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## Documentation of databases in the Wilmar planning tool

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## Wilmar Deliverable D6.2 (f)

### Documentation of databases in the Wilmar Planning tool

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**Abstract:**

The Wilmar Planning tool consists of a number of databases and models as shown in Figure 1. This report documents the design of the following subparts of the Wilmar Planning tool:

1. The Scenario database holding the scenario trees generated from the Scenario Tree Creation model.
2. The Input database holding input data to the Joint Market model and the Long-term model apart from the scenario trees.
3. The output database containing the results of a Joint Market model run.

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## Preface

The Wilmar Planning tool consists of a number of databases and models as shown in Figure 1. This report documents the design of the following subparts of the Wilmar Planning tool:

1. The Scenario database holding the scenario trees generated from the Scenario Tree Creation model.
2. The Input database holding input data to the Joint Market model and the Long-term model apart from the scenario trees.
3. The output database containing the results of a Joint Market model run.

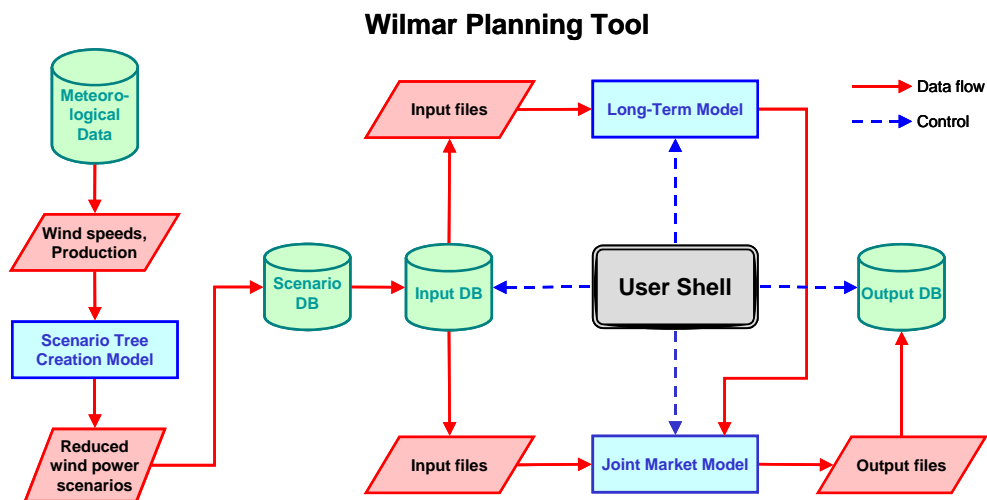


Figure 1 Overview of Wilmar Planning tool. The green cylinders are databases, the red parallelograms indicate exchange of information between submodels or databases, the blue squares are models. The user shell controlling the execution of the Wilmar Planning tool is shown in black.

# 1 Design Planning tool input database

The purpose of the Planning tool input database is to (1) store technology data, time series data, and geographical data as well as to (2) select the subset of the total data that is needed as input in a specific Joint Market model (JMM) simulation or Long term model (LTM) simulation and (3) convert this data into the format required by the GAMS modelling language. The output from the database is a series of text files formatted such that the GAMS programme can read the files and include the values specified in the files in the Joint Market Model simulation, or alternatively a series of text files such that the LTM can read the files. The design of the Planning tool input database reflects the data needs of the JMM and LTM as well as the level of detail used in the model for the description of the Northern European power (and heat) system.

## 1.1 Terminology

The tables and fields in the database have names that are independent of the naming used in the Joint Market Model. In general tables containing Sets have names that start with “Base ...”. Tables containing data have names starting with “Data ...”. The output files are generated in queries and these queries are named with “O Parameter xx” where xx is the name of the parameter in the Joint Market Model or in case of sets “O Sets xx” where xx is the name of the set in the Joint Market Model. Some parameter outputs need several queries to generate. In these cases, the queries delivering sub results are named “Subquery xx” where xx is the parameter name in the Joint market Model.

Tables containing data used specifically for the LTM are named “ LTM ...”. Queries generating output for the LTM are named “OWV ...”.

## 1.2 General table structure

Sets have been tagged with ID's in order to reduce the size of the output database. These include Countries, Regions, Areas, UnitGroups, Fuels, and technology types. The data in the input database does not rely on ID's for the most part, since the amount of data is not that big and it is more readable to have string values. String values are used in the JMM as well – they are converted into ID's once they are outputted from the JMM into text files for the output database.

