1 Base Configuration and Case Studies

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The purpose of Wilmar is twofold: 1) to develop tools enabling analysis of wind integration issues, and 2) to use these tools to analyse technical and economic consequences of introducing large amounts of wind power in a North European power system in 2010.

This note describes the base configuration of the North European power system in 2010 that will be used as the starting point for different case studies. The base configuration has been discussed and agreed upon among the partners in the Wilmar project.

Furthermore apart from the base configuration, this note also contains a description of the wind power capacity scenarios to be used in case studies.

1.1 Data needs

A lot of data is needed when making a model of the power systems in Denmark, Finland, Germany, Norway and Sweden. Many of the data is linked to the geographical representations used in the model. The geographical representations covered are countries, regions and areas. Table 1 gives an overview of the data needs in Wilmar.

Table 1 Overview of the data needs in the Joint Market model. Those data with scope equal to "Year 2000-2010" need both to be specified for the historical reference years (2000-2002) and to the future scenario year 2010.

Data Object	Scope
Fuel data (C and S content)	Not time dependant
Hourly regional time series: - Electricity demand - Exchange with third countries - Scenario trees for wind power production	 Year 2000-2002 Year 2000-2002 Year 2000-2002
Daily regional time series: - Uncontrollable hydro inflow Finland and Germany - Controllable hydro inflow Finland and Germany	 Year 1980-2002 Year 1980-2002
Weekly regional time series: - Controllable inflow Norway and Sweden - Uncontrollable inflow Norway and Sweden	 Year 1980-2002 Year 1980-2002
Hourly area-dependent time series. - Heat demand	 Year 2000-2002
Weekly, unit group data: **-** Outages due to planned revisions and demand for slow reserves	 Year 2000-2010
Yearly time series (projections) - Fuel prices (specified on area) - Yearly heat demand (specified on area) - Yearly electricity demand (specified on region) - Need for positive and negative primary reserve (spinning reserves) - Need for positive secondary reserves (minute reserves) to cover outages	 Year 2000-2010 Year 2000-2010 Year 2000-2010 Year 2000-2010 Year 2000-2010
Technology data (capacities, technical and economic characteristics):	

- Existing units (production, transmission and storage) - Future units - Decommissioning of existing units	Year 2000-2003 Year 2000-2010 Year 2000-2010
Taxes, Tariffs and Support: - Support to electricity production on specific fuels - Tariffs on electricity used to produce heat - Tariffs on fuel consumption used to produce heat - Taxes on fuel consumption independently of end product	 Year 2000-2010 Year 2000-2010 Year 2000-2010 Year 2000-2010
Emission policies: - CO2 emission permit price - Sulphur tax	 Year 2000-2010 Year 2000-2010
Price flexible electricity demand	Year 2000-2010

The starting point is the installed capacities of power plants and transmission lines in 2003 and the historical electricity and heat demands in the power system in either year 2000, 2001 or 2002. A lot of time has been used in collecting these data, and hopefully the data set is of reasonable quality, although improvements are certainly possible especially with regard to harmonisation of assumptions for Germany and the Nordic countries regarding power plant parameters such as start-up times and start-up costs. Therefore we have to consider the development of the power system in the period 2004-2010. The data in the lower part of the table need to be projected into 2010.

1.2 Base Configuration of the North European Power system in 2010

1.2.1 New capacity except wind power

The general rule in the selection of new power plant investments has been to only select plants that are under construction or far in the planning process. The new investments are shown in Table 2.

Type	DK_W	DK_E	Norway	Sweden	Finland
Hydro	None	None	435 MW (910 GWh yearly prod)	None	71 MW (84 GWh yearly prod)
Nuclear	None	None	None	Ringhals: 2007: +145 MW, 2005-2011: +351 MW Forsmark: 2006: +135 MW, 2008-2010: +410 MW Oskarshamn: 2012: +30 MW, 2008: +255 MW	1600 MW Finnish nuclear in 2010 at Olkiluoto
Other thermal	None	70 MW AMV1 repowering in 2009	600 MW NGCC in 2009 (Kaarstø and Kolsnes together)	Rya NGCC in Göteborg with 260 MW in 2007.	Look in Table 3

Table 2 New capacities in the Nordic countries except wind power in the base configuration in the period 2004-2010. Sources (Söder 2005; Energistyrelsen 2005; Nordel 2005). All nuclear upgrading in Sweden mentioned in the table is included in the base power system configuration in 2010 except the 30 MW in Oskarshamn happening in 2012. Thereby the Swedish nuclear upgrading consists of 1296 MW.

