Deliverable 1.4
Report on the understanding of the character of the balancing problems and strategies for solving it, emphasising the role of CHP (short term)

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Abstract: This deliverable discusses the use of CHP for balancing fluctuating electricity production (wind turbines) on the basis of energy scenario calculations performed by the EnergyPLAN programme [D 1.3]
It is partly based on calculations performed for Western Denmark 2020 and partly on new calculations using the reference scenarios presented in D 1.3.

Introduction

This deliverable discusses the use of CHP for balancing fluctuating electricity production (wind turbines) on the basis of energy scenario calculations performed by the EnergyPLAN programme [D 1.3]

It is partly based on calculations performed for Western Denmark 2020 described in an article by the authors in the ‘Energy Policy’ journal [1] and partly on new calculations using the reference scenarios presented in D 1.3.

Western Denmark 2020 calculations

The question of the benefits of using CHP power plants for balancing wind power in the short term can most effectively be illustrated by scenario calculations dealing with future energy systems. In this way, different possible developments of the energy system can be assumed (in particular the amount of wind power in the system) and the function of the CHP plants can be illustrated under varying conditions. In this way, guidelines for a suitable development of the function of the CHPs can be found.

In [1], such calculations are made for a likely 2020 energy system of Western Denmark corresponding to the DK-W 2020 reference scenario [D 1.3].

In the calculations, the amount of wind power is used as a variable. It is varied from zero to 25 TWh corresponding to a variation from 0 to 100 % of the electricity consumption.

The capacity of the CHPs remains constant at 1500 MWel for the small plants (below 100 MW) and 3400 MWel for the bigger plants. The heat storages (total 25 GWh) are used for optimisation of the overall efficiency of the system by minimising production by condensing power plants and maximisation of production by CHP. A price elasticity of 0,003 €/MWh/MW is assumed. This will cause the decrease of prices in hours of high wind production.

The capacity of the present transmission lines to Norway, Sweden and Germany (1700 MW) is considered unchanged. Overloading (critical export) is avoided by the following measures:

1) replacing CHP with boilers, 2) using electric heating and 3), if necessary, stopping the wind turbines.

The assumptions for fuel type distribution and prices are similar to the data given in D1.3 for DK-W 2020 including the price for CO_2-quotas: 13 €/t.

The cost of wind power is estimated to 29 €/MWh (all costs are socioeconomic costs uninfluenced by actual tariffs, taxes, etc.)

In the following, a number of different options for regulation are compared.

1. Condensing power plants are trading on the spot market within the limits of the transmission lines. CHPs are producing according to the heat demand and the triple tariff (fixed price variation between low, high and peak demand hours)
2. The same, but the CHP plants are also trading while the heat demand is alternatively covered by boilers. (regCHP)

3. As above, but including 350 MWe of heat pump capacity used for replacing boilers when feasible because of low spot prices.

The above alternatives are compared to a reference situation, in which the CHPs produce solely according to the heat demand and the triple tariff. The condensing plants in the reference situation produce according to the electricity demand or to the demand for stabilising power. Import and export are minimised in this situation.

