FIGHTING CLIMATE CHANGE

100

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FIIA BRIEFING PAPER 100 ▪ March 2012

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- Renewable energies will be *the* major contributor to any future low carbon energy system and the share may be as high as nearly 80% of the world's energy supply by 2050.

- Renewable energies have vast potential but require a set of coherent policies to reach necessary deployment rates, because the market place neither accounts sufficiently for their climate change-related and wider benefits nor for the benefits of technological learning, making them appear less competitive than they really are.

- Renewable energies can be integrated in all supply systems and end-use sectors but at some point they will require investment and change. In electricity, an enhanced Pan-European network infrastructure (smart grid) would smooth variability and the remaining non-renewable generation capacity would be highly flexible.

- Energy security would be enhanced by greater efficiency and a broader and less import-dependent energy portfolio with less vulnerability to energy price volatility. Network stability needs to be addressed but some renewable energies are fully dispatchable and part of the solution.

- The transition to renewable energies is possible and beneficial, not only due to climate change but also because it serves energy security concerns and necessary infrastructure improvements. The EU's proposed long-term strategy concerning emission reductions and competitiveness, as well as the related legislation, is moving in the right direction and it is up to the member states to pick this up and push it forward.

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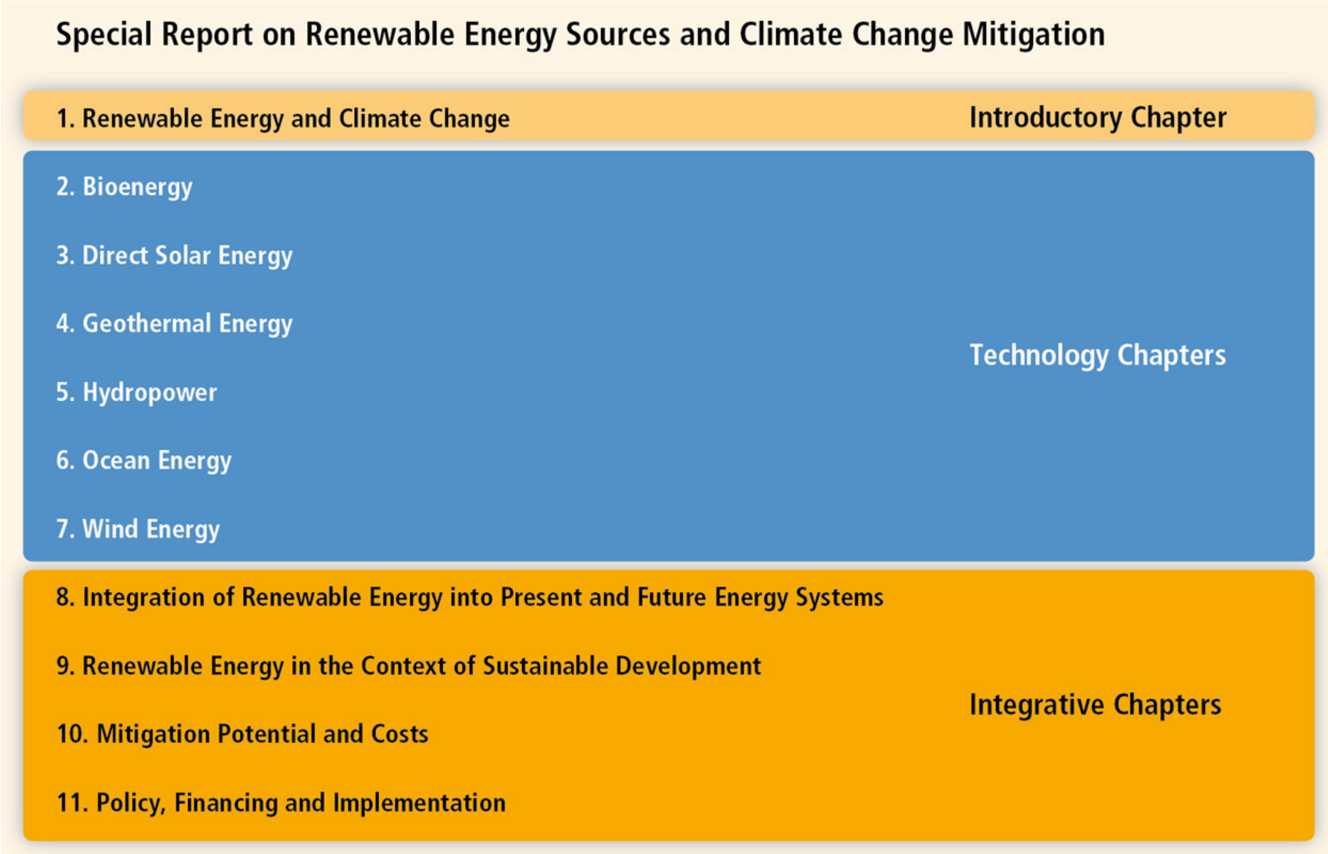


Figure 1: Structure of the SRREN. Source: IPCC 2011, Figure SPM.1.

