in developing countries are key drivers for increased energy consumption.

Figure 2:
Global electricity generation in TWh by fuel



Source: **OECD/IEA (2011b).**

However, the increasing energy demand coupled with the current electricity generation mix is unsustainable as it causes severe environmental problems. Air pollution caused by energy systems are estimated to cause to about 5 million premature deaths (van Vuuren et al., 2012), predominantly at the local level. At the global level, CO_2 emissions causing climate change are the major concern. To reduce emissions from the electricity sector, generation from coal and to some extend from natural gas will have to be replaced by low-carbon alternatives including energy from hydropower, bio-energy, solar, wind and nuclear or CCS technologies.[2] None of these technology options appears to be a silver bullet, since there are drawbacks from nuclear (potential risk and storage of spent fuel), CCS (uncertainty on costs and lack of demonstration plants and public acceptance), or renewable energy (some technologies have negative side effects on land-use, as well as intermittency).

Globally, the target to keep the temperature rise from climate change within two degrees has been acknowledged in the Copenhagen accord. However, the "door to reach [this] target is closing" (IEA, 2011). To reach the two degree target, the electricity sector has to achieve low-carbon shares of 75 % to almost 100 % in 2050 (van Vuuren et al., 2012).

Future scenarios of energy/electricity mix and solution space

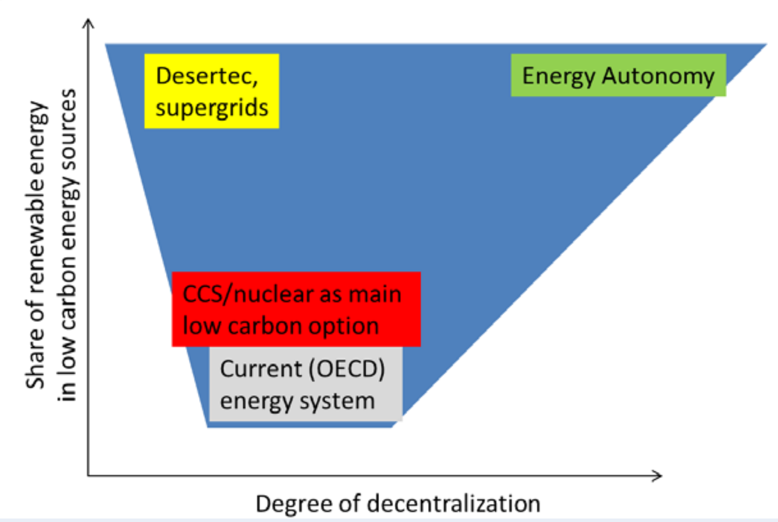
Globally, there is easily enough potential to feed the global electricity demand by using solar or wind energy or other generation options like biomass or geothermal. Jacobson and Delucchi (2011) demonstrate that wind, water and solar energy alone could constitute 100 % of the global energy supply in 2050. In an overview of recent scenarios from energy-economy and integrated assessment models, Krey and Clarke (2011) find that renewable energy shares are expected to increase over the 21st century, but not uniformly across models: Some models follow a path with more energy coming from nuclear or fossil energy with CCS, while other models are more optimistic for renewable energy.

In another dimension, the degree of centralized energy generation might differ between visions for future energy systems. Centralization here is understood as the concentration of market participants or large generation units. Decentralization reduces the distance from production to consumption. For scenarios with high renewable energy shares, both a centralized as well as a decentralized vision would be feasible.

Figure 3 shows the possible solution space along these two dimensions. A system with a low degree of centralization and with a low share of renewables seems implausible, since non-renewable, low-carbon energy technologies such as nuclear or CCS are only possible as large-scale power plants. Box 1 gives three more concrete visions of future energy systems close to the corners of this space. The example of renewable electricity generation in Brazil and its current as well as possible future position in the solution space is presented in Box 2.

[2] Low-carbon refers to the fact that neither of the technologies would have zero carbon emissions, taking into account emissions over the whole life-cycle. All energy technologies would have some carbon footprint for construction of the generation plant and the production of fuel where applicable. CCS only captures about 80–90 % of CO_2 emissions.

Figure 3:
Solution space of future energy systems (blue area) with the current OECD energy system and possible future energy systems



Box 1: Three visions of future low-carbon energy systems:

<u>CCS/nuclear focus</u>: A high share of electricity from power plants equipped with CCS or nuclear could be added to the current grid infrastructure of many (OECD) countries, replacing current coal power plants with high CO_2 emissions. New infrastructure would however be needed for transport and storage of waste (CO_2, spent nuclear fuel). Possible problems include the use of critical technologies in terms of acceptance and risk of damages.