A set table (Base tables) has first an ID and after that an associated string value. Most base tables have also fields which enable linking the tables. For example Base Regions table has Country field as well. Data table has the needed information to distinguish the data: time and place for the most part. Some data is also hypothesis (scenario) or year dependant – that is the user can select in the user shell which hypothesis to use, for example high or low CO<sub>2</sub> allowance prices.

## 1.3 Geographical Entities

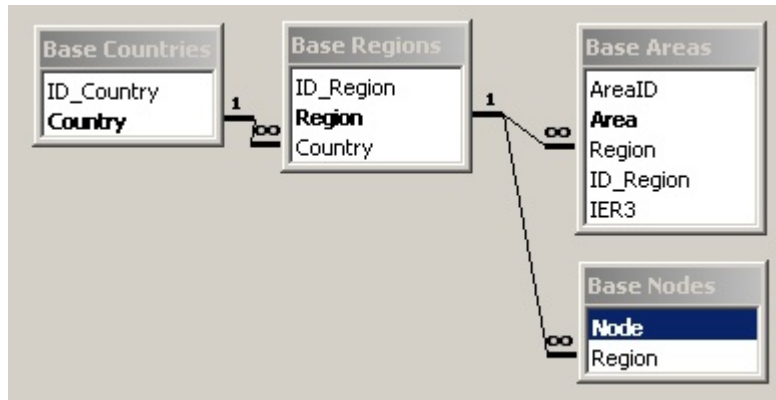


Figure 2: The tables and relationships used to specify the geographical entities used in the Wilmar project.

### 1.3.1 Base Countries

Contains the countries that are included in the model. The output query is named “O Set C”.

### 1.3.2 Base Regions

Contains the total number of regions. Each *region* is assigned to a specific *Country*. The output query is named “O Set RRR”.

### 1.3.3 Base Areas

Contains the total number of areas. Each *area* is assigned to a specific *Region*. Through yes/no-indication, each area can be defined as a heat area being modeled with minimum heat bounds derived from the model “IER3” or without minimum heat bounds but a more detailed subdivision into heat areas. The output query is named ”O Set AAA”.

### 1.3.4 Base Nodes

Contains the total number of nodes used in the load-flow model used in the system stability studies in the Wilmar project (WP5). Each *node* is assigned to a specific *Region*.



