Memo on High-RE Scenarios
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Scenarios for a high penetration of renewable energy:

Considerations about technology, behaviour change and policy

Chapters 11.1-11.6 of the IPCC Special Report on Renewable Energy Sources (IPCC 2011) have laid out the menu of policy options available to policy makers, including an assessment of the efficiency and effectiveness of existing policies, and highlighting the importance of embedding specific policy instruments into a broader set of elements of an enabling environment. This short memo looks into the future, and outlines linkages between scenarios and policy options. It especially addresses the question what the policy options are for decision-makers who attempt at mitigating climate change by achieving a high share of renewables.

1. Methodological Note

While there is now substantial evidence for renewable energy policies in a multitude of countries, the overall share of renewable energy is still limited in most countries, and is below 20 % worldwide. Also, while some countries can now look back upon two decades of renewable energy policy, there is a shorter time series of data available in most countries. Therefore, trying to assess what is needed for achieving a high share of renewable energy is a question that lends itself to ex-post empirical analysis only to a very limited extent so far. As such, any attempt to answer the questions asked in this memo is subject to substantial uncertainties, comparable, for example, to the economic assessment of new technologies for climate change mitigation such as carbon dioxide capture and storage (IPCC 2005). Further research is needed to fully understand the effectiveness and efficiency of policy instruments designed to achieve high penetration of renewables in the long term.

2. The Link between Scenarios and Policies

The 164 scenarios presented in chapter 10 of the IPCC Special Report on Renewable Energy Sources have demonstrated that a wide range of energy futures is possible, differing in their share of renewable energy from approximately 20% to 80% of primary energy by 2050. The scenarios also differ with regard to the level of primary energy consumption that they imply (see figure 1). Conceptually, the scenarios can be distinguished into the four quadrants[1] presented in figure 1. The left part of the graph represents energy-intensive future energy systems, while the right part of the graph is characterized by lower energy consumption. The

[1] The conceptual nature of this figure implies that the boundaries of each quadrant have been chosen for illustrative purposes. To determine a simple 2050 benchmark and position the crosslines in figure 1, we took today's situation (marked by a fine cross in the lower right quadrant) and applied a 1.25% annual growth rate on total primary energy supply and a 2.5 % annual growth rate on renewable primary energy supply.

lower part of the graph shows scenarios with a low penetration of renewable energy sources[2], while the upper part of the graph represents future energy systems with a high penetration of renewable energy sources.

Of the 164 scenarios presented in chapter 10, most of the baseline (or business as usual) scenarios are placed in the lower left quadrant of the graph, which would combine a low share of renewables with high levels of energy consumption. Scenarios in this quadrant tend to result in CO_2 concentration levels of 600 pm or more, as evidenced by the black dots in figure 1. These high-energy intensity, low RE scenarios would not only make the world vulnerable to climate risk, but also imply significant fuel price risk.

The lower right quadrant of figure 1 depicts a world with relatively low penetration of renewable energy in combination with relatively low energy demand. Such scenarios could be a result of a shortage of energy supply or strong changes in energy demand – either as a consequence of fuel price shocks or of active policies – while at the same time no particular efforts were made to support renewable energy. A number of the category IV scenarios (440-485 ppm) are placed here, indicating that there may still be a challenge with regard to climate stabilization.

The upper half of the graph depicts two types of energy futures with widespread deployment of renewable energy ("high RE scenarios"). The scenarios in the upper left quadrant combine significant expansion of renewables with strong growth in energy demand and supply, whereas the upper right quadrant represents a combination of a high share of renewables with higher levels of energy efficiency, to the extent that some of these scenarios actually assume global energy demand to be lower in 2050 than in the base year 2007. When comparing these two versions of a high-RE world, a few differences become apparent. First, while many of the scenarios in the upper right quadrant tend to reach low levels of CO2 concentration, there is more variation in the upper left quadrant. In other words: a high-RE high-energy intensity future seems to bear a higher risk of overshooting global carbon targets. Second, given the need to create energy systems at a larger scale in a world characterized by high energy demand, the scenarios in the upper left quadrant are arguably more capital intensive than the ones in the upper right quadrant. Finally, there are different societal risks involved in the two kinds of high RE scenarios. Those scenarios that combine high RE with low energy intensity rely on either active energy efficiency policies or they assume significant fuel price shocks, both of which may create barriers to political acceptance. On the other hand, the high RE, high energy intensity scenarios rely on greater levels of deployment of RE supply infrastructure, which in turn could be a social acceptance issue in many countries.