<u>Energy Autonomy</u>: Scheer (2007) envisions production of renewable electricity close to demand, possible with small scale generation facilities. This allows savings on grid infrastructure because consumption location would be in the vicinity of production. Such systems can be set up relatively fast because there is little need for large-scale planning. In developing countries mini- or micro-grids could contribute to electrification of rural areas. On a political level, this could reduce the struggle for ever scarcer energy resources and alleviate geopolitical tensions. Production on-site from intermittent sources such as wind or solar would however require large storage or back-up capacities.

<u>Desertec</u>: Large-scale wind or solar production sites would produce electricity where generation costs are lower because of abundant natural resources within a larger region. For example, in the desserts of northern Africa electricity would be generated from solar power, while the coastal regions of northern Europe specialize in wind energy. Large wind farms or solar power plants would capture economies of scale. When the region under consideration is large and energy sources diverse, less storage would be needed compared to the Energy Autonomy vision, however, high costs are expected from the need to connect the generation and consumption sites via a high-voltage direct current (HVDC) super-grid. This includes also costs for international coordination and planning of a complex technological system. Moreover, several issues arise in such projects regarding political instability, security issues and social impacts.

Box 2: Electricity generation from renewable sources in Brazil
(by Otavio Mielnik, FGV Projetos Consultant):

The Brazilian electricity matrix is dominated by in large hydropower plants linked to an interconnected operating system with a 67 % share. Bioenergy has a 6 % share in electricity supply. The share of other renewables (wind energy, solar power and small hydropower) is marginal (5 %) but relevant as it introduces diversity and additional security to the system. In addition, the expected development of decentralized generation should provide some autonomy to power customers and reduce transmission congestion.

In terms of the solution space of Figure 3, Brazil is in a position with a high share of (centralized) renewables in its current system. In the long term, Brazil could be close to its current more centralized position, but also promoting small scale based generation.

A feed-in tariff implemented under Proinfa (an incentive program for renewables development), set up in 2004, and was the first regulatory incentive mechanism for development of wind energy in Brazil. Proinfa made possible the development of 1,423 MW wind energy that have been purchased by the state-owned electric power company Eletrobras under special conditions. Development of small hydropower plants has been significant since the 1990s and reached roughly 4,000 MW (30 % under Proinfa). Bioenergy power generation capacity is 7,272 MW, partly used in the ethanol and sugar production process while 20 % is being traded through the grid. Bioenergy also plays a large role in providing energy for the transport sector.

In 2009, in the aftermath of the global financial crisis, when renewable programs were postponed in Europe and in the US, a substantial reduction in equipment costs affected the wind energy industry in those countries. The Brazilian wind power potential became an opportunity. As a result, wind energy was traded at competitive prices (US$80/kW in 2010 and US$63/kW in 2011) in Brazilian auctions aimed at providing power to distribution companies and introduced a new pace in the country wind energy development. Total wind power capacity is expected to reach 7,400 MW by 2014.

Wind power development has been connected to the grid. There are 1.455 MW wind farms in Brazil located mainly in the country’s Northeast (in the coastal area of the states of Ceará (519 MW) and Rio Grande do Norte (221 MW), and in the Chapadas area (inland) of the state of Bahia (294 MW in July 2012) and one in the Southern state of Rio Grande do Sul (340 MW).

Since August 2011, the country has its first commercial photovoltaic solar power plant (1 MW capacity) located in the state of Ceará and connected to the grid. A new regulation (from April 2012) makes possible microgeneration by small scale renewables up to 100 kW capacity by individuals. The surplus will be fed into the grid and provide a credit on the customer’s bill. This is expected to have a major impact on development of small scale solar cells and contribute to a more decentralized provision of electricity.

Trade-off between renewables and nuclear and/or CCS

Not neglecting that efficiency improvements are necessary and some focus needs to be put on the demand side, the electricity sector needs to drastically reduce its CO_2 emissions. While any range between 0 and 100 % renewables would be *technically* feasible, it needs to be discussed what range of renewable energy is desirable and how it can be achieved. Many countries provide incentives to renewables and have set targets to increase the share of renewable generation or consumption.