## 1.4 Technology Data

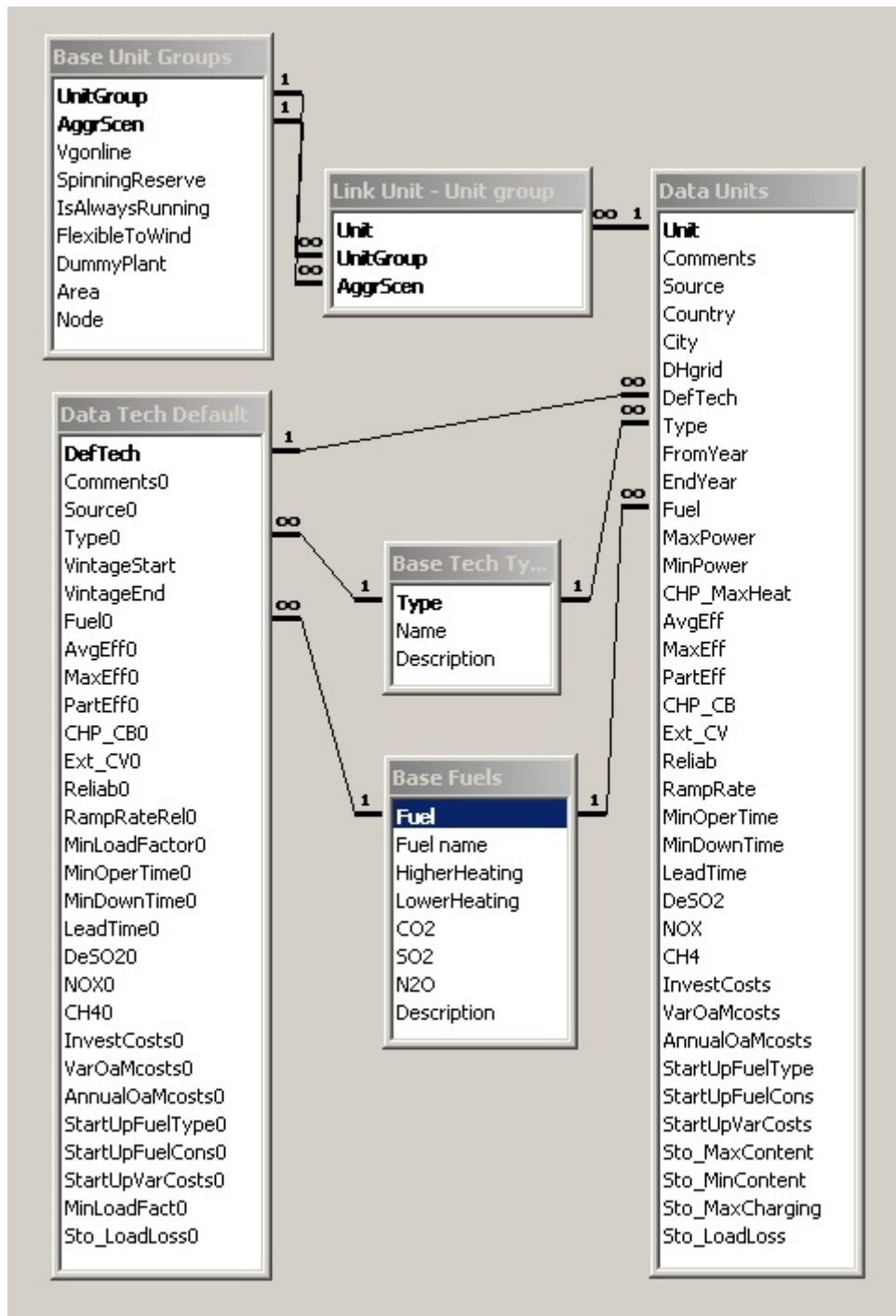


Figure 3: The tables involved in the specification of unit data and default technology data (the Areas table is not shown) including the tables defining the unit aggregation schemes.

The design of the tables and queries related to the treatment of technology data reflects the following two purposes:

1. Technology data exists on two levels in the database: Data for real, existing units (unit data) and data for default technologies. Public unit data typically only

exists for a few of the technology parameters used in the Joint Market Model<sup>1</sup>. Therefore, each unit has a default technology allocated, and each unit inherits data from the default technology. The default technology represents the “average” or most typical technology data for a certain vintage and type of technology.

2. The possibility for aggregating the units into unit groups must be included in the database, because aggregation of units is one way to reduce calculation time in the Joint Market Model. The aggregation is done in the database to make it transparent. Several aggregation schemes can be specified in the database. The aggregation of technology parameters is done in queries.

#### 1.4.1 Data Units

The Data Units table contains unit data. The data can either be for a specific unit or a specific group of units. Each unit has information about the country, city and district heating grid where the plant is, but this is not used for the JMM. Instead this depends on which UnitGroup the data unit is allocated into. Table 1 shows the parameters used to specify a unit.

*Table 1: Parameters used to specify a unit. Usually only a small subset of these data are public available.*

Parameter	Definition (and Parameter Name in the Joint Market Model)
Unit	Name of the unit.
Comments	Additional information about the unit.
Source	Data source.
Country	Country where the unit is located.
City	Name of the city in which the unit is situated or nearby.
DHgrid	Name of the district-heating grid to which the unit delivers heat.
DefTech	The default technology from where the unit inherits data in case of missing data for the unit
Type	Technology type. -GDTYPE
FromYear	First operational year of the unit. -GDFROMYEAR
EndYear	The last operational year of the unit.
Fuel	Main fuel used. -GDFUEL
MaxPower	Max output production [MW]. Only electricity output for backpressure and extraction. -GKFX
MinPower	Minimum output production when online [MW]. Only electricity output for backpressure and extraction. Used to calculate $GD\_MIN\_LF = \text{MinPower}/\text{MaxPower}$
CHP_MaxHeat	Max heat production [MW]. Only applies for backpressure and extraction.
AvgEff	Net average output efficiency [MWhOut/MWhFuel]. Only to be specified if data for MaxEff and PartEff do not exist. -GDFE
MaxEff	Net efficiency at maximum electricity output for electricity producing units and maximum heat output for units producing heat only [MWhOut/MWhFuel].-GDFULLLOAD
PartEff	Net efficiency at minimum electricity output for electricity producing units and minimum heat output for units producing heat only [MWhOut/MWhFuel]. -GDPARTLOAD
CHP_CB	Back pressure constant. Minimum power production at maximum heat production. [MWElec/MWHeat]. Applies only for backpressure and extraction. -GDCB

<sup>1</sup> The capacities of heat and power production are often publically available.

