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WIND ENERGY REPORT GERMANY 2013

FRAUNHOFER VERLAG

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Special Report

BUSINESS MODEL FOR RENEWABLE ENERGY

Norman Gerhardt, Fabian Sandau, Carsten Pape

The cost of switching to renewable energy

The switchover to renewable energy is currently dominated by the public and political debate about the cost. Much overlooked is the fact that the switchover to electricity generation from renewables is in fact an economically viable and low-risk project. In order to investigate this point, Fraunhofer IWES carried out detailed analyses in an internal project [1].

In order to analyze the "business model for renewable energy", a comparison must be made between the investment in new, capital-cost intensive renewable technologies and the savings from old, operating-cost intensive technologies that use fossil fuels. Future renewable energy supply systems here will be dominated by wind and solar energy. Besides primarily being used for power generation, these sources will also cover the energy requirements for transport and heating. The detailed calculations of Fraunhofer IWES show that the cost of the overall switchover to renewable energy is acceptable, even with very conservative assumptions and even if no increases in fuel costs and no costs for CO_2 emissions are taken into account.

Current imports of energy sources and distribution by sector

Primary energy consumption in Germany in 2011 totaled 3772 TWh, with 285 TWh of this accounting for non-energy usage, namely for material utilization. The annual cost of the energy sources is ca. 96 billion euros. The majority of the energy sources have to be imported. This costs 87 billion euros and hence accounts for ca. 90% of the primary energy costs. Although the share of primary energy requirement for power generation is similar to the shares for heating and transport (see Figure 1), the costs are relatively low. In contrast, oil and gas are expensive and are difficult to substitute. These energy sources are mostly used for transport and heating.

The current cost-benefit debate about the switchover to renewables is strongly focused on the power sector. In the power sector, however, expansion of electricity generation from renewables brings very little cost-saving because mainly coal and nuclear sources are replaced. That is why today there are

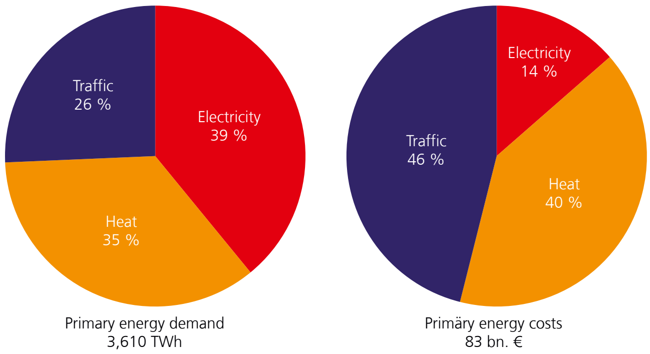

Figure 1: Share and cost of primary energy for power, heating, and transport (temperature-adjusted, excluding non-energetic consumption)

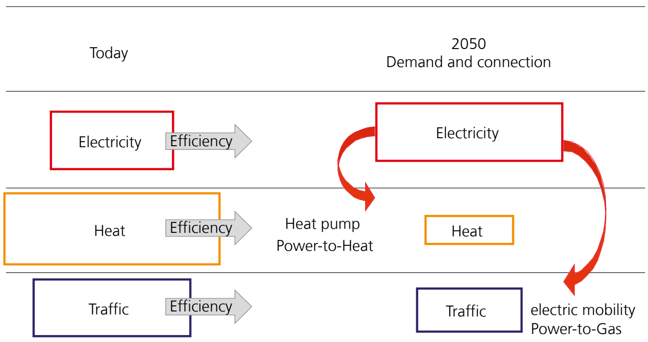

Figure 2: Increasing importance of electricity generated from renewables for heating and transport