[2] Note that the vertical axis shows absolute levels of renewable energy supply, rather than a percentage share of renewable energy, which could be calculated by dividing the values on the vertical axis (renewable energy) by those on the horizontal axis (total primary energy). As a consequence, along the line that distinguishes the "low RE" part from the "high RE" part of the graph, the relative share of renewables varies from about 20 % in the scenarios on the left side of the graph to about 50 % in the scenarios on the right side of the figure.

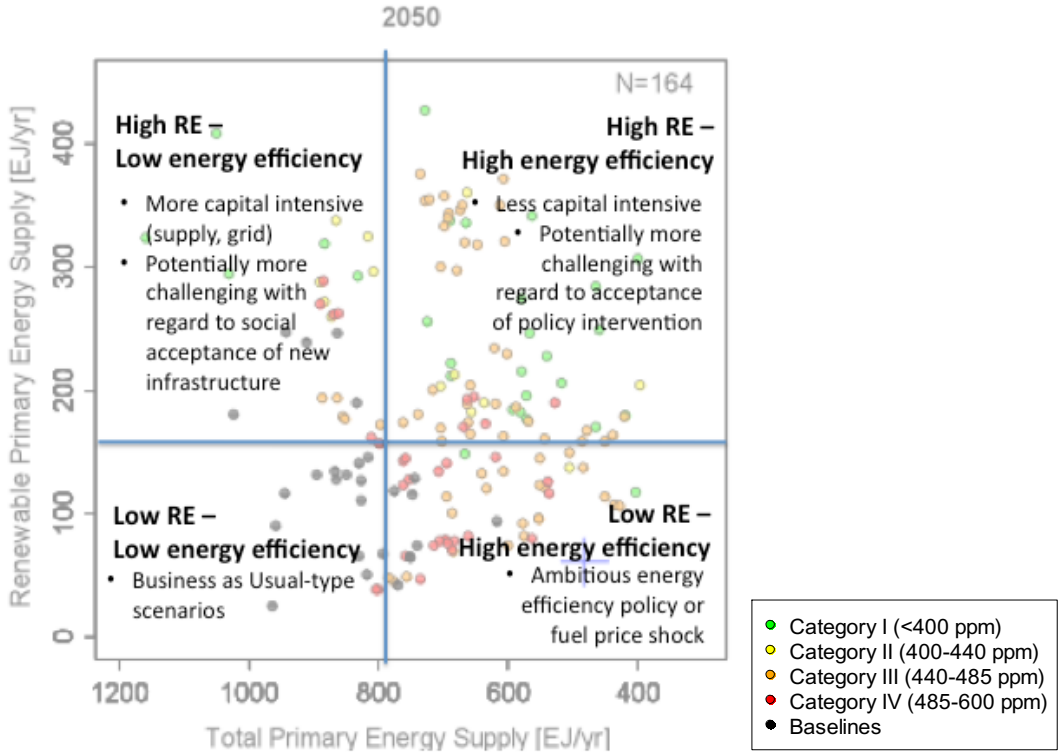


Figure 1: Energy scenarios for high- and low-renewable energy futures[3]

3. Structural shifts result from a combination of technology and behaviour change

An important, yet often implicit dimension of energy scenarios is whether they assume changes to be mainly driven by technological development, or whether they assume changes in behaviour as a driver for future development of energy systems. Figure 2 disentangles the spectrum of possible futures according to these two dimensions (see also Unruh 2002). The vertical axis distinguishes futures characterized by incremental technological changes from those based on disruptive technological change. The horizontal axis characterizes the level of behaviour change that is implied (incremental or disruptive). Most "business as usual" scenarios are based on the assumption that both technological development and behaviour change remain incremental (Quadrant I), leading to a continued rise in energy demand and a focus on deployment of existing renewables. As a consequence, a high penetration of renewable energy is relatively unlikely in these scenarios. Quadrant II ("High-Tech Path") can be referred to as a technology optimistic world (Friedrichs 2010). Scenarios in this camp tend to assume that disruptive technological change (e.g. availability of very low-cost solar cells) may result in a quantum leap in the competitiveness of renewable energies, leading to higher market penetration (for similar arguments related to other examples of low-carbon