<b>Parameter</b>	<b>Definition (and Parameter Name in the Joint Market Model)</b>
Ext_CV	CV-value, Isofuel line. Decrease in electricity generation through increased heat generation [MWElec/MWHeat]. Applies only for extraction type of units. –GDCV
Reliab	Average available capacity due to technical breakdown, i.e., the reliability of the unit [ratio]. --part of GKDERATE
RampRate	Maximum ramp rate per hour [MW/h]. –GDRAMP
MinOperTime	Minimum operation time [hours]. –GDMINOP
MinDownTime	Minimum shut down time [hours]. –GDMINSD
LeadTime	The number of hours it takes between deciding to put a unit online and start of the production from the unit [h].–GDLEADTIME
DeSO2	The degree of desulphoring, i.e., how much SO2 is removed from the flue gas [ratio]. --GDDES02
NOX	The amount of NOx in the flue gas [mg/MJFuel]. –GDNOX
CH4	The amount of CH4 in the flue gas [mg/MJFuel]. --GDCH4
InvestCosts	Investment cost specified relatively to the capacity MaxPower [M€/MW]. Value discounted into Euro 2002. -GDINVCOST
VarOaMcosts	Variable operating and maintenance costs specified relatively to the total useful energy output [€/MWh]. Value should be discounted into Euro 2002 currency –GDOMVCOST
AnnualOaMcosts	Annual operating and maintenance costs specified relatively to the capacity MaxPower [k€/MW]. Value should be discounted into Euro 2002 currency. –GDOMFCOST
StartUpFuelType	The type of fuel used to start up the plant.
StartUpFuelCons	Start-up fuel consumption. MWh fuel used to increase the electricity capacity online by one MW [MWh/MW]. –GDSTARTUPFUEL
StartUpVarCosts	Other variable start-up costs than fuel costs [€/MW]. Value should be discounted into Euro 2002 currency. –GDSTARTUPCOST
Sto_MaxContent	The maximum energy capacity of the storage [MWh]. Only relevant for storages and hydro reservoirs. –GDMAXCONTENTFACTOR
Sto_MinContent	The minimum energy capacity of the storage [MWh]. Only relevant for storages and hydro reservoirs. –GDMINCONTENTFACTOR
Sto_MaxCharging	The capacity for the charging process of storages (pumping process of pumped hydro storage) [MW]. –GDMAXSTOLOADFACTOR
Sto_LoadLoss	The efficiency of storage when loading [Energy stored/Energy input].--GDLOADLOSS

Not all parameters are directly used in the Joint Market Model. “MinPower” is divided with “MaxPower” to give the minimum load factor “GD\_MIN\_LF” that is used in the Joint Market Model. To account for the efficiency at part load usually being lower than at fuel load, the following equation is used for the fuel usage in the Joint Market Model:

$$VGEFUELUSAGE = GDFE\_SLOPE(VGELEC + GDCV \cdot VGHEAT) + GDFE\_SECTION \cdot GKFX$$

where  $GDFE\_SLOPE$  is the marginal fuel consumption [GJ/MWh<sub>output</sub>] and  $GDFE\_SECTION$  [GJ/MW] is a factor introduced to represent part load efficiency. It can be understood as a constant fuel consumption connected to having a unit online. “MaxPower (GKFX)”, “MinPower”, “MaxEff” and “MinEff” are then used to calculate  $GDFE\_SLOPE$  and  $GDFE\_SECTION$  using that the following two equations must hold when producing respectively at maximum and at minimum power<sup>2</sup>:

<sup>2</sup> The equations are written for backpressure types of units. The same equations apply for the other technology types by deleting the term 1/GDCB from the equations.

$$GDFE\_SLOPE \cdot GKFX \left(1 + \frac{1}{GDCB}\right) + GDFE\_SECTION \cdot GKFX = \frac{GKFX \left(1 + \frac{1}{GDCB}\right)}{MaxEff}$$

$$GDFE\_SLOPE \cdot MinPower \left(1 + \frac{1}{GDCB}\right) + GDFE\_SECTION \cdot GKFX = \frac{MinPower \left(1 + \frac{1}{GDCB}\right)}{MinEff}$$

