[R]enewables 24/7 – EXECUTIVE SUMMARY

Infrastructure needed to save the climate

Grids keep power systems working

The electricity “grid' is a collective name for all wires, transformers and infrastructure that transport electricity from power plants to users.

The existing electricity transmission and distribution system was mainly designed and planned 40 to 60 years ago. All over the developed world, the gri ds were built with large power plants in the middle, with high voltage alternating current (AC) power lines to the areas where the power is being used. A smaller “distribution network” carries the current to the final consumers. Centralised grid system like this run mostly on coal and gas power stations. The systems supported massive industrialisation in cities and also brought electricity to country areas in most developed parts of the world, but in the future, we need to change the grids so they do work instead on clean energy, from sources like wind, solar, hydro and biomass.

Renewable energy generators are typically smaller and they will be distributed throughout the grid, as well as concentrated in large power plants such as offshore wind power plants. Examples of big generators of the future are the massive wind farms in the North Sea and large areas of land covered in concentrating mirrors to generate energy in South Europe or Africa.

The challenge ahead is to integrate new generation sources and at the same time phase out of most large scale conventional power plants, while keeping the power supplied when it is needed. This will need new types of grids and power systems architecture. The major new technologies needed are to balance fluctuations in energy demand and supply. Plenty of new measures are available today, like demand-side management, advanced weather forecasting and energy storage, we just need to put them to work.

Some critics of renewable energy say it is not ever going to be able to provide enough power for our current energy use, let along projected growth of energy demand, because natural resources like wind and sun, don’t appear to be available 24/7.

The report “[R]enewable 24/7”is report shows how that thinking is wrong.

We have sun, wind, geothermal, run of river, available right now, and ocean energy, biomass and efficient gas turbines set to provide massive energy supplies in the future. This, together with clever technologies that track and manage energy use patterns and shift power between where it is being made to where it is being used, better storage options and lots of customers grouped together by information technologies acting like giant batteries, we can secure the renewable energy future needed to avert catastrophic climate change.

We just need Smart Grids to put it all together and effectively “keep the lights on.”

Smart Grids can handle renewable energy and manage demand

A smart grid is an electricity grid with a minimal amount of waste and a highly efficient use of power. It uses distributed energy resources and advanced communication and control technologies to deliver electricity more cost-effectively, with lower greenhouse intensity and in response to consumer needs. Typically, smaller forms of electricity generation are combined with energy management to balance out the load of all the users on the system. Small generators include wind turbines, solar panels, micro turbines, fuel cells and co-generation (combined heat and power). These types of energy sources can be closer to the users, rather than one large centralised source a long way away. Advanced types of control and management technologies for the electricity grid can also make it run more efficiently overall. These include things like smart electricity meters that show real-time use and costs and can respond to remote communication and dynamic electricity pricing.

When you look at the real scenarios, for example in Spain where huge amounts of solar thermal power have been added to the system, large, inflexible fossil and nuclear power plants simply do not fit together with renewable energy.

Bringing renewable energy into power systems

The task of integrating renewable energy technologies into existing power systems is similar in all power systems around the world, whether they are large, centralised systems or island systems. The main aim of power system operation is to balance electricity consumption and generation at all times.

Thorough planning ahead is needed to ensure that the available production can match demand at all times. In addition to balancing supply and demand, the power system must also be able to:

- Fulfil defined power quality standards e.g. for voltage and frequency; and
- Survive extreme situations such as sudden interruptions of supply (e.g. a fault at a generation unit) or interruption of the transmission system.

Typically, power systems use conventional power sources as base-load power plants which operate most of the time at rated capacity. These centralised units are often "inflexible" generation resource, meaning they are quite inefficient and it is expensive to change their output over the day, to match what people actually use (load variation).

In reality, load varies over time so more flexible power generation resources are required to provide the right amount of power. There is a wide range of different power generation technologies available to guarantee a 24/7 supply:

- Biomass/geothermal/solar thermal (CSP)/hydro power with storage: power output can be regulated, i.e. they can supply base load as well as peak load;

- Hydro power without storage (run–of-the-river), photovoltaic and wind power: these depend on the available natural resources, so the power output is variable.[1]

There are two main types of impact to consider when introducing renewable energy to grids, the balancing impact and reliability impact.