Despite the slow progress during the last few international climate change meetings, we are now at the dawn of a structural shift in the energy system and its infrastructures. The Intergovernmental Panel on Climate Change (IPCC) has shown in a recent report that renewable energies will be *the* major contributor to any future low carbon energy system. Indeed, the share may be as high as nearly 80% of the world's energy supply by 2050, if backed by the right set of coherent policies.Even though this is at the upper end of the reviewed estimates, the report's overall conclusion is that renewable energies will gain higher market shares in the future – even in the absence of any climate change policies. Furthermore, most of the reviewed estimates show that renewable energies will play a greater role in 2050 than nuclear energy or fossil fuels combined with carbon capture and storage.

The quest for low emission clean energy services

The rise of renewable energies is due to the fact that emissions of greenhouse gases – mainly energy-related carbon dioxide (CO_2) – need to be reduced drastically, while at the same time much of the developing world still has no access to modern clean energy services in the first place. Those services are required to meet basic human needs (lighting, cooking, space comfort, mobility, communication) and serve productive processes. They are instrumental in achieving poverty eradication and sustainable development in general. In particular, this is true with regard to meeting the Millennium Development Goals, which are at the heart of any of today's development efforts. Still, an estimated 1.4 billion of the global poor have no access to electricity and 2.7 billion rely on traditional biomass for cooking, which causes significant health and various other problems.

At the same time, fossil fuels have dominated global energy supply since around 1850, leading to an increase in CO_2 emissions into the atmosphere. The IPCC stated in its 2007 assessment report that the associated rising concentrations of greenhouse gases in the atmosphere are 'very likely' to be responsible for global warming. Standing a realistic chance of preventing the worst climate change impacts requires a confinement of the increase in the global average temperature, with respect to 1850 levels, to a maximum of 2°C. This translates into the global reduction of greenhouse gas emissions by 50–85% until 2050 (from 2000 levels), with emissions starting to decrease by 2015 at the latest.

Zooming in from the global view to the regional and country level, it becomes clear that the reductions of the industrialised countries need to be at the upper end, or even beyond that, to give developing countries some space to develop. Consequently, the IPCC concluded in 2007 that reductions need to be in the range of 80–95% (from 1990 levels). In any case, the implication is basically a carbon-free society which requires an entirely new energy system.

The IPCC process and the Special Report on Renewable Energies

Being the leading international body for the assessment of climate change, the IPCC periodically prepares general assessment reports, with the fourth round published in 2007 and the fifth round scheduled for 2013/2014. In between, it prepares special reports on specific topics. A guiding principle for the IPCC is to be policy relevant but not policy prescriptive in its assessments. The production of the reports is subject to a transparent multi-stage drafting and review procedure, as well as a final approval and adoption by over 190 governments[1]. This elaborate and transparent procedure ensures the widest possible participation combined with access to the most relevant and best available information. It results in broad and impartial state of knowledge reports, with the main messages being universally approved by governments around the world.

The IPCC has now, for the first time, dedicated an entire special report to the assessment of the potential contribution of renewable energies to climate change mitigation. For the 'Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN)'[2], a core author team of some 130 experts, which represented a broad spectrum of technological expertise as well as expertise on energy systems as a whole, was gathered and divided into chapter teams in order to contribute to the report's eleven chapters, as shown in figure 1; six dedicated chapters also reviewed the status of the key renewable energies.