Isolating  $GDFE\_SLOPE$  and  $GDFE\_SECTION$  from the two equations we get:

$$GDFE\_SLOPE = \frac{GKFX \cdot MinEff - MinPower \cdot MaxEff}{MinEff \cdot MaxEff (GKFX - MinPower)}$$

$$GDFE\_SECTION = \frac{MinPower \left(1 + \frac{1}{GDCB}\right) (MaxEff - MinEff)}{MaxEff \cdot MinEff (GKFX - MinPower)}$$

#### 1.4.2 Data Tech Default

This table contains the data for default technologies (see Figure 3). Most of these parameters are the same as the unit parameters and a “0” has been added to the end of the parameter names to distinguish between these parameters and the parameters in the Units table. The data in the Default Tech table are characterised by being independent of a specific realisation of the default technology, i.e., all size parameters have been left out of the table<sup>3</sup>. If a need for allocating a default technology to a specific area arises, this can be done by defining a realisation of the default technology in the “Data Units” table, which will be characterised by only having values in the parameters Unit, Type, Fuel, MaxPower and DefTech, where the corresponding Default Technology is allocated in the parameter DefTech. This “default technology” unit can then be allocated to a certain area using the tables “Link Unit – Unit Group” and “Base Unit Groups”.

#### 1.4.3 Base Unit Groups and Link Unit – Unit Group

The units defined in table “Data Units” can be allocated to unit groups defined in table “Base Unit Groups” using the table “Link Unit - Unit Group” (see Figure 3). Only units having the same technology type (parameter Type) and fuel (parameter Fuel) can be aggregated.

The primary key in the Unit Groups table consists of the combination of the parameters UnitGroup and AggrScen, i.e., the combination of a unit group and an aggregation scenario. This combination is allocated to a specific area (parameter Area) and a specific Node<sup>4</sup> (parameter Node). This definition of the primary key ensures that a certain unit group can keep the same name in different aggregation scenarios although the definition of areas in the Joint Market Model changes.

#### 1.4.4 Base Tech Types

“Base Tech Types” is a look-up table containing the technology types used in the Joint Market Model (see Table 2).

<sup>3</sup> The capacity MaxPower, for storages the parameters StoMaxContent, StoMinContent, StoMaxCharging. Instead of directly specifying the minimum capacity MinPower for default technologies, this parameter is specified relatively to the MaxPower in the parameter MinLoadFactor0.

<sup>4</sup> A Node is the geographical entity used in the load-flow model used in the system stability studies in Wilmar. It is introduced to make the technology data available for these studies as well.

Table 2 The technology types used in the Joint Market Model. A technology type corresponds to a certain model of the technology i.e., a certain set of restrictions in the optimisation model.

Type	Name	Description
1	IGCONDENSING	Condensing thermal units
2	IGBACKPR	CHP Back pressure thermal units
3	IGEXTRACTION	CHP extraction thermal units
4	IGHEATBOILER	Heat-only boilers
5	IGHEATPUMP	Heat pumps or electrical heaters
6	IGHEATSTORAGE	Heat storage
7	IGELECSTORAGE	Electricity storage
8	IGHYDRORES	Hydropower with reservoir
9	IGHYDRORUN	Hydropower without storage (run-of-river)
10	IGWIND	Wind power
11	IGSOLAR	Photovoltaics

#### 1.4.5 Base Fuels

Table with fuel names and fuel properties (see Table 3).

Table 3 The parameters used to characterise the fuels used in the Joint Market Model. The emission values are calculated using the lower heat content of the fuel.

Parameter	Definition and Parameter Name in Joint Market Model
Fuel	The number used to identify the fuel. --FDNB
Fuel Name	The name of the fuel
CO2	The CO2 content in the fuel [kg/GJ]. --FDCO2
SO2	The SO2 content in the fuel [kg/GJ]. --FDSO2
N2O	The N2O content in the fuel [kg/GJ]. --FDN2O
Description	The description of the fuel

#### 1.5 Aggregation Rules for Technology Data

As previously mentioned, units are aggregated into unit groups in the database. How to calculate the value of technology parameters for unit groups on the basis of the parameter values for several units are for some parameters not obvious and several aggregation principles can be employed.