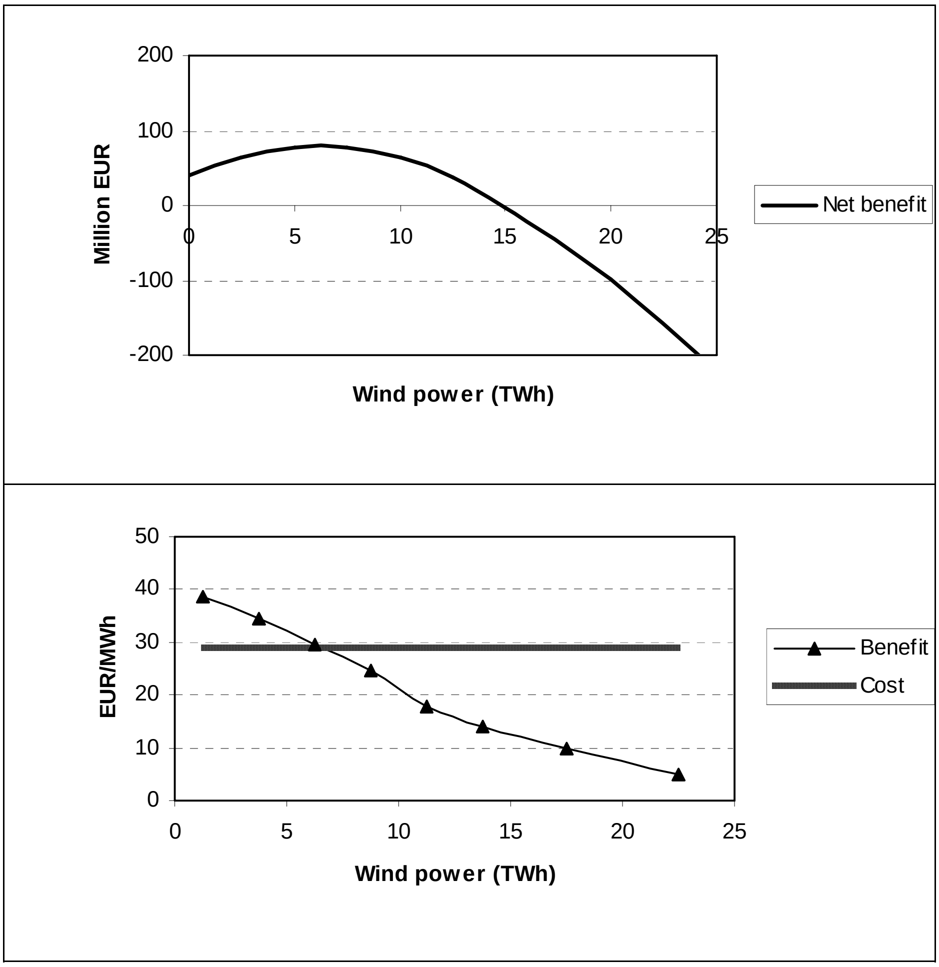

Figure 1. Net profit (top) and marginal cost benefit (bottom) of wind power (per year).

Figure 1. shows the results of alternative 1.It is seen that, for a wide range of wind power capacities, it pays well to make use of the trading capacity of the condensing power plants. The maximum benefit is reached close to the actual production capacity of 2004: 6 TWh. Above this, the marginal benefit becomes negative.

Calculations have been made to test if it is economically feasible to increase the capacity of the condensing power plants. The result was negative. The increased benefit from trading could not pay the investment.

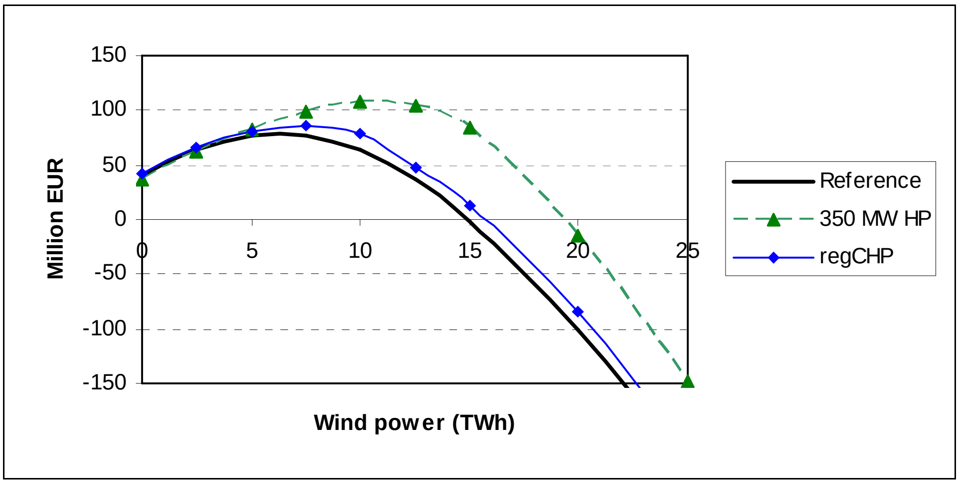

Figure 2. Feasibility of investing in flexible energy systems

Figure 2. shows the results of alternative 2 and 3. The use of the CHPs for regulation increases the net benefit slightly and moves the point of maximum benefit from app. 6 to app. 7 TWh.

The addition of heat pumps has a much larger effect. (Investments for heat pumps are included). This is due to the strong regulating effect caused by the possible shifts at the CHPs from electricity production to electricity consumption by the heat pumps.