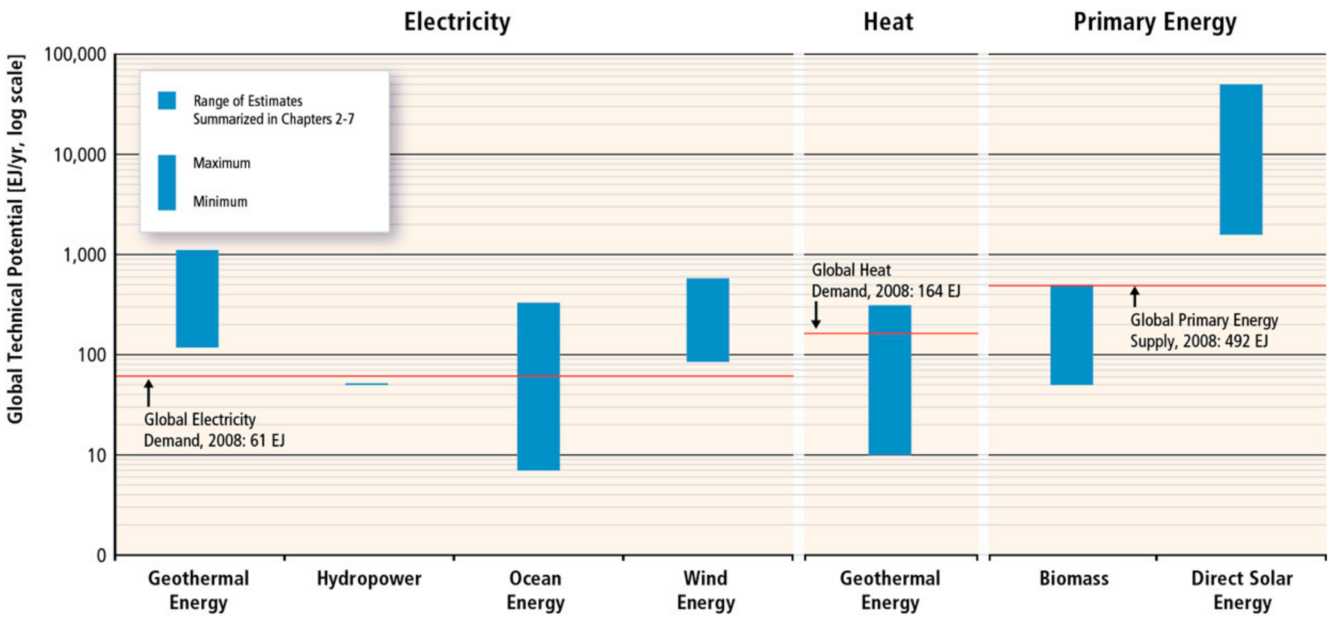
The chapters include estimates on resource potential, the status of the market and industry, prospects for innovation and the current penetration. Furthermore, the chapters include coherent assessments of costs and potential. A scenario review chapter assesses the potential deployment of renewable energies over the coming decades, and covers 164 existing scientific scenarios. Another chapter is dedicated to the integration of renewable energies into energy supply systems as well as end-use sectors. The interactions between renewable energies and sustainable development are covered in a dedicated chapter that includes aspects of social and economic development, energy access and energy security, as well as environmental and health impacts. A concluding chapter deals with policies, finance and investment and related institutional requirements. The SRREN is preceded by a summary for policy makers and a technical summary, with the latter mirroring the structure of the report.

Potential, competitiveness and polices

The SRREN shows that – despite different definitions and uncertainties – the global technical potential of renewable energies is vast and by far exceeds any projected global energy demand, as shown in figure 2. The scenarios consistently show that only a small fraction of the global technical potential is being tapped. The technical potentials differ depending on the different energies and also on the region but, generally, there are significant opportunities beyond

1 More specifically, the IPCC gathers hundreds of authors from all over the world in chapter teams to prepare consecutive drafts. These drafts are sent to hundreds of expert reviewers, as well as government reviewers, for comments, and these (thousands of) comments have to be considered by the author teams in the following draft. Review editors for each chapter ensure the appropriate treatment of each comment. At the end of the process, governments approve the report's summary for policy makers line-by-line and adopt the report as a whole. After the publication of the report, the drafts, the review comments and the author teams' reactions are also published.

2 IPCC 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press. Cambridge, United Kingdom and New York, NY, USA. Also available at http://srren.ipcc-wg3.de/



Range of Estimates of Global Technical Potentials

	Geothermal Energy	Hydropower	Ocean Energy	Wind Energy	Geothermal Energy	Biomass	Direct Solar Energy
Max (in EJ/yr)	1109	52	331	580	312	500	49837
Min (in EJ/yr)	118	50	7	85	10	50	1575