[3] Figure shows global RE primary energy supply (direct equivalent) from 164 long-term scenarios as a function of total primary energy supply in 2050. Colour coding is based on categories of atmospheric CO2 concentration level in 2100 (Fisher et al., 2007). The blue cross shows the relationship in 2007. RE deployment levels below those of today are a result both of model output as well as differences in the reporting of traditional bioenergy. Note that some of the scenarios in the upper right quadrant of the figure would migrate to the upper left quadrant if the substitution method would be applied instead of direct equivalent accounting, under which high deployments of non-biomass renewables automatically lead to primary energy reduction. See Appendix A.II.5 and Box 10.1 of the IPCC Special Report on Renewable Energy Sources for methodological details.

technologies see Weizsäcker et al. 1998, Lovins et al. 2004). However, behaviours and lifestyles in quadrant II resemble the business-as-usual world, leading to efficiency improvements that may be compensated by rebound effects (Dimitropoulos 2007), and hence levels of energy consumption that remain high. Quadrant III ("Sufficiency Path") depicts a behaviour optimistic view of the future (Daly 1996, Princen 2003, 2005, Scherhorn 2002). Scenarios in this cluster assume that due to changes in lifestyles and increased awareness for energy and climate issues, energy demand decreases and penetration of renewable energies increases. Such disruptive behaviour change may be supported through active policies, e.g. energy disclosure and awareness campaigns (Markard and Holt, 2003; Boardman and Palmer 2007; Litvine and Wüstenhagen 2011), and could also be a result of external constraints, such as fuel price shocks (Friedrichs 2010, Hirsch 2008). If policy makers would like to build their climate change mitigation policies on an energy mix with a high penetration of renewable energy, it is likely that disruptive changes will have to occur on both levels, i.e. with regard to technology and behaviour. Quadrant IV ("Structural Change") illustrates where such scenarios, which include for example the Energy [R]evolution scenario (Teske et al., 2010), are placed on the map of possible energy futures.

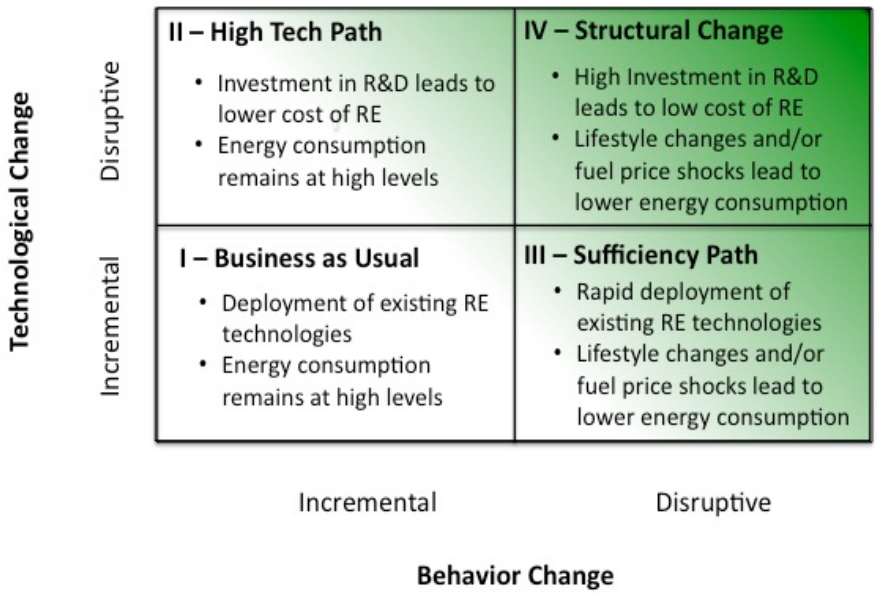


Figure 2: Technology and behavior change as underlying drivers of energy scenarios