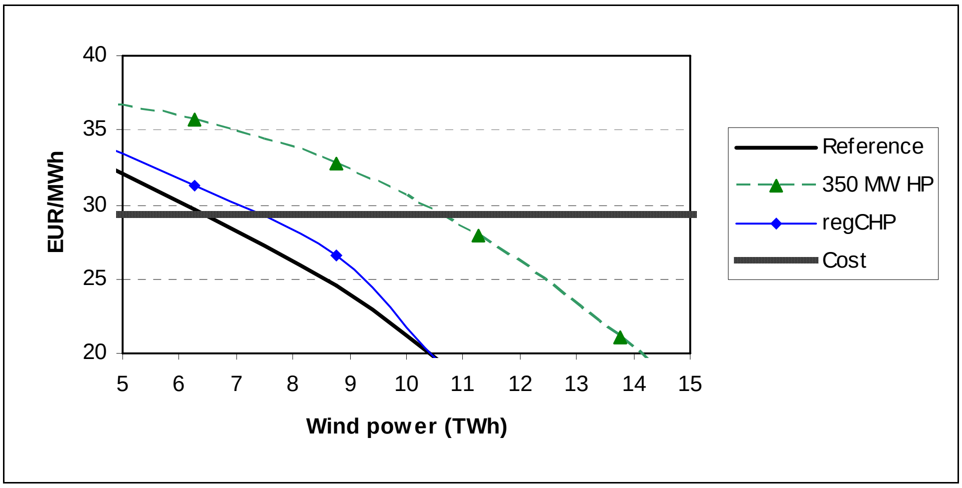

Figure 3. Marginal benefit of wind power in flexible versus non-flexible energy systems.

Fig. 3 refers to the same calculations and shows the results in greater detail. (Please note that the scale at the x-axis is changed compared to figure 2.)

A comprehensive sensitivity analysis of the feasibility analysis above has been conducted including the following parameters:

A 50 per cent increase in the investment costs of Heat Pumps

Changes in the CO_2 payment (Between 0 and 33 EUR/t).

Changes in the wind power production costs (Between 23 and 37 EUR/MWh)

Changes in fuel costs

Changes in marginal CO2 savings on the Nord Pool market
Changes in the influence of CO2 reductions on the Nord Pool spot prices
Changes in the future average price on Nord Pool from 32 to 40 EUR/MWh.
Change in import/export to Germany.
Change in range of Nord Pool price variations (More volatile prices).

The result of the sensitivity analysis is that the feasibility of new wind power investments is very sensitive to especially the CO2 payment and the wind power production costs, as illustrated in figure 4 for the reference system. The same influence has been found for the flexible energy systems; however, the feasibility is better in general. Meanwhile, two things have proven to be very resistant to any changes in the assumptions, namely:

- the high feasibility of investing in flexible energy systems (such as heat pumps) whenever wind power exceeds 20 per cent of annual electricity productions
- the result that flexible energy systems at the same time make wind power more feasible.

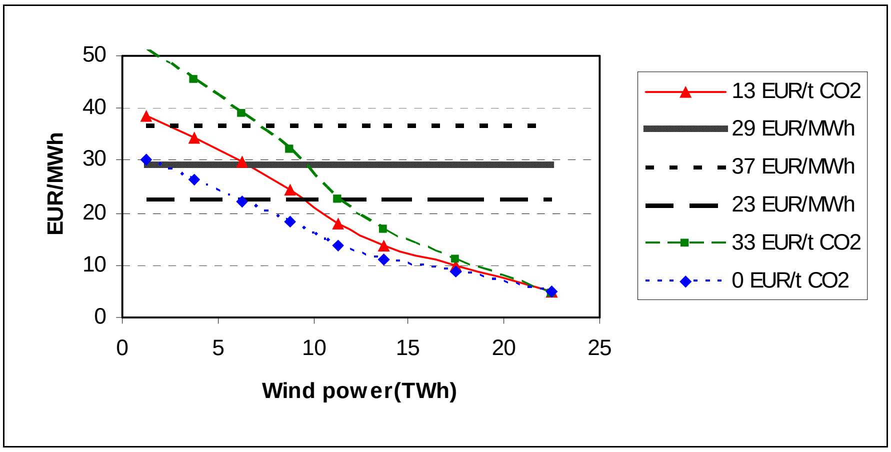

Figure 4. Sensitivity analysis. Variations of CO2 and wind power production costs.