Advancements of current fossil/nuclear based generation technologies would be able to make use of the current infrastructure and a gradual transition would be feasible by replacing current power plants with CCS equipped equivalents. However, future cost development of nuclear or CCS-equipped power plants is highly uncertain.

For CCS, studies expect learning effects as in renewable energy, however, plans to build demonstration plants have been cancelled of delayed in several countries. Without such demonstration plants and currently low prices of CO_2 emissions, it is unclear when the learning benefits will materialize. Furthermore, underground storage of carbon might not be accepted by the population. Finally, CCS from fossil fuels does not achieve a capture rate of 100 %. In the second half of the century, studies analyzing different emission pathways assume negative (net) emissions which would require even lower emissions from the electricity sector than those possible from coal power plants with CCS.

After the Fukushima accident, the risk of nuclear technology became evident and the potential cost associated with this small probability - high impact event of a nuclear accident led to a reassessment of nuclear energy, most notable in Germany. Other countries like China do not fundamentally change their nuclear expansion strategy, but carry out a re-assessment of security. The external costs of nuclear energy posed by the risk of an accident and secure long term storage of waste are hard to assess. Over the past decades however, direct cost for nuclear generation also grew rather than declined (Grubler, 2007). If the Fukushima accident leads countries to require operators to adhere to stricter security standards, this would further escalate costs for electricity from nuclear energy.

Currently electricity generated from renewable sources is however more expensive than conventional electricity. This would be even more the case for high shares of intermittent electricity, e.g. fluctuating wind or solar energy, since additional storage and/or backup capacity would also need to be priced in. However, positive learning rates are observed for several renewable generation technologies and in some regions with high electricity prices and high availability of natural resources such as wind, renewable energy is already competitive. Renewable technologies have the advantage of having zero fuel costs (except biomass), hence running costs are low. However, front-up costs are generally high, access to credit markets is therefore necessary to finance new installations.

Trade-off between decentralized and centralized systems

Figure 3 shows that with a high share of renewable electricity, both more centralized and more decentralized systems would be possible. Compared to fossil or nuclear based generation technologies, renewable energy is better scalable than large centralized systems and can thus be deployed on a more decentralized basis close to the consumer.

Van Vuuren et al. (2012) propose as one of the objectives for a future energy vision to provide universal access to electricity by 2030. Especially in developing countries, decentralized systems are able to improve access to electricity because small grids are relatively easy to be built on a local scale.

More centralized systems need to have stronger and probably “smarter” grid that connects energy markets in a large region. The diversity of a region however could contribute to the utilization of different complementing technologies and reduce the uncertainty of intermittency of any given single technology in a local generation facility. In developed countries, this would require additional investments into the grid infrastructure However, also developing countries with a high potential for renewable energy could be able export. Northern African countries could for example be able to export solar energy to Europe as envisioned in the Desertec project. For such projects regional stability and cooperation must be ensured to not endanger the energy security of importing countries.

The solution space allows for several possibilities to solve the climate change problem. Different regions might be better suited for different points, also a combination of centralized and decentralized energy systems would be possible in the same region. It is unlikely that one of the energy visions presented in Box 1 is implemented in its pure form. Rather a mixture of these visions is likely to emerge from the current perspective. This is very probable, because there is not a sudden change, but rather a transition from the current energy system. The share of renewable energy is likely to increase in the future; the optimal share of renewable energy might also increase over time as the cost structure changes in favor of renewable electricity. Different countries or regions start from different preconditions with differences in their energy mix, stability and coverage of the grid. In the following we lay out several policy recommendations on how to achieve a low-carbon electricity/energy system.

Solutions Strategies

Formulate a global, long term energy vision and act according to it

The climate goal of limiting temperature change to 2 degree is generally acknowledged, for example in the 2009 Copenhagen accord. While this defines a long-term vision, immediate impacts and pathways on how to reach this target are not obvious. It is important to recognize this long term target and countries should commit to reduce CO_2 emissions accordingly. While it is not likely that there will be a full global carbon market in the near future, national policies should be in line with such a vision.

Van Vuuren et al. (2012) propose to have a set of goals forming a vision for sustainable energy, similar to the millennium goals. The goals include universal access to electricity in 2030, reducing air pollution in compliance with guidelines of the World Health Organization, and limit global average temperature change to 2 degree above pre-industrial level. Because these problems are intertwined, it is argued that tackling them together is cheaper than individually. Having an integrated view could maximize co-benefits e.g. from reducing adverse health effects from pollution.