Inflexible Coal- and Nuclear versus flexible renewable power generation

Renewable energy integrated into a smart grid can overcome the perceived need for constant “base-load” power. In the new energy vision, it is better to think of energy as “inflexible” or “flexible”. In countries with good support for renewable energy and natural resource, in Spain for example, the clean, renewable technologies can provide more than 50% of daily demand on certain days. Worldwide, we can bring about an energy switch, where there is little need for base-load power in a renewable-based system. Instead, a mix of flexible energy providers can follow the load during the day and night (e.g. solar plus gas, geothermal, wind and demand management), without energy waste and without blackouts.

Figure X shows a typical situation with significant variable renewable generation –in this case mainly PV- in the European power system. Here, geothermal, ocean and run of the river power plants are operated in base load and conventional plants – in this case gas fired- and biomass are used to follow the variations caused by demand changes and changes in renewable generation such as PV and wind power.[2]

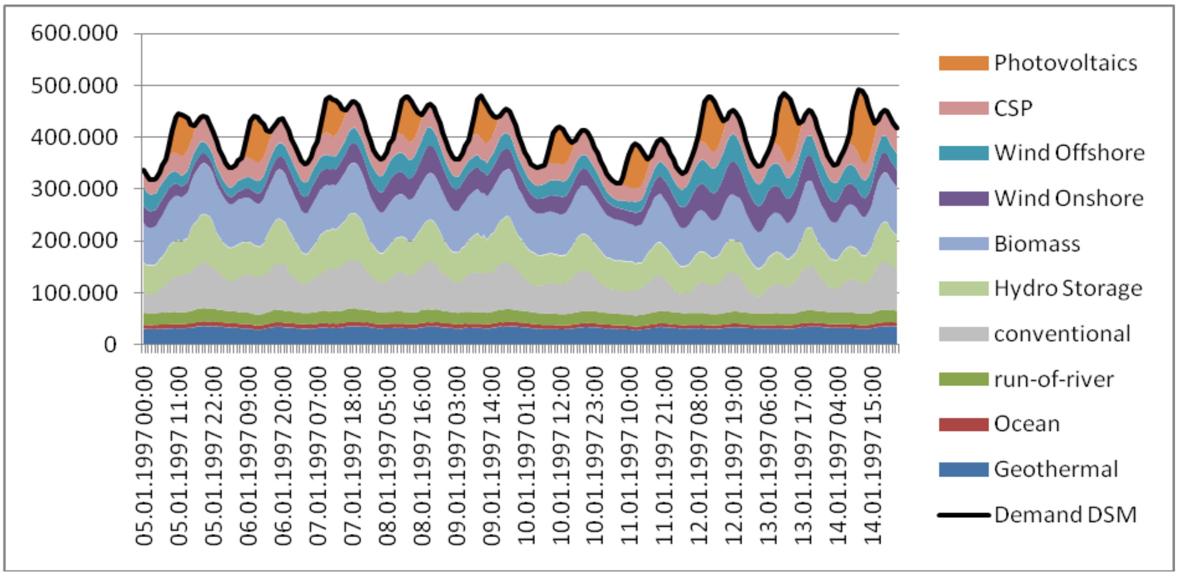

Figure X: Power production (in MW) from different sources and overall demand in Europe during extreme January event

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[1] Sometimes these renewable energy sources are described as ‘intermittent’ power sources, however, the terminology is not correct as intermittent stands for uncontrollably, i.e. non-dispatchable, but the power output of these generation plants can be forecasted, hence they can be dispatched. Furthermore, they can always be operated down-regulated if needed, see also **Błąd! Nie można odnaleźć źródła odwołania.**.

[2] In principal also geothermal could be used to provide load following capabilities.

Technical or economic barriers?

In the example of Spain, renewable power supply can surpass 50% of the daily demand on certain days. The power system is able to cope with this, there are no black-outs or technical problems at experienced. However, the renewable industry now faces an economic barrier, because Spain now has an overcapacity of supply. Effectively, Spain has much more generation capacity than demand, and the gap is exacerbated because of the economic crisis. The reason is that extra renewable capacity (and combined-cycle gas turbines - CCGT) was built with the intention to move Spain to a clean renewable energy future, however no conventional capacity had been decommissioned so far.