*The basic principle leading the first set of aggregation algorithms developed in the project is that the result should be correct when all units within a unit group produce at maximum. In this way, the considerations about what units will be operating when the unit group produces at part-load have been avoided. Furthermore, the penalty for operating at part-load in the Joint Market Model will probably result in most unit groups operating at maximum load for most of the time. For parameters where the rule about being right when producing at maximum cannot be applied, mean values are used where the parameter value of each unit is weighted with the capacity of the unit. Finally, a last check on the developed aggregation algorithms is that the aggregated values should be right when only one unit is aggregated, i.e., the aggregated value should be equal to the unit value.*

Table 4 gives the aggregation equations for each parameter.

Table 4 List of aggregation equations for each parameter used in the Joint Market Model. The aggregation rules for MaxPower, StoMaxContent, StoMinContent, StoMaxCharging are just the sum of each unit value. Type and Fuel are assumed having the same value for all units aggregated in a unit group. The aggregation rule “correct when all produce at maximum” is used for the parameters: GD\_MIN\_LF, GDPARTLOAD, GDFULLLOAD, CHP\_CB, Ext\_CV, DeSO2. The parameters MinOperTime, MinDownTime, LeadTime, InvestCosts, VarOaMCosts, AnnualOaMcosts, StartUpFueConsl, StartUpVarCosts are calculated as the capacity-weighted average of the values of each unit. The RampRate aggregation rule is correct under the assumption that all units in a unit group are online.

Apply to Technology Types <sup>5</sup>	Parameter Name (Data-base/Joint Market Model)	Aggregation Equations u: unit index, i: unit group index, U(i): set of units belonging to unit group i, t: year index
All	Type/GDTYPE	The same type for all units belonging to a certain unit group
C, E, B, ES, HRES, HRUN, WP, SO	MaxPower/ GKFXELEC	$MaxPower_i^t = \sum_{u \in U(i)} MaxPower_u^t$
HOB, HP, HS	MaxPower/ GKFXHEAT	$MaxPower_i^t = \sum_{u \in U(i)} MaxPower_u^t$
E,B	CHP_MaxHeat/ GKFXHEAT	$CHPMaxHeat_i^t = \sum_{u \in U(i)} CHPMaxHeat_u^t$
C, E, B	/GDMINLOAD FACTOR	$GD\_MIN\_LF_i^t = \frac{\sum_{u \in U(i)} MinPower_u^t}{\sum_{u \in U(i)} MaxPower_u^t}$
All	Fuel/GDFUEL	The same fuel for all units belonging to a certain unit group
B, E	CHP_CB/GDCB	$CHP\_CB_i = \frac{\sum_{u \in U(i)} CHP\_MaxHeat_u \cdot CHP\_CB_u}{\sum_{u \in U(i)} CHP\_MaxHeat_u}$
E	Ext_CV/GDCV	$Ext\_CV_i = \frac{\sum_{u \in U(i)} CHP\_MaxHeat_u \cdot Ext\_CV_u}{\sum_{u \in U(i)} CHP\_MaxHeat_u}$
C, E, B	RampRate/ GDRAMP	$RampRate_i = \sum_{u \in U(i)} RampRate_u$ ; the RampRate should be decreased with the CapacityOnline variable in the Joint Market model.
C, E, B	MinOperTime/ GDMINOP	$MinOperTime_i = \frac{\sum_{u \in U(i)} MaxPower_u \cdot MinOperTime_u}{\sum_{u \in U(i)} MaxPower_u}$

<sup>5</sup> The following technology types are defined in the Joint Market Model: Condensing (C), Backpressure (B), Extraction (E), Heat only boilers (HOB), Heat pumps (HP) (and other forms of heating using electricity), Heat storage (HS), Electricity storage (ES), Hydro with reservoir (HRES), Hydro run-of-river (HRUN), Wind power (WP), Solar voltaics (SO).