Name of unit in database	Power capacity	Heat capacity	From year
CHP Wood FI_R_Industry 2004	130	220	2004
CHP Wood FI_R_Industry 2005	140	235	2005
CHP Wood FI_R_Industry 2006	150	250	2006
CHP Wood FI_R_Industry 2007	62	105	2007
CHP Wood FI_R_Industry 2008	50	84	2008
CHP Wood FI_R_Rural 2006	30	65	2006
CHP Wood FI_R_Rural 2007	40	88	2007
CHP Wood FI_R_Rural 2008	50	110	2008
Espoo nat_gas chp 2006	380	300	2006
CHP Gas FI_R_Rural 2008	100	70	2008

Table 3 New thermal capacity in Finland based on wood and natural gas in the base configuration in the period 2004-2010. Sources (Kiviluoma 2005).

Type	DE_CS	DE_NE	DE_NW
Hydro	2004: IGELECSTORAGE: Maxpower 1060 MW; Sto_Maxcontent 8840 MWh; Sto_MaxCharging: 1140 MW 2007: IGHYDRORUN: 90 MW		
Nuclear	none	None	None
Other thermal	2004: CHP (NGCC): 450 MW 2005: Condensing (gas turbine): 240 MW Condensing (NGCC): 251 MW Condensing (Misc fuel): 102.5 MW 2007: Condensing (gas turbine): 540 MW Condensing (NGCC): 2017 MW 2008: Condensing (NGCC): 800 MW 2009: Condensing (Lignite): 2230 MW 2010: Condensing (Coal): 2850 MW	2007: Condensing (NGCC): 1600 MW	2005: Condensing (Misc fuel): 40 MW CHP (gas turbine): 86 MW 2007: CHP (NGCC): 120 MW

Table 4 New capacity in Germany except wind power in the base configuration in the period 2004-2010. Source: Conventional and hydro plants: IER-own power plant database.

The following new transmission lines are assumed in the base configuration:

1. Germany: There is planned a new 380 kV line connecting DE_NW with DE_NE (currently there is no transmission capacity) for commissioning in 2007. The transmission capacity will be 1200 MW under the assumptions made also for the other transmission lines in Germany.

2. Fennoskan 2: 600 MW DC-link between FI_R and SE_M for commissioning in 2010.

3. Storebælt: 600 MW DC-link between DK_E and DK_W for commissioning in 2010.

1.2.2 Decommissioning

No decommissioning is assumed until 2010 in DK_W in accordance with (Eltra 2004) and in Norway. No decommissioning in Sweden except Barcebäck 2 with 600 MW in SE_S shut down from the start of 2006. No decommissioning in Finland except Inkoo (coal) reduced from 1080 MW to 480 MW in 2010. Power plants in DK_E are shut down according to the information in Table 5. No decommissioning in Germany except for nuclear power as given in Table 6.

Power plant	**Shut down year**	**Fuel**	**Power capacity**
H.C. Ørsted Værket, Rest	2006	Natural gas	155
Svanemølleværket, Rest	2007	Natural gas	75
Asnæsværket 4	2006	Coal	270
Stignæsværket 1	2006	Coal	143
Amagerværket 1	2004	Coal	136

Table 5 Assumed shut downs in DK_E in the period 2004-2010 based on E2 announcements (Wittrup 2004).

Year	DE_CS	DE_NE	DE_NW
2003			Stade : 630 MW
2004			
2005	Obrigheim: 357 MW		
2006			
2007	Biblis A: 1225 MW		
2008	Neckarwestheim 1: 840 MW (maybe in 2009 due to re-accounting of remaining electricity production from Obrigheim!)		
2009	Biblis B: 1300 MW		
2010	May be: Isar 1: 912 MW??		Brunsbüttel: 806 MW

Table 6 Decommissioning of nuclear power plants up to 2010. The planned decommissioning year can be delayed or pre-drawed due to unexpected outages or re-accounting of the remaining electricity production from or to other nuclear power plants..