Now, renewable generation is now taking more and more market share in the electricity supply, taking it away from conventional fossil power plants. The conventional power plants are selling less KWh than originally planned, and they cannot run power plants in base mode anymore, which increases cost of operation, so lowering the profit on each KWh sold. In Spain, the operators of conventional powers have begun to lobby against renewable power generation because renewable generation impacts their business plan. They are typically providers of base-load power, which is being surpassed by new technology. With the advent of Smart Grids, the integration of large scale renewable generation is becoming ess a technical issue, it is more an economic issue.

Why do we need Smart Grids for High Penetration of Renewables?

The future power systems around the world will need to be based on renewable generation with up to 90% of the consumption supplied by renewable energy technologies such as wind, solar, biomass or hydro power.

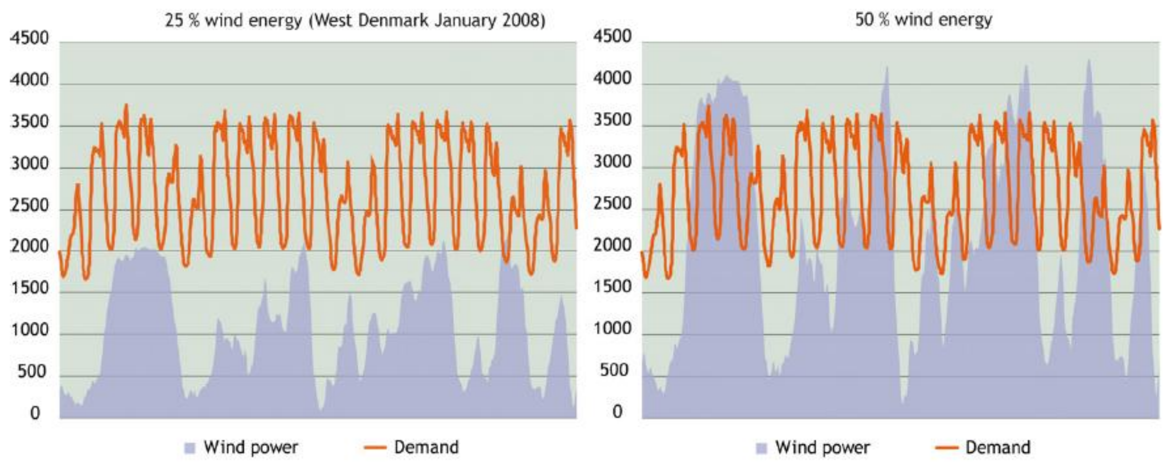

Figure 1: The left picture shows 25% wind energy in the Western Danish power system while the left picture shows 50% wind penetration (wind in grey/demand as orange line). It can be seen that with increasing penetration levels surplus wind power might be available at certain times, while at other times, it will be not sufficient to supply the load. Hence, the power system must become more flexible to follow the variable renewable power generation, for example by adjusting demand via demand-side management and/or by deploying storage systems.

Smart-Grid technology will play a significant role in achieving this, in particular by integrating demand-side management into power system operation.

The future power system will not consist of a few centralised power plants but of tens of thousands generation units such as solar panels, wind turbines and other renewable generation, partly distributed in the distribution network, partly concentrated in large power plants, like offshore wind power plants. Smart-Grid solutions will help to monitor and integrate this diversity into power system operation and at the same time will make interconnection simpler.

Smart Grids and information and communication technology (ICT)

New technologies are required in smart grids, particularly to:

- easily interconnect a large number of renewable generation assets into the power system (plug and play);
- create a more flexible power system through large-scale demand-side management and integrating storage to balance the impact of variable renewable generation resources;
- provide the system operator with a better information about the state of the system, which so they can operate the system more efficiently;
- minimise network upgrades by using network assets efficiently and supporting an efficient coordination of power generation over very large geographic areas needed for renewable energy generation.

The Smart-Grid Vision for the Energy [R]evolution

To develop a power system based almost entirely on renewable energy sources will require a new overall power system architecture –including Smart-Grid Technology.[3] Figure 2 shows a very basic graphic representation of the key elements of future, renewable-based power systems using Smart Grid technology.