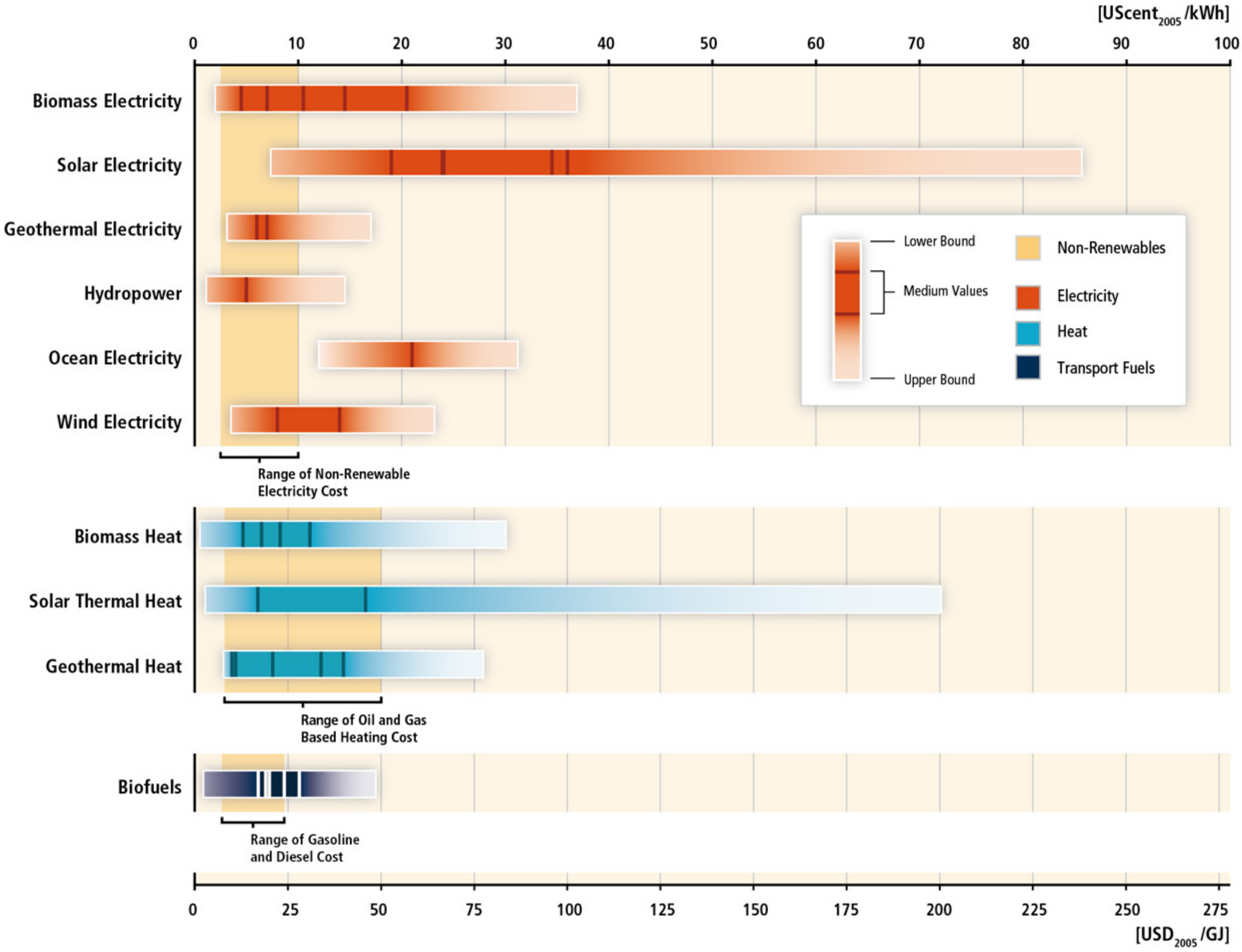
Figure 2: Ranges of global technical potentials of renewable energy sources. Source: IPCC 2011, Figure SPM.4.

current deployment levels for any given renewable energy before other issues such as concerns over sustainability or system integration arise.

Despite the high technical potential, renewable energies are not yet as competitive in the market place as would be necessary (see figure 3) to reach the deployment levels mentioned above. However, even though some renewable energies are broadly competitive today, for others this is only true under specific conditions such as favourable resource conditions or a lack of infrastructure in other energy supplies. However, very often renewable energies still depend on policies to ensure rapid deployment. Partly, this has to do with the (lack of) maturity of some of the renewable energies, while it also concerns the fact that the market place itself neglects the renewable energies' wider benefits and their future potential. Both these issues relate to what economists call externalities to the market or market failures, and with respect to renewable energies there are both negative and positive externalities at work.

First and foremost, burning fossil fuels causes negative externalities in terms of impacts from climate change, whose additional burden on society is not (yet fully) reflected in their prices. It also causes air pollution with related negative health effects. Furthermore, renewable energies have lower fatality rates and a low risk of severe accidents, due to their often decentralised nature. And from an energy security perspective, renewable energies often lead to a broader energy supply portfolio and may diversify supply routes. Not accounting for these climate change-related and wider benefits of renewable energies makes non-renewable energies more competitive in the market than they really are, from a societal point of view. Putting a price on the carbon content via taxes or emission trade and valuing the further benefits would raise the renewable energies' competitiveness.