The existing transmission capacities are not shut down.

1.2.3 Fuel prices

Different scenarios for fuel prices are used in the Wilmar analysis. Many of our studies have used a fossil fuel prices scenario for 2010 provided by IER. Table 7 shows the assumed fuel prices in Euro2002/GJ prices.

	Uran	Natural gas	Coal	Fuel oil	Light oil	Peat	Munici-pal waste	Straw	Wood	Wood Waste
2010	0.35	6.16	2.25	6.16	7.19	1.5	0.0	4.4	4.3	4.0

Table 7 Assumed fuel prices in Euro2002/GJ in 2010 an plant without taxes. The same fuel prices are assumed for all areas in the model.

1.2.4 Heat demand

	DK_E	DK_W	Finland	Norway	Sweden	Germany
2001	53.4	64.5	118.7	5.9	117.0	328.2
2002	54.3	65.5	119.7	6.0	117.7	327.8
2003	55.2	66.5	120.6	5.6	119.5	328.9
2004	56.1	67.4	120.9	5.7	120.0	330.0
2005	57.0	68.4	122.5	5.9	120.5	331.2
2006	57.3	68.9	123.0	6.0	121.0	332.4
2007	57.5	69.4	123.5	6.1	121.4	333.5
2008	57.8	70.0	124.0	6.2	121.9	334.7
2009	58.1	70.5	124.5	6.3	122.4	335.8
2010	58.3	71.0	124.7	6.5	122.9	337.0
Increase 2003-2010	**5.6%**	**6.8%**	**3.4%**	**14.9%**	**2.8%**	**2.8%**

Table 8 Yearly heat demand ab plant in PJ.

Table 8 shows the assumed values of the yearly heat consumption ab plant in PJ. The focus has been on representing the heat demand connected to combined heat and power plants correctly. The heat consumption connected to district heating areas without CHP is therefore underestimated, especially in the case of Sweden. The numbers are taken from (Elkraft 2003) in case of the Nordic countries and from annual reports of the German heat and power association for historical values for Germany. The total increase of the heat demand in Germany is taken from (Blesl et al. 2004). For Germany the heat demand covers the whole demand of the individual district heating grids, which is covered by the heat production from both CHP plants and boilers.

1.2.5 Electricity consumption

	DK_E	DK_W	Finland	Sweden	Norway	Germany
2001	14.6	20.9	81.6	150.5	125.5	492.9
2002	14.3	20.9	82.1	148.0	121.0	493.9
2003	14.2	21.0	83.6	148.6	122.5	501.4
2004	14.3	21.3	85.9	149.3	124.0	509.0
2005	14.5	21.7	87.0	150.1	125.5	516.7
2006	14.7	22.0	88.0	150.9	127.0	524.5
2007	15.0	22.4	89.6	152.3	128.5	532.4
2008	15.3	22.7	91.1	153.7	130.1	540.5
2009	15.6	23.1	92.7	155.1	131.7	548.7
2010	15.9	23.5	94.2	156.4	133.2	557
Increase 2003-2010	11.9%	11.8%	12.7%	5.2%	8.8%	11.1%

Table 1 Yearly power consumption ab plant in TWh.

The yearly electricity consumption in 2001-2003 for the Nordic countries has been found by summing the hourly data from Nord Pools ftp server. The electricity demand scenarios for the Nordic countries are taken from (Pedersen 2004). The scenario for Germany is taken from: Report of the Enquete-commission “Nachhaltige Energieversorgung unter den Bedingungen der Globalisierung und der Liberalisierung.

	DK_E	DK_W	Finland	Sweden	Norway	Germany
2001						
2002	-1.6	-0.1	0.6	-1.7	-3.6	0.2
2003	-1.1	0.9	1.8	0.5	1.2	1.5
2004	1.2	1.3	2.8	0.5	1.2	1.5
2005	1.2	1.7	1.2	0.5	1.2	1.5
2006	1.6	1.5	1.2	0.5	1.2	1.5
2007	1.8	1.6	1.8	0.9	1.2	1.5
2008	1.7	1.7	1.7	0.9	1.2	1.5
2009	1.9	1.7	1.7	0.9	1.2	1.5
2010	1.9	1.8	1.7	0.9	1.2	1.5
Increase 2003-2010	11.9%	11.8%	12.7%	5.2%	8.8%	11.1

Table 9 Percentage increase from year to year in the yearly power consumption ab plant in TWh.