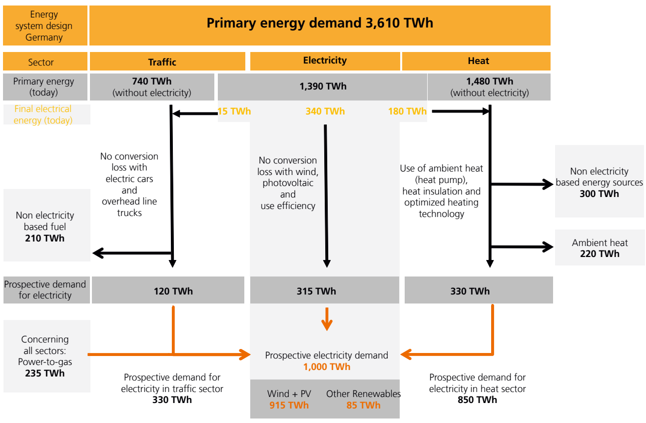

Figure 3: Electricity requirement in a 100% renewable energy scenario (power-heating-transport) without non-energetic consumption

high differential costs (e.g. REA surcharge) – but this argument is too short-sighted.

In the future, wind energy and solar energy will be the primary energy sources and electricity for heating and transport must also be generated from renewable sources (Figure 2).

Holistic consideration of all sectors is hence vital in order to determine the beneficial macro-economic effects of expansion of the necessary infrastructure.

In order to realize these macro-economic benefits, there must be efficient electricity usage for transport and heating in order to replace the high-cost primary energy sources and reduce the differential costs for the power sector. In order to meet the electricity requirements of all sectors, the preliminary investment must focus on dynamic expansion of the power sector. Only by considering all these aspects is it possible to perform a detailed cross-sector cost-benefit analysis.

Derivation of a 100% renewable energy scenario for 2050

A 100% renewable energy scenario for 2050 has been derived for autarchic energy provision in Germany. This scenario fully balanced the application areas and fuel utilization paths (Figure 3). This resulted in an electricity requirement of ca. 1,000 TWh. This requires realization of the potential efficiencies via very high electrification and full utilization of the potential of electric cars and overhead line trucks and very high utilization of heat pumps (75% of the low temperature requirement). In the area of high temperature process heat, high amounts of electricity are used for steam generation (power-to-heat).

The success of electricity generation from renewables also depends on considerable efficiencies being made, such as reduction of traditional electricity consumption by 25%, as specified in the energy scenario [2]. Measures such as insulating buildings, efficiency increases for industrial process heat and in the transport sector, more efficient heating technologies, and substantial utilization of waste heat (see [3]) will allow the primary energy consumption of ca. 3900 TWh (ca. 2400 TWh end energy) to be reduced to 1500 TWh end energy. The residual requirement for chemical energy sources will be covered by power-to-gas (electricity, heating, transport) and by mineral oil (non-energetic consumption).

Scenario for 100% renewable energy in all sectors

Based on the electricity requirement and the available renewable energies, a renewable energy mix was identified which minimized the fluctuations in the residual load and which was able to cover the requirements. A viable energy mix under these conditions was found to be 50 GW offshore wind energy, 180 GW onshore wind energy, and 200 GW photovoltaic energy. Hydroelectric power is already almost fully utilized and only makes a small overall contribution to electricity generation. Biomass utilization is already at a high level. It is assumed here that this remains constant in the power-heating-transport sectors. Based on the quantity of energy, the energy generation from fluctuating renewable sources comprises 22% PV, 26% offshore wind, and 52% onshore wind (Figure 4).

The required energy system infrastructure for the energy consumption and energy generation mix was then determined. The integration of the renewable energy utilized the flexibility of thermal power stations, grids, energy storage systems, power-to-heat converters, and electricity-to-material converters. Depending on the electricity requirement (Figure 3), this also includes E-cars, overhead line trucks, electric heat pumps, power-to-heat systems, local battery storage, and the utilization of power-to-gas.

Required investment

For this scenario, Fraunhofer IWES used literature surveys and its own experience of the power generating sector to determine the differential costs, namely additional costs, compared with continuing the status quo (reference scenario). Summing these costs, taking into account the increase in the number of wind turbines and the repowering necessary up to 2050, indicates that an investment of 1500 billion euros (Figure 5) is required, excluding capital costs.

Industrial-political implications

In order to meet the 2°C target, 100% renewable energy generation must be achieved by 2050. In order to ensure there is also a continuous transition between the construction of new WTs and the repowering of existing WTs, including after 2050, the construction must be largely complete by 2040. Otherwise considerable generating capacity would have to be built to meet the 2050 target which, in the phase after 2050, would no longer require repowering and would lead to unnecessary costs. This situation is clearly shown in Figure 6 for the expansion of onshore wind energy.