The second category concerns positive externalities and relates to the fact that renewable energies are often less mature. There have been significant technical advances and related cost reductions for many renewable technologies over the last decades and further reductions are expected. However, they require more investment in research and technological learning; and from innovation economics it is known that knowledge is a public good and therefore firms are not able to exploit all the benefits of this learning process by themselves. Furthermore, investments in research and development are viewed as more risky and firms may underestimate the benefits. Taken together, this, again from a societal point of view, is why they invest too little in innovation. Therefore, policies dedicated to the development



Notes: Medium values are shown for the following subcategories, sorted in the order as they appear in the respective ranges (from left to right):

Electricity	Heat	Transport Fuels
Biomass: 1. Cofiring 2. Small scale combined heat and power, CHP (Gasification internal combustion engine) 3. Direct dedicated stoker & CHP 4. Small scale CHP (steam turbine) 5. Small scale CHP (organic Rankine cycle) **Solar Electricity:** 1. Concentrating solar power 2. Utility-scale PV (1-axis and fixed tilt) 3. Commercial rooftop PV 4. Residential rooftop PV **Geothermal Electricity:** 1. Condensing flash plant 2. Binary cycle plant **Hydropower:** 1. All types **Ocean Electricity:** 1. Tidal barrage **Wind Electricity:** 1. Onshore 2. Offshore	**Biomass Heat:** 1. Municipal solid waste based CHP 2. Anaerobic digestion based CHP 3. Steam turbine CHP 4. Domestic pellet heating system **Solar Thermal Heat:** 1. Domestic hot water systems in China 2. Water and space heating **Geothermal Heat:** 1. Greenhouses 2. Uncovered aquaculture ponds 3. District heating 4. Geothermal heat pumps 5. Geothermal building heating	**Biofuels:** 1. Corn ethanol 2. Soy biodiesel 3. Wheat ethanol 4. Sugarcane ethanol 5. Palm oil biodiesel

The lower range of the levelized cost of energy for each RE technology is based on a combination of the most favourable input-values, whereas the upper range is based on a combination of the least favourable input values. Reference ranges in the figure background for non-renewable electricity options are indicative of the levelized cost of centralized non-renewable electricity generation. Reference ranges for heat are indicative of recent costs for oil and gas based heat supply options. Reference ranges for transport fuels are based on recent crude oil spot prices of USD 40 to 130/barrel and corresponding diesel and gasoline costs, excluding taxes.

Figure 3: Range in recent levelised cost of energy for selected commercially available RE technologies in comparison to recent non-renewable energy costs. Source: IPCC 2011, Figure SPM.5.