1.2.6 Need for positive and negative primary and secondary reserve

In the following the classification of reserve capacity from [Nordel 2002] is used:

1. **Frequency regulation reserve** consist of both up and down regulation reserves that are activated momentarily when the frequency changes such that the total amount is activated at ± 0.1 Hz deviation from 50 Hz. The required amount is decided by Nordel.

2. **Momentarily disturbance reserve** consists of up regulation reserve activated automatically when the frequency drops between 49.9 and 49.5 Hz. The required amount is decided by Nordel using a so-called N-1 criteria for the whole of the Nordic system, i.e. the system should be able to handle fall-out of the largest unit in the Nordic system. Planned, automatic shedding of consumption e.g. of electrical heating can be part of the momentarily disturbance reserve.

3. **Fast (secondary) reserve** is up regulation that are activated manually and has to be available within 15 minutes. It can be delivered by both production and consumption. The required amounts are decided by the different system operators using an N-1 criteria for each country considered separately.

4. **Slow (tertiary) reserve** is up regulation reserve activated manually with a warning varying from one to several hours.

In the Nordic countries the negative primary reserve is equal to the frequency regulation reserve. The positive primary reserve is taken as the sum of the frequency regulation reserve and the momentarily disturbance reserve as mentioned in [Nordel 2004] (see Table 10). The demand for positive secondary reserves to cover outages is given in Table 10 as the demand for fast reserves.

Region	Frequency reserve (±MW)	Momentarily disturbance reserve [MW]	Fast reserves [MW]
DK_E	24	90[1]	600 (450[2])
DK_W	35[3]	75	620 (420[4])
Finland	141	205	1000
Norway	192	313	1600
Sweden	243	303	1200
Total	**635**	**986**	**4800**

Table 10 Reserve capacities in the Nordic system distributed on types [Nordel 2004].

The demand for positive primary reserve in Finland, Norway and Sweden is changed in 2010 due to the introduction of the new Finnish, nuclear power plant, which represents a dimensioning fault of 1300 MW and the upgrading of Swedish nuclear power (see Table 11).

Region	Frequency reserve (±MW)	Momentarily disturbance reserve [MW]	Fast reserves [MW]
DK_E	25	90	600 (450[5])
DK_W	35	75	620 (420[6])
Finland	135	329	1300
Norway	200	303	1600
Sweden	240	329	1300
Total	**635**	**1136**	**5200**

Table 11 Reserve capacities in the Nordic system distributed on types in 2010 [Holttinen 2005]. Changes caused by the introduction of the new Finnish, nuclear power plant in 2010 and the upgrading of Swedish nuclear power.

In the following table the values are subdivided according to the German classification of reserve capacity. Thereby the frequency reserve can be allocated directly to the Nordic frequency reserves. Also the minute reserves can be allocated directly to the the Nordic fast reserves. There is only a problem with the secondary reserves, that don’t really fit to the other categories of the Nordic classification. It is automatically activated and supports the minimization of frequency deviations and deviations of transmitted power. As a rule it is provided by spinning units and used for some minutes. We choose to allocate it to the primary (spinning) reserves in Wilmar.

1 40-50 MW of this comes from the Kontek transmission line.

2 The 450 MW is mentioned in Elkraft System, 2003, ”Uddybdende beskrivelse om udbud af systemydelser til Elkraft System a.m.b.a.

3 UCTE obligation that are not included in the Nordel obligation.

4 The 420 MW is mentioned in Eltra, 2003, “Beskrivelse af Eltras køb af systemtjenester og reguleringsreserver”, Notat ELT2003-251.

5 The 450 MW is mentioned in Elkraft System, 2003, ”Uddybdende beskrivelse om udbud af systemydelser til Elkraft System a.m.b.a.

6 The 420 MW is mentioned in Eltra, 2003, “Beskrivelse af Eltras køb af systemtjenester og reguleringsreserver”, Notat ELT2003-251.