In order to operate a 180 GW wind farm continually, assuming a WT service life of 20 years, repowering of 9 GW per year will be necessary in the future (today ca. 3 GW/year). Only be expanding the generating capacity by ca. 2030 to the future requirement of 9 GW/year will a continuous transition between new WT construction and repowering be possible. Likewise, for the expansion of offshore wind energy (service life of 20 years) and photovoltaic installations (service life of

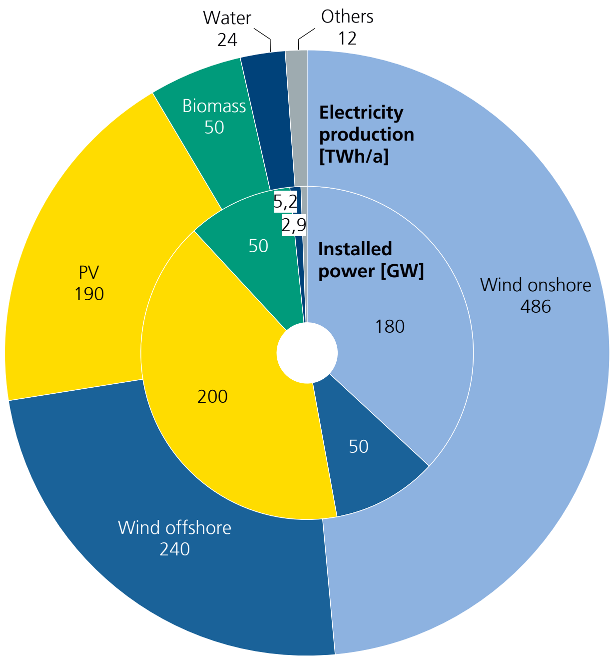

Figure 4: Selected mix of renewables for 100% renewable energy generation (with consideration of partial downpowering of renewable energy installations)

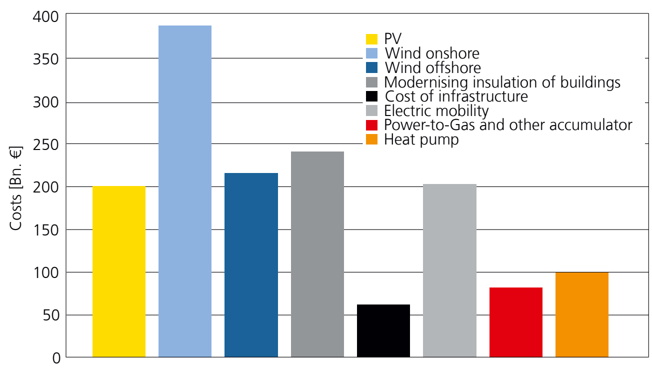

Figure 5: Required investment from 2011 to 2050

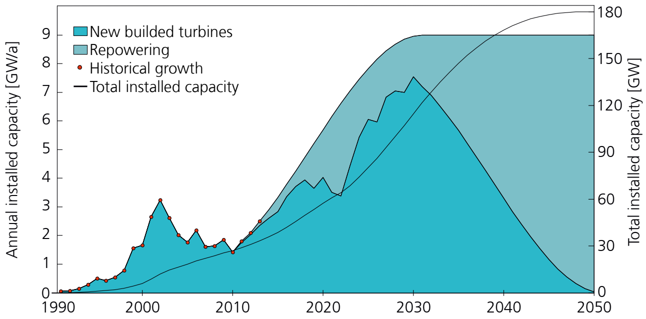

Figure 6: Required new wind turbines and repowering of onshore wind turbines up to 2050