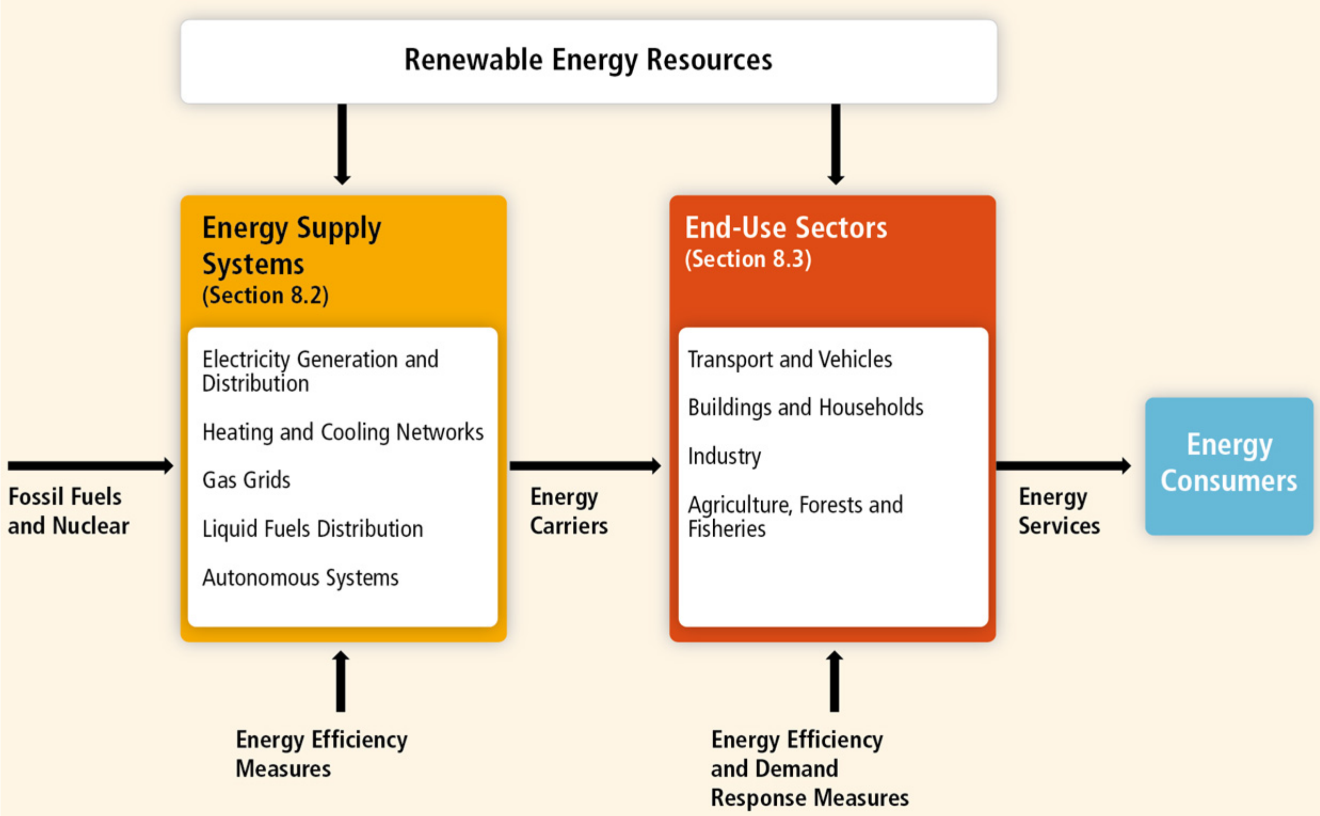


Figure 4: Pathways for RE integration to provide energy services, either into energy supply systems or on-site for use by the end-use sectors. Source: IPCC 2011, Figure SPM.7.

and deployment of renewable energies are needed on top of general carbon pricing policies. Indeed, the highest shares of renewable energy occur in those scenarios where there is a coherent policy package that recognises these aspects.

In addition to the specific policies mentioned above, wider sectoral policies and related institutions need to facilitate the deployment of renewable energies, which is referred to as 'enabling environment' in the SRREN. These policies are, for instance, agriculture, transport, urban planning, finance and general energy policy. They interact with the climate and technology policies above and either enhance their effectiveness or constitute barriers.

An example of a policy *not* creating an enabling environment but instead constituting a barrier is the subsidies given to non-renewable energies, which make them more competitive in the market than they really are. More generally, policies can be regarded as means to remove barriers to the deployment of renewable energies. These include dedicated policies to remove market failures as well as improving the general policy landscape that translates into, for example, removing barriers to energy network access or access to finance.

Integration into the energy system

An issue that deserves particular attention is the integration of renewable energies into the existing energy infrastructure, or rather the adaptation of the current system to one that is dominated by renewable energies. Renewable energies may be integrated in the various energy supply systems or directly in the respective end-use sectors, as shown in figure 4.

The SRREN concludes that current energy systems are able to integrate some renewable energy (and have done so successfully) but at some point they need to be adapted, which will require investments in the respective energy supply systems as well as changes in end-use sectors such as novel methods of transport and innovative distributive energy control in buildings. Current systems are mainly centralised and mostly involve fossil fuels, so they need to be tailored to integrate higher shares of renewable energies.

The exact challenge is contextual and site-specific; that is, it depends on the amount and characteristics of the renewable energies to be integrated and on the system in question, including the amount of renewable energies already in the system. Furthermore, it