Region	Frequency reserve (MW)		Secondary reserves [MW]		Minute reserves [MW]	
	Incremental	Decremental	Incremental	Decremental	Incremental	Decremental
DE_CS	625	625	2944	2299	2979	1786
DE_NE	6	6	28	22	38	17
DE_NW	76	76	358	279	362	217

Table 12 Reserve capacities in the Germany system distributed on types in 2003 (Meibom et al 2003). The same reserve capacity is assumed for Germany in 2010.

The reserve need in each country is distributed on regions proportional to the installed dispatchable capacity in each region relatively to the total dispatchable capacity in the country.

We only have a demand for positive and negative primary reserve, and positive secondary reserve represented in the Wilmar Planning tool. The demand for negative secondary reserve is assumed to be so easy to satisfy (e.g. in the worst case by shutting down wind power production), so it does not have to be treated explicitly in the Wilmar model.

1.2.7 Outages due to planned revisions and demand for tertiary reserves

Weekly data for the reduction in available capacity due to planned revisions have been provided by Elkraft System for the Nordic countries and IER for Germany. The data for Elkraft System was with regional resolution, i.e. they express an average availability factor for all power plants in a certain region.

1.2.8 Development in flexible electricity demand

Mikael Togeby from Elkraft has made a scenario for the development in the price flexible electricity demand, which he himself calls optimistic with regard to the development.

	DK			FIN			N			S			I alt		
Kr/kWh	0.5	1	5	0.5	1	5	0.5	1	5	0.5	1	5	0.5	1	5
2005	1	5	25	20	100	500	80	400	2,000	40	200	1,000	141	705	3,525
2010	20	50	100	200	500	1,000	700	1,750	3,500	400	1,000	2,000	1,320	3,300	6,600
2015	40	150	400	220	825	2,200	450	1,688	4,500	350	1,313	3,500	1,060	3,975	10,600
2020	50	200	660	227	909	3,000	455	1,818	6,000	379	1,515	5,000	1,111	4,442	14,660

Table 13 Scenario for the development in the price flexible electricity demand in 2005-2020 at different day-ahead market prices. The second row from the top indicates the price in DKK2003/kWh while the next four rows give the amounts that the electricity consumption is reduced with. For example in DK in 2015 the consumption is reduced with 40 MW when the power price becomes larger than 0.5 DKK/kWh. Is the price above 1 DKK/MWh the reduction is 150 MW. Is the price above 5 DKK/kWh the total reduction is 400 MW.

Translating the steps specified by Mikael Togeby to a more traditional elasticity factor gives a price elasticity of consumption on the day-ahead market (the relative change in consumption divided by the relative change in day-ahead market prices) on the total Nordic market of -0.066 in 2010.

So far the analysis done with the Wilmar Planning tool has not included price flexible electricity demand on the day-ahead market, although the possibility for having this is included in the model. The steps in the price flexible demand specified by Mikael Togeby for 2010 will be used as a starting point for a scenario for price flexible demand in the Nordic countries. For Germany no data for price flexible demand has been found so far.

1.2.9 Exchange between the countries within the model and third countires

Historical time series for the exchange with third countries have been collected. We assume that the exchange in 2010 is the same as the exchange in the historical year.

1.2.10 Emission policies

We have three scenarios for a CO2 emission permit price of 10, 17 and 25 Euro2002/Tons CO_2 in 2010 for respectively the low, medium and high CO_2 price scenario. We have collected the historical taxes on emission of SO2, but they have not been applied for the 2010 model runs, due to need for an update concerning the efficiencies of SO_2 emission reduction equipment on power plants.

1.2.11 Taxes, tariffs and support

Historical tax levels have been collected, and the possibility for including the effect of taxes and tariffs has been implemented in the Wilmar Planning tool. So far zero taxes are assumed for the 2010 model runs.

1.3 Case studies for wind power development

When analysing the technical and economic consequences of increasing the amount of wind power in the electricity system and the performance of integration measures, the development in the installed capacity of wind power is an important parameter. As we are making case studies for year 2010 it is limited how large a wind power development that can take place in this period. Therefore we have two possibilities if we want to test more extreme cases: either to supplement the year 2010 scenarios with a high wind scenario in e.g. year 2020, or alternatively just to increase the wind power in year 2010 disregarding considerations about the reality of such an development. As a lot of work is involved in defining a 2020 base configuration, we have done the following:

1. Defined a base wind power capacity scenario consisting of a “most likely to happen” projection of wind power capacity according to a review of public information provided by the Wilmar consortium.