4. Policy options for an accelerated transition to a high-RE world

Achieving a high level of renewable energy penetration represents a structural shift from today's energy systems. Facilitating such a transition requires active policy approaches for the following reasons:

- Substantial new investment is needed. In the absence of stable and predictable policy frameworks and clearly communicated long-term targets (SRU 2010, Teske et al. 2010), investors will shy away from such investment due to perceived policy risk (IEA 2007, Bürer and Wüstenhagen 2009).
- The necessary infrastructure investment may require some level of public funding or public-private partnerships (for example grid connection for offshore wind, intercontinental trading of concentrated solar power, new storage facilities) (IEA ETP 2010).
- While low levels of RE penetration can be achieved with a relatively limited number of technologies, a high-RE world is likely to rely on a broader portfolio of renewable energy sources with differing levels of maturity. Sustained efforts of research, development and deployment at significantly higher levels than today will be required to bring these different technologies to market over time (Sandén and Azar 2005; IEA ETP 2010, p. 459; Neuhoff 2009, p. 50).
- Technology R&D alone is likely not going to be sufficient to ensure commercialization of new energy technologies. Countries like the Netherlands have implemented specific deployment policies to create protected spaces for experimentation with new energy technologies, and subsequent scale-up of promising concepts (Voss et al. 2009; Sandén and Azar 2005). Other countries, such as the United States, have created government programmes (e.g. SBIR, Rahm 1993, Lerner 1999) that aim at facilitating technology transfer to private firms, and private investors, especially venture capitalists (Moore and Wüstenhagen 2004), work towards the same aim.
- Two of the currently fastest growing renewables, wind and solar, differ in their generation profile from current power generation technologies. A further sustained growth of these variable output technologies will require adaptation of electricity market rules if inefficiencies are to be avoided (Teske et al. 2010).
- Most High-RE scenarios simultaneously assume a substantial increase in energy efficiency. While some scenarios assume high penetration of renewables at relatively high levels of energy consumption, and technical potential is high for many renewables, a high-RE & high-energy consumption scenario tends to face tighter constraints when it comes to capital requirements and social acceptance issues than a high-RE scenario that simultaneously increases energy efficiency. Such energy efficiency increases may be driven by market forces (e.g. fuel price shocks) or by active policies (e.g. carbon pricing, energy taxes, efficiency standards, labelling) (Teske et al. 2010).
- Both the level of energy consumption and the share of conventional energy in the mix depend on strategic choices made today that are heavily interconnected to other policy areas, notably urban planning and transportation policies (Dowall 1980, Hankey and Marshall 2010). Achieving a high-RE world will depend on early policy integration.
- The magnitude of changes will require public consent to a variety of policies, which in turn implies increased efforts to raise public awareness for energy (West et al. 2009, IEA 2010, SRU 2010, p. 79).

5. Conclusion

Renewable energy is one of the options policy-makers have at hand to mitigate climate change. While considerable evidence now exists in several countries for how policy can efficiently and effectively increase the share of renewable energy, open questions remain as to how this initial growth can be translated into future energy systems where the majority of energy needs are supplied from renewable sources. This short memo has explored aspects in which such long-term structural shifts may differ from some of the shorter term policies that have helped to start renewable energy markets. Achieving the kind of continuity that is needed to secure investment in building up the infrastructure for renewable energy systems poses some important challenges to political systems that tend to operate in short electoral cycles. While it is beyond the scope of this document – and will likely depend on national and regional circumstances – to explain how such general challenges for long-term policies can be overcome, we have identified a number of specific ingredients for successful policies that would support a structural shift towards high shares of renewable energy. These include a balanced focus on technology and behaviour, a prominent role for energy efficiency alongside the development of renewable energy sources, and policies that extend beyond R&D to support technology deployment and the creation of an enabling environment including education and creating awareness. Future research is warranted to monitor how different countries are making progress towards creating effective policy frameworks that help to reap the full benefits of renewable energy towards climate change mitigation and the creation of a sustainable global energy system.

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