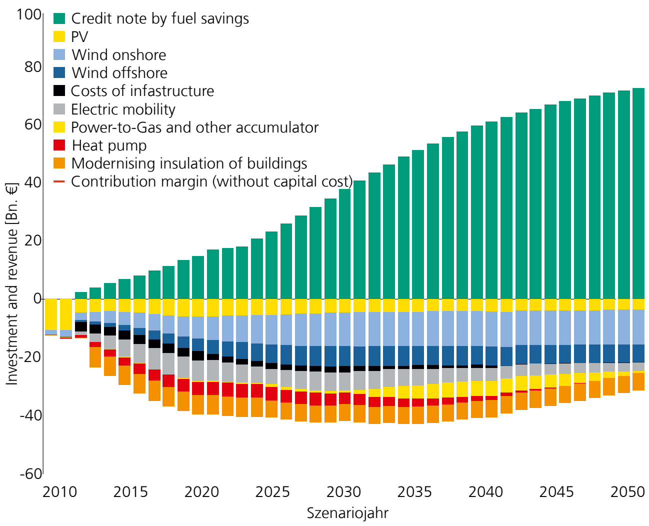

Figure 7: Costs, excluding capital costs, and revenues assuming a constant primary energy price

30 years), new additional generating capacity of 2.5 GW/year and 6.7 GW/year respectively is necessary.

The numbers also suggest that more than 90% of the renewable energy infrastructure must be constructed by 2040. This demonstrates furthermore how little flexibility there is with regard to expansion of renewable energy generation if the 2°C is to be met.

Modeling the cost of the switchover to renewables

Based on the assumptions for the end energy requirement in 2050, a holistic scenario can be derived to describe the energy requirements, generating costs, and investment costs for the new infrastructure for the whole period from 2011 to 2050. To evaluate the economic viability of the overall project, the residual value of the investments in 2050 must also be considered. For this, solely the residual values of the wind turbines and PV installations were considered. This is therefore a conservative assumption.

The expansion of renewable energy generation initially largely replaces fossil fuel based energy generation, which only makes up a small fraction of the primary energy costs. In addition, being relatively new, these technologies still have high investment costs. This means that initially the differential costs are high. In order to realize the macro-economic benefits, there must be efficient electricity usage for transport and heating in order to replace the high-cost primary energy sources and reduce the differential costs for the power sector. There is hence a need to use renewable energy for transport and heating at an early stage. Therefore, the expansion of renewable energy generation for power usage must only be viewed as the initial financing step. Figure 7 compares the annual investment costs for expansion of renewable energy generation (downward bars) and the saved primary energy costs (green, upward bars). The calculated investment costs for the 100% electricity generation from renewables scenario over a period of 40 years indicate that from 2030 (namely after ca. 20 years) there are positive contributions to profit, if interest rates and capital costs are not considered. The required initial financing is 383 billion euros. In 2050 there is significant financial gain because the savings for fossil fuels are many time greater than the ongoing investment for wind turbine repowering.

On taking account of an interest rate on borrowed capital, there is a delay in achieving a positive contribution to profit. Assuming this interest rate is 2%, a positive contribution to profit can be achieved from 2035 onwards (namely after ca. 25 years). The required initial financing is 501 billion euros.

The economic viability of the overall project becomes even more evident if increasing primary energy costs are assumed in the climate protection model of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) [4]. This scenario attains profitability sooner. Positive contributions to profit occur after just 15 years (without considering interest) or 18 years (with consideration of interest on borrowed capital). The required initial financing is 295 billion euros. without considering interest and 356 billion euros taking interest into account.

Results

The conclusion that can be drawn from these initial considerations is that financing the 100% renewable energy project is feasible, even with very conservative assumptions (no increase in fossil fuel prices, no costs for CO_2 emissions). Assuming a constant price for primary energy at 2011 levels and constant residual values, there are interest payments of 2.3% for the full investment (inflation-adjusted). If price increases for oil and natural gas are taken into account, the profitability is enhanced and reaches values of 6.7% (inflation-adjusted) for the price increases specified in the climate protection model.

Even very ambitious climate change goals (requiring 100% energy generation from renewables) are economically feasible, and particularly so if increases in primary energy costs and costs for CO_2 emissions are expected. The "cost of renewable energy generation" should therefore not be the sole factor for political decisions on climate change.

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Funded:

Federal Ministry for Economic Affairs and Energy

on the base of an act of the German Parliament

Supervised by:

PtJ Projektträger Jülich Forschungszentrum Jülich