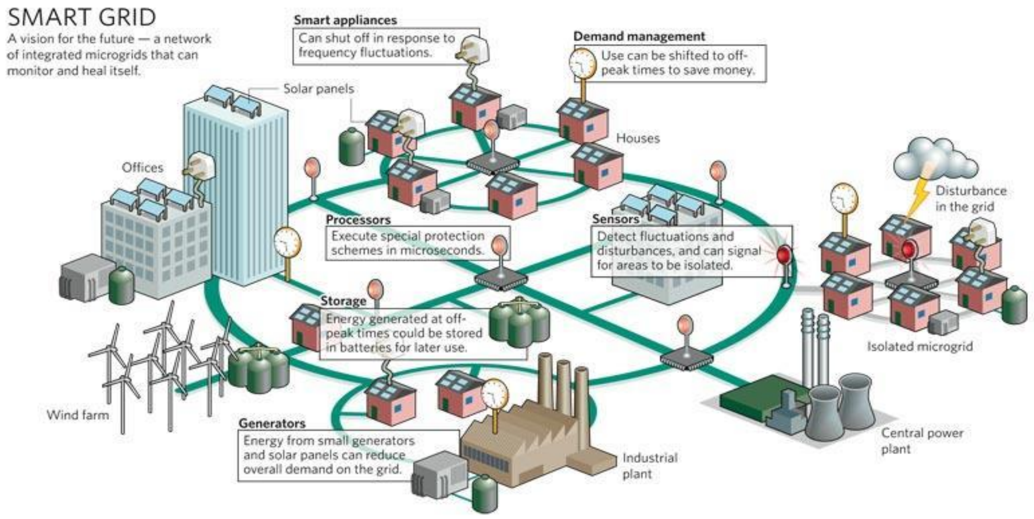

Figure 2: The Smart-Grid Vision for the Energy [R]evolution

Smart grids, micro grids and super grids will all be needed to work in harmony to provide day-to-day system balancing and also transport power to areas with large amounts of renewable resource to areas with high electricity demand.

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[3] See also Ecogrid Phase 1 Summary report, available at: http://www.energinet.dk/NR/rdonlyres/8B1A4A06-CBA3-41DA-9402-B56C2C288FB0/0/EcoGriddk_phase1_summaryreport.pdf

Super Grid – the interconnection of Smart Grids

Smart and super grids are not a science fiction but a further development from today's grids. So we do not need to start from scratch. In fact, various types of high voltage systems are under development and deployment already that are suitable for long-distance connections. With super grids, we can effectively plug in areas of high demand like Central Europe to areas of high supply, like Northern Africa, and provide a more sustainable energy supply and income to all.

Different storage technologies such as electrochemical batteries are already available today, but it is not clear whether large-scale electricity storage, other than hydro power, will become technically and economically viable. Feasible storage systems would have to cover most of the European electricity supply during two successive weeks of low solar radiation and little wind – this is difficult to envision based on current technology development. The new Greenpeace simulation study shows those extreme situations with low solar radiation and little wind in many parts of Europe are not frequent, but they can occur. The power system, even with massive amounts of renewable energy, must be adequately designed to cope with such extreme situations.

To design a power system that can adequately react to such extreme situations a substantial amount of planning to ensure available generation capacity and sufficient network capacity can match demand. In order to do so, different timescales must be considered:

- Long-term system plans to assess the system adequacy over the coming years (typically a time horizon of 2 to 10 years ahead is considered).
- Day-ahead planning, making sure that sufficient generation is available to match expected demand (typically 12 to 36 hours ahead)
- Short-term balancing, covering events such as a mismatch between forecasted generation/demand or sudden loss of generation (typically seconds to hours ahead planning).

Small changes in the power system –such as a small addition of solar or wind generation to an existing power system - will have little impact on the overall design of the system design. The Energy [R]evolution energy mix proposed by Greenpeace, would be a major change in the generation structure, hence the network structure must be adopted to the new generation structure to be able to "keep the lights on" even in extreme situations such as low solar radiation and little wind in many parts of Europe. A key element of this new network structure will be the onshore & offshore super grid, discussed in more detail in the following.

Transmission network expansion has always been key role to developing a reliable and economic power supply. Now, shifting to the approximately 90% of the electricity supply from renewable energy sources will also require a significant redesign of the transmission network. The right kind of grid gives us an economic, reliable and sustainable energy supply.