Reference Scenario calculations

In this section, the reference scenarios for Denmark West, Germany and Scotland South for the year 2004 described in D 1.3 are used in order to assess the potential of CHP to regulate wind power in these regions. These calculations have relevance to the practical tests on making CHP plants trade on the spot markets, which will be carried out in WP5.

A similar method to the calculations presented in the former section is used. The potential for regulation is found for a wide range of wind power for each region.

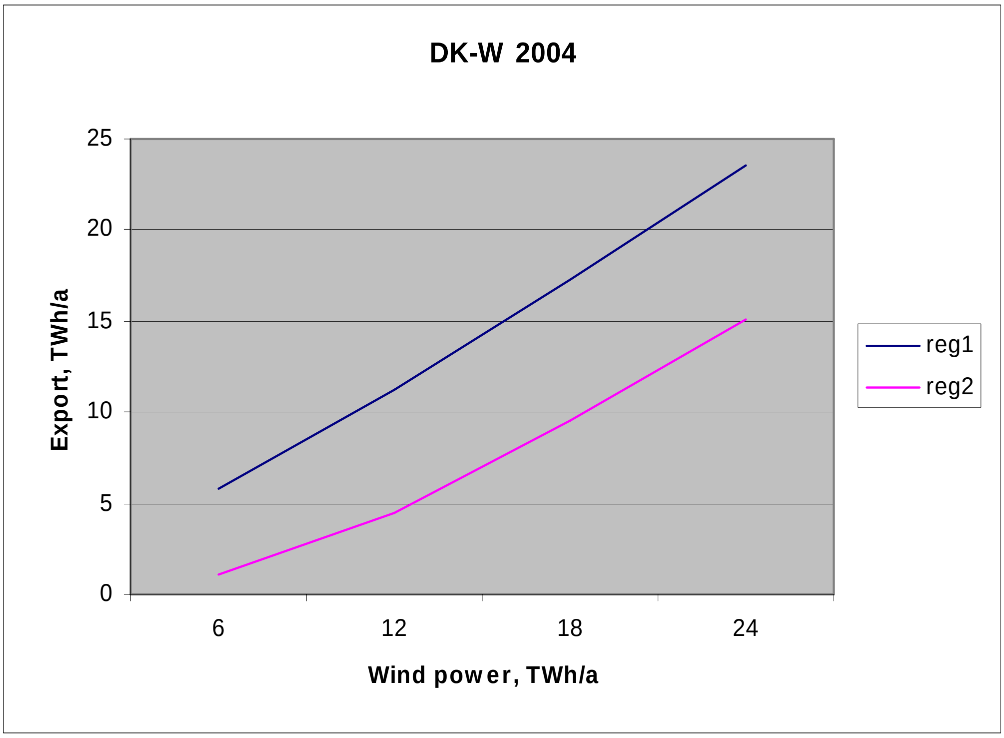

Figure 5. Export reduction by CHP regulation, Denmark West

Figure 5 shows the technical capability of the CHP plants in Denmark (4500 MWe in 2004) to reduce export if the regulation capacity is used solely for this purpose. No trading is assumed (and export is, in these calculations, not limited by transmission line capacities.)

It is seen that the CHPs are almost able to remove the excess electricity production in a situation corresponding to the present (6 TWh wind power). This result has relevance both to the question on necessary extensions of the transmission lines and to the problem of forced export at unwanted hours (with low prices).