2. A 10% wind power capacity scenario consisting of installed wind power capacity in Denmark and Germany corresponding to a “most likely to happen” 2015 projection, i.e. a stronger growth than in the base scenario. A unrealistic strong growth of wind power capacity in Finland, Norway and Sweden corresponding to installed wind power producing 10% of the electricity consumption in these countries in 2010 is furthermore assumed.

3. A 20% wind power capacity scenario with the same assumption for Denmark and Germany as in the 10% scenario, but a stronger growth in Finland, Norway and Sweden with wind power production covering 20% of electricity consumption in 2010.

The reason for supplementing the base wind scenario with two unrealistic high growth wind power scenarios for especially Finland, Norway and Sweden is that we wanted scenarios where wind power production had a significant effect on the operation of the rest of the power system, and these amounts will most likely not be present in the Nordic power system (except Denmark) in 2010.

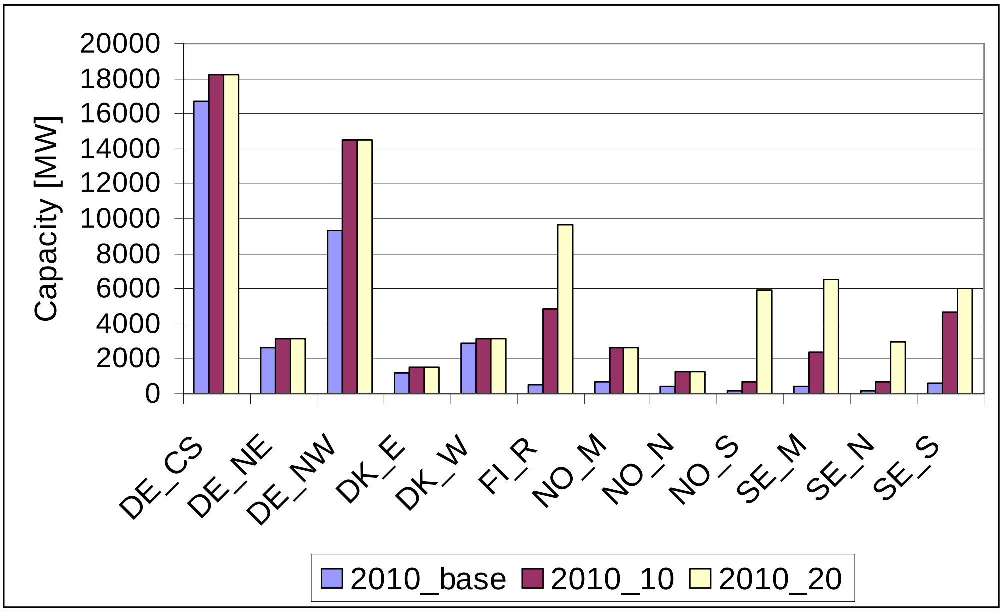

Figure 1 Installed wind power capacity in each region in the three wind power capacity development scenarios.

For Germany the values of the wind power capacity scenarios for 2010 (base) and 2015 (10% and 20%) are based on scenarios of the Dena-study. Comparable scenarios for Germany (except BTM that is only up to 2009) show lower values than the used ones.

Table 14 The development in installed wind power capacity in the base, 10% and 20% wind capacity scenarios. German values are based on DENA (2005). Nordic values are based on estimations among the Wilmar partners.

Regions	End of Year 2004	Base scenario	10% scenario	20% scenario
DE_CS	9972	16716	18245	18245
DE_NE (on-shore)	1085	1655	1711	1711
DE_NE (off-shore)	0	930	1400	1400
DE_NW (on-shore)	5809	5835	6087	6087
DE_NW (off-shore)	0	3452	8400	8400
DK Elkraft (on-shore)	554	600	600	600
DK Elkraft (off-shore)	200	600	900	900
DK Eltra (on-shore)	2240	2340	2340	2340
DK Eltra (off-shore)	160	560	760	760
FI_R	83	500	4847	9694
NO_M	104	650	2600	2600
NO_N	51	400	1300	1300
NO_S	9	150	650	5950
SE_M	197	400	2350	6500
SE_N	45	200	705	3000
SE_S	200	600	4700	6000

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