Super Grid: Simulation of the Energy [R]evolution for EU-27

In the Energy [R]evolution energy mix, distributed generation that is close to the actual demand plays a key role (about 70% of all generation is located close to the load centres). Biomass, pump storage systems as well as large-scale renewable power plants, such as offshore wind farms in the North-sea and Concentrating Solar Power in North Africa are used to fill up the variations in local supply caused by the variability of the demand and the local renewable energy sources. The future scenario assumes that customers become more flexible in their demand; that about 20% of the local demand can be reduced for a 3-4 hours by demand-side management and/or local storage options.

The main aim of the transmission system redesign under the E[R] energy mix scenario is to keep energy flowing 24/7, even in extreme situations. Such extreme situations are, for instance:

- no wind over main parts of Europe during the winter, when solar radiation is low;
- a unscheduled interruption of supply, for instance, an unscheduled interruption of a major interconnection to a large offshore wind farm (n-1 criteria). The impact of such a sudden interruption will be within milliseconds).

An appropriately designed transmission system is the solution in both cases as it can be used to transmit the required electricity from areas with surplus of generation to areas that have an electricity deficit.

In general, the transmission system must be designed to cope with long-term issues (variability between years), medium-term issues (e.g. seasonal availability of resources), and short term issues (planning over minutes or hours).

Results of the Energy [R]evolution EU 27 simulation

To evaluate the frequency of occurrences of extreme events, the study analysed the wind data of the last 30 years. As simulations showed, the extreme events can be expected during winter time, when the electricity demand is high and the solar production low.

During the last 30 years the potential power production from wind during the winter time within Europe in the E[R] scenario would have been only dropped below 50GW 0.4% of the time, equivalent to once a year if the average duration of the event is 12 hours.

This study selected key “extreme events”, with regard to balance of wind and solar power production on the one hand and high demand on the other hand, and created model of power supply based on the E[R] energy mix. The results were:

- In an extreme **summer** event of high demand and extremely low wind (as in August 2003), the available power from PV is enough to compensate for the lack of wind power so no change to the existing grid would be needed under a renewable energy scenario.
- In an extreme **winter** event of high demand, low solar power and wind and low sun (as in January 1997), Central-Europe and Great Britain have a higher demand than they can supply where as north and south of Europe have higher productions than demand. Energy is being transported from North Europe (mainly hydro power) and from South-Europe (mainly solar power) to Central-Europe. For this to be achieved by renewable energy, the interconnections between Spain and France, Italy and

France, Romania and Poland, Sweden and Poland, and Ireland and Great Britain have to be strengthened

- In an extreme **autumn** event of (as in November 1987) with very low sun and low wind, the reinforcement of the HVAC grid as well as the installation of the Super Grid as proposed would be sufficient to also cope with this event.

Recommendations for Grid Improvements

To be able to provide reliable, secure power supply to Europe, taking into account extreme weather and high demand scenarios, this study proposes:

- Strengthening 34 HVAC interconnections between neighbouring countries in Europe – 5,347 km of upgrades at a cost of € 3 billion

- 17 new or strengthened HVDC interconnections within Europe – 5, 125 km of upgrades at a cost of approximately €16 billion (see diagram X)

- 15 new HVDC "Super Grid" connections, including between France and Africa, Egypt and Italy, and Great Britain and Belgium – 12,000km of upgrades at a cost of €190Billion (see diagram X)

The total costs of the Super grid and reinforcements sums up to €.209 billion between 2010 and 2050 or € 5.23 billion per year. The HVAC collector grid of the CSP power in North Africa has not been included in this cost estimation. Over the lifetime of 40 years and an assumed energy consumption of 3500TWh/a in Europe, the cost for the Super Grid and reinforcements would be equivalent to 0.15 €Cent/kWh.
The additional connections and costs in the context of the existing European grid:

These costs are likely to be the maximum investments, because if grids are optimised via a slight change of the overall energy mix and/or the use of more storage capacity, the need for grid expansion can go down.

This level of grid improvement would be enough to cope with an energy supply of 90% renewable energy, including the massive Concentrating Solar Power that would be built under Mediterranean CSP scenario put forwards by Greenpeace in the Concentrating Solar Power Outlook 09.

Policy recommendations