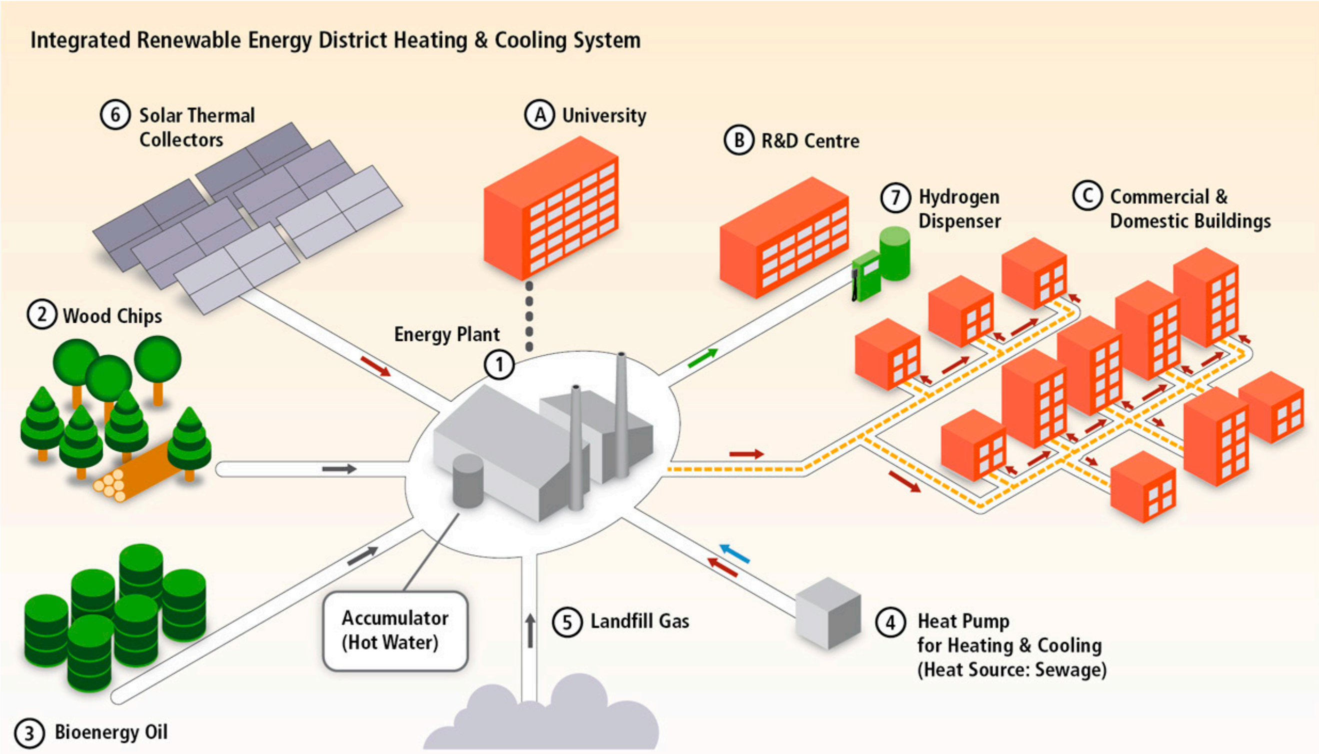


Figure 5: An integrated RE-based energy plant in Lillestrøm, Norway. Source: IPCC 2011, Figure TS.8.3.

depends on the regulatory environment mentioned above, which in turn needs to be tailored to the respective technology-specific challenges.

Concerning *energy supply systems*, integrating renewable electricity often places higher demands on network reliability. Partially dispatchable wind and solar energy, for instance, may be more difficult to integrate than fully dispatchable hydropower and bioenergy. This calls for greater generation flexibility of the remaining non-renewable capacity, despite the fact it is often in conflict with current systems which rely on centralised based load oriented condensation power plants, especially in the event of high shares of particularly inflexible nuclear capacity. Furthermore, integration of renewable electricity calls for greater energy storage capacities (e.g. storage-based hydropower) and for better supply forecasting and planning methods in general. Renewable energies are also often site-specific and therefore more decentralised.

All of this calls for an extension of electricity networks within a country and for greater cross-regional integration. Better Pan-European integration, for instance, would smooth variability and enhance dispatchability through better access to different renewable energies and renewable energies on a wider geographical scale, as well as allowing for greater access to energy storage capacities. An enhanced network infrastructure is not only key in terms of extent but also in terms of functionality (smart grids). Apart from managing a more variable supply and better demand forecast in general, the network needs to include information from the demand side that would, in turn, also be more flexible. For instance, the application of information technologies like smart electricity meters linked to control centres and electricity prices differentiated by time would smooth peak demand. Taken together, a renewable-based system implies more requirements on the electricity infrastructure than are in place today.

District heating, which is already quite common in high latitude countries like Finland, may use inputs from low-temperature thermal renewable energies such as biomass, solar or geothermal in combination with thermal storage capabilities and flexible co-generation, as shown in figure 5. Centralised heat production facilitates the use of, for example, waste by-products that are unsuitable for individual systems and allow for input-substitution. Provided that gas quality standards are met and pipelines are upgraded, where necessary, biomethane and, in the longer term, hydrogen derived from renewable energies as well as synthetic natural gas may be injected into gas grids. Similarly, biofuels for transport (or cooking and heating) may be integrated in liquid fuel systems if standards are compatible with vehicle engine fuel specifications. So far, petroleum-based fuel systems have usually been blended with biofuels.

Concerning *end-use sectors*, liquid and gaseous biofuels may be integrated into transport systems, as mentioned above. Future options may include hydrogen, electrification or hybrid schemes. A large enough electrical vehicle fleet could contribute to the balancing of the electricity network in a vehicle-to-grid system by using the batteries as supply in peak times and then charging them during off-peak hours. In buildings, renewable energies may be included in centralised or decentralised ways; that is, renewable electricity may be supplied either by the electricity grid or by, for example, solar PV on the roof and renewable heating. This could be achieved using either district heating systems, as mentioned above, or by, to use another example, biomass pellet systems with enclosed stoves. Renewable energies may be integrated in new and existing premises – the latter in combination with an efficient building design/retrofit – and may even turn them into net renewable energy suppliers.

Similar to buildings, several industries can directly (through their own production) or indirectly (via grids or other purchased RE-based energy carriers) integrate renewable energies for heat and power. Some process industries may be net suppliers of renewable energies, usually either through sales of biomass by-products or sales of the (onsite produced) derived energy from them (electricity, heat). Furthermore, energy intensive industries, which swallow up the major share of industrial energy consumption, will have an increasing role in the demand side management of the energy system through contractual cuts in their demand during peak-hours. In agriculture, there is a combined use of land (e.g. grazing and wind turbines) as well as the use of animal manure and crop residues. In a more targeted approach, biomass energy crops may be specifically grown.