Take into account local circumstances

While there is the need to work on a global solution, the design of the policy to implement it might vary across countries or regions. The solution space to achieve a low-carbon electricity provision allows for a broad range in the degree of centralization and the use of renewable energy. For different regions or countries, the optimal solution could therefore be different. The reasons for this could be manifold: Some technologies might be more suitable for certain regions due to availability of given resources, such as solar or wind, but possibly also other fuel sources (coal/gas/nuclear?). At another scale, the pre-existing grid structure and the share and spatial distribution of the population without electricity access might determine what vision is followed in different regions.

From an economic perspective it is hard to argue for a specific renewables share that would be optimal – most likely this would also be different for different regions and different time horizons. It is uncertain, how costs for different generation technologies will develop – but these costs will be reflected in the future energy mix. It is also unclear how costs of storage or super-grid technologies will develop. Given these uncertainties, it might be useful to abstain from the corner solutions in the solution space provided above.

Formulate a research strategy with a portfolio of technologies

In line with a global vision, research in low-carbon energy technologies is necessary. Technology transfer should be part of the global strategy. Renewable generation technologies often show evidence of a learning rate. That is, with increased (global) deployment, the (real) unit cost decreases. This is most visible in the photovoltaic industry where prices were reduced by about 50 % in the last 3 years. Support policies such as feed-in tariffs to achieve deployment are therefore a suitable measure to decrease the cost of additional capacity in the future.

Rather than just a single technology, a portfolio of technologies should be targeted by R&D funding and support to achieve integration into the market. Research should also focus on grid improvements and storage possibilities. This is less risky because some generation, grid or storage technologies might have technical or economical shortcomings, which we are not aware of today or which are underestimated today. A mix of generation technologies also improves energy security in any given country.

There are also important dynamic effects that affect the development path of the energy system. As Acemoglu et al. (2012) argue, technological change could be directed towards a greener growth path by a combination of carbon taxes and subsidies for environmental technologies. Once these technologies are sufficiently competitive with “dirty technologies”, a pure carbon tax would suffice. Firms would then automatically re-direct their research activities to the environmental friendly alternatives.

Use multiple financing sources

Carbon emissions should be priced to account for the externality of climate change damages. This could work via carbon taxes or an emission trading scheme to achieve efficiency. At the same time, subsidies for fossil fuels should be phased out. A clear strategy derived from the global vision implemented on a national or regional scale helps to achieve the necessary credibility for investment decisions in the energy sector, where plant and grid infrastructure has a long lifetime. This helps renewable technologies (but also other low-carbon technologies) to become more competitive with conventional energy generation.

Renewable electricity generation is often characterized by high initial capital cost but low running costs. The functioning of the credit market as well as stable conditions such as a guaranteed feed-in tariff for several years could therefore contribute to the increase of low-carbon technologies.

In developing countries, the clean development mechanism (CDM), which finances carbon abatement on a project basis, could be further improved to give incentives to engage in renewable energy. Developing countries, where much of the infrastructure for the future is built now, have also more flexiblility setting the path to a sustainable low-carbon development.

Act now to avoid lock-in effects

Delaying action to shift the energy system towards a low-carbon one, leads to higher costs in the long run. Because the total emission budget in line with achieving the two degree target is fixed, more emissions now would mean higher reduction requirements at a later stage. In a study assessing the economic cost of such a scenario, van Vuuren et al. (2007) conclude that “the costs of not peaking global emissions within the next two decades could include higher temperature change and/or more rapid emission reduction rates in the longer term (which can be costly if they would require premature replacement of capital).” The most recent World Energy Outlook (IEA 2011) points out that because the energy system is characterized by inertia, due to the fact that components such as power plants of grid have a very long life, emission for the next years are already pre-determined. Building additional (conventional) power plants now would lead to lock-in effects: Either the power plant is not used over its full live time which leads to economic inefficiency, or the carbon abatement goal becomes more costly as emissions need to be avoided elsewhere.

To avoid lock-in effects, it is necessary to start the conversion to a low-carbon energy system without delay. Dynamic effects could also contribute to the advantage low-carbon energy generation technologies. When delaying a transformation now, more deployment of low-carbon technologies will be needed later to reach a given climate target. An earlier start is however favourable for the development of unit costs due to the learning rates, which can be observed for example in the photovoltaic industry. Learning from early experiences (learning by doing) as well as R&D will likely contribute to a decline in costs.

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