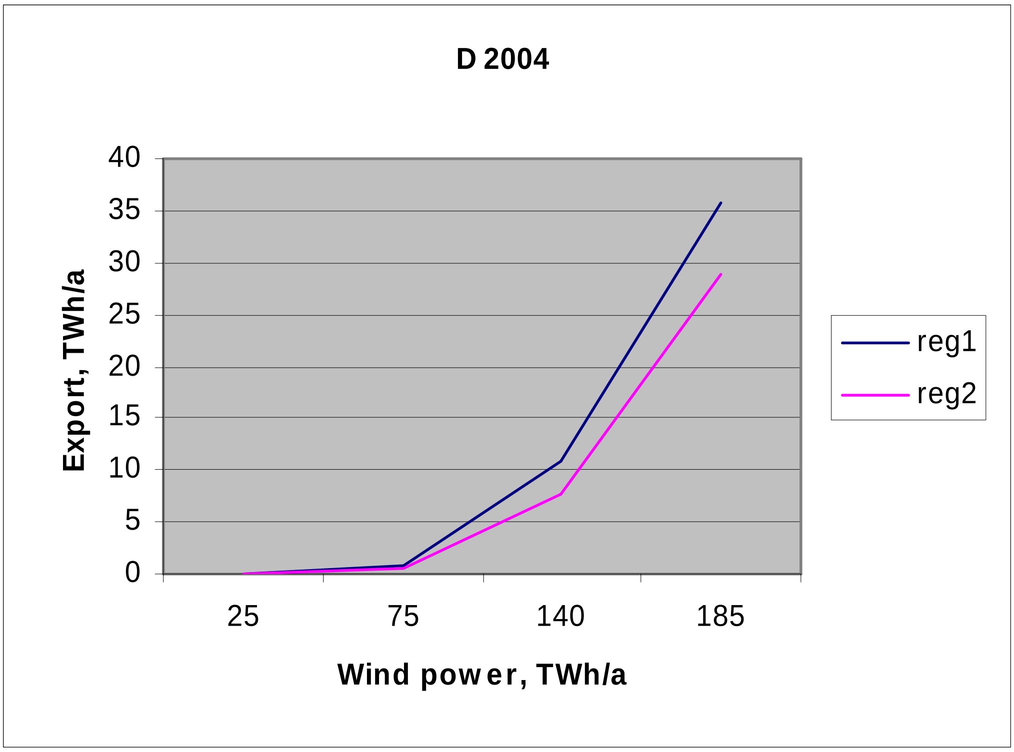

Figure 6. Export reduction by CHP regulation, Germany

Figure 6. shows that excess electricity is not a problem in Germany today, unless the amount of wind power will triple from the level of 2004 (25 TWh). The excess is due to the assumed inflexibility of the nuclear power plants. If wind power production is increased to more that app. 100 TWh, the present capacity of CHP (5300 MWe) is able to reduce the yearly excess by about 5 TWh – very much the same amount as in Denmark.

Figure 7. Export reduction by CHP regulation, Scotland South

For Scotland, the reference scenario for 2020 is used for the calculations because the CHP capacity in 2004 is negligible. In 2020, in which 298 MWe of CHP is assumed, the CHPs are able to reduce the excess caused by increasing amounts of wind power with app. 1 TWh/a.

Finally, the regulating potential of the heat storages is assessed.

Storage	CHP	PP	Import	Export
GWh	TWh	TWh	TWh	TWh
0	15,29	10,31	0,08	12,85
25	15,61	9,56	0,08	12,44
Difference	0,32	-0,75	0	-0,41

Table 1. Effect of heat storages. DK-W 2020

Table 1. shows the differences between two calculations performed for Denmark West, 2020. In the first calculation, no heat storages are assumed. In the next one, 20 GWh and 5 GWh of storages are assumed for the decentralized and the central CHPs, respectively. The heat storages are, in this calculation, used for minimising production at the condensing power plants (PP) by time shifting of the production at the CHPs. Trading on the spot market is assumed and the limits of the transmission lines are observed. Use of storages is seen to have the wanted effect. The production of the PPs decreases with 750 GWh and the production of the CHPs increases by 320 GWh. This is quite remarkable considering the size of the storages. These changes will increase the overall efficiency of the energy system and hence save fossil fuel and CO2 emissions. The storages could alternatively have been used for a purely economic optimisation, maximising the income by trading. Depending on the level of the costs of CO2

quotas, this regulation will give comparable results. This type of calculations is planned to be performed during the investigations on long term solutions and reported in deliverable D 1.5.

Conclusions

In this deliverable, it has been demonstrated that CHP plants have the potential of playing an important role in the regulation of fluctuating electricity production, like wind power. They can reduce the excess electricity production and, at the same time, increase the economic feasible level of renewable energy. The function is relevant in Denmark West already today, while it is likely to become relevant in Germany and Scotland South in the near future.

References

[1] Lund, H and Munster, E. Integrated energy systems and local energy markets. Energy Policy 2006;34(10):1152-1160]