The importance of energy efficiency

A key feature of an energy system based on renewable energies is enhanced energy efficiency (see figure 4), as they often have lower energy densities. What people require are the *services* (e.g. a well-lit and well-tempered room, as well as input to production) from energy, as mentioned above, and the same energy service may be supplied in different ways; that is, with different primary energy requirements. In current energy systems, inefficiencies can be tracked throughout the whole system, from production via transmission and distribution to the various end-uses. Therefore, only a small share of the primary energy reaches the point where it can actually perform the required energy services, and these, in turn, are often inefficient in themselves. Furthermore, raising the efficiency of end-use in the various sectors is an important step in lowering primary energy needs and is also, at the same time, often the lowest cost option.

In the transport sector, efficiency measures include changes in the mode of transport and raising the efficiency of vehicles. In the building sector, improved design of the building envelope and more efficient appliances lower the energy demand for heating and cooling, as well as lighting and other services. In industry, opportunities for energy efficiency are very diverse and refer to the respective production processes. Furthermore, the measures for buildings and transport apply as appropriate. On the energy supply side, heat-to-power conversions in electricity and transport are characterised by high losses, and therefore high primary energy input requirements, as opposed to direct energy conversions such as solar PV, hydro and wind (despite other conversion inefficiencies). The lowering of primary energy requirements will also allow energy efficiency to contribute to energy security.

Implications for energy security

Basing future energy supply on renewable energies will also benefit energy security. There are various definitions of energy security but the SRREN identified the availability and distribution of resources and the variability and reliability of energy supply as the main themes. Concerning availability and distribution, renewable energies allow substituting away from increasingly globally scarce, concentrated and imported resources; that is, renewable energies are usually more diverse and local and therefore lead to a broader and less import-dependent energy portfolio – even though the definition of energy security goes beyond mere import dependency and rather concerns the question of access to markets. The transport sector, however, still requires major innovations in order to significantly lessen oil-dependence.

Concerning the variability and reliability aspects, the above mentioned challenges to network security, especially with regard to electricity, need to be met – keeping in mind that some renewable energies (biomass, hydro power) are fully dispatchable and may be part of the solution. Nuclear energy, however, is particularly inflexible and will be in conflict with the rising flexibility requirements of the remaining non-renewable capacity. Broadening the energy portfolio also leads to less vulnerability to energy price volatility.

Conclusions

Taken together, the IPCC's special report on renewable energy sources and climate change mitigation (SRREN) shows that the transition to an energy system based on renewable energies is possible and beneficial. It requires additional policies that incur costs but these can be reduced significantly through the right policy mix. Furthermore, the transition is not only necessary due to climate change but also because it serves a variety of other purposes like broadening the energy portfolio and necessary infrastructure improvements. Therefore, striving for an energy system based on renewable energy is a robust strategy that makes sense in any case.

The latter point on infrastructure improvements is particularly true with regard to recent electricity failures in Finland that were related to severe weather conditions. This points to another issue that is not really mentioned in the SRREN: the necessity of making infrastructures 'climate proof' against the degree of future climate change that is already upon us. It is often forgotten that – due to historical emissions – we are already committed to some degree of climate change and that adherence to the 2°C-target will only prevent the worst impacts. The amount of costs of transition that are really *additional* when taking into account all of these other necessities is very much up for debate. Rather, it appears very likely that the costs of unabated climate change to society will be much higher anyway.

With the SRREN in mind, it becomes apparent that an ambitious global climate change regime, particularly one which includes a carbon pricing mechanism, is pivotal and that the international process is much too slow in the face of what is necessary. More generally, it is of utmost importance to agree on a long-term vision of a low carbon energy system and – more broadly – on a low carbon energy society rather quickly. Despite the slow process in the international arena, the transition has to start now due to the long lead times in infrastructure changes – even though the international regime is not yet in place. Being the first to move, however, may just provide the cutting edge in the markets of the future, in terms of competitiveness, which is currently so desired.

For the European arena, this implies that the recently proposed flagship initiative of a 'resource-efficient Europe' and its related long-term strategy papers, for instance the 2050 roadmaps on energy and low-carbon economy, move in the right direction in order to create such a vision and competitive advantage. This is also true for its proposed further legislation on, for instance, long-term mitigation targets, energy efficiency and energy infrastructures. This conceptually coherent approach consistently addresses a number of the issues highlighted above. The EU's '20/20/20' targets on emission reduction[3], renewable energies and energy efficiency as of 2007, as well as the European emissions trading scheme, mark important first steps. Yet, they still appear to be too little with regard to the challenge at hand, but the European Commission's proposed long-term strategy is designed to complete the remaining necessary steps. It is now up to the member states to embrace this and push it forward.

3 A 30% emission reduction in the event of an international climate change agreement

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ISBN 978-951-769-337-0
ISSN 1795-8059
Cover photo: Manuguf / Wikimedia Commons
Language editing: Craig Houston