Apply to Technology Types <sup>5</sup>	Parameter Name (Data-base/Joint Market Model)	Aggregation Equations u: unit index, i: unit group index, U(i): set of units belonging to unit group i, t: year index
C, E, B	MinDownTime/ GDMINS	$MinDownTime_i = \frac{\sum_{u \in U(i)} MaxPower_u \cdot MinDownTime_u}{\sum_{u \in U(i)} MaxPower_u}$
C, E, B	LeadTime/ GDLEADTIME	$LeadTime_i = \frac{\sum_{u \in U(i)} MaxPower_u \cdot LeadTime_u}{\sum_{u \in U(i)} MaxPower_u}$
C, B, E	DeSO2/ GDDES	$DeSO2_i = \frac{\sum_{u \in U(i)} DeSO2_u \left( \frac{MaxPower_u}{MaxEff_u} \right)}{\sum_{u \in U(i)} \left( \frac{MaxPower_u}{MaxEff_u} \right)}$
All	InvestCosts/ GDINVCOST	$InvestCosts_i = \frac{\sum_{u \in U(i)} InvestCosts_u \cdot MaxPower_u}{\sum_{u \in U(i)} MaxPower_u}$
All except B	VarOaMcosts/ GDOMVCOST	$VarOaMCosts_i = \frac{\sum_{u \in U(i)} VarOaMCosts_u \cdot MaxPower_u}{\sum_{u \in U(i)} MaxPower_u}$
B	VarOaMcosts/ GDOMVCOST	$VarOaMCosts_i = \frac{\sum_{u \in U(i)} VarOaMCosts_u (MaxPower_u + CHP\_MaxHeat_u)}{\sum_{u \in U(i)} (MaxPower_u + CHP\_MaxHeat_u)}$
All	AnnualOaMcosts/ GDOMFCOST	$AnnualOaMCosts_i = \frac{\sum_{u \in U(i)} AnnualOaMCosts_u \cdot MaxPower_u}{\sum_{u \in U(i)} MaxPower_u}$
C, E, B	StartUpFuelCons/ GDSTARTUPFUEL	$StartUpFuelCons_i = \frac{\sum_{u \in U(i)} StartUpFuelCons_u \cdot MaxPower_u}{\sum_{u \in U(i)} MaxPower_u}$
C, E, B	StartUpVarCosts/ GDSTARTUPCOST	$StartUpVarCosts_i = \frac{\sum_{u \in U(i)} StartUpVarCosts_u \cdot MaxPower_u}{\sum_{u \in U(i)} MaxPower_u}$
ES, HS, HRES	Sto_MaxContent/ GDMAXCONTENTFACTOR	$StoMaxContent_i = \sum_{u \in U(i)} StoMaxContent_u$
ES, HS, HRES	Sto_MinContent/ GDMINCONTENTFACTOR	$StoMinContent_i = \sum_{u \in U(i)} StoMinContent_u$
ES, HS, HRES	Sto_MaxCharging/ GDMAXSTORAGEFACTOR	$StoMaxCharging_i = \sum_{u \in U(i)} StoMaxCharging_u$

Apply to Technology Types	Parameter Name (Data-base/Joint Market Model)	Aggregation Equations u: unit index, i: unit group index, U(i): set of units belonging to unit group i, t: year index
All except B	MaxEff/GDFULL LOAD	$MaxEff_i = \frac{\sum_{u \in U(i)} MaxPower_u^t}{\sum_{u \in U(i)} \left( \frac{MaxPower_u^t}{MaxEff_u} \right)}$
B	MaxEff/GDFULL LOAD	$MaxEff_i^t = \frac{\sum_{u \in U(i)} \left( MaxPower_u^t + CHP\_MaxHeat_u^t \right)}{\sum_{u \in U(i)} \left( \frac{\left( MaxPower_u^t + CHP\_MaxHeat_u^t \right)}{MaxEff_u} \right)}$
C, E	MinEff/GDPART LOAD	$MinEff_i = \frac{\sum_{u \in U(i)} MinPower_u}{\sum_{u \in U(i)} \left( \frac{MinPower_u}{MinEff_u} \right)}$
B	MinEff/GDPART LOAD	$MinEff_i = \frac{\sum_{u \in U(i)} MinPower_u \left( 1 + \frac{1}{CHP\_CB_u} \right)}{\sum_{u \in U(i)} \left( \frac{MinPower_u \left( 1 + \frac{1}{CHP\_CB_u} \right)}{MinEff_u} \right)}$
ES, HS	StoLoadLoss/GD LOADLOSS	$StoLoadLoss_i = \frac{\sum_{u \in U(i)} StoLoadLoss_u \cdot StoMaxCharging_u}{\sum_{u \in U(i)} StoMaxCharging_u}$

## 1.6 Technology Data Output

Two queries “Default Tech Data to Units - HistRef” and “Default Tech Data to Units - YearSim” transfer the default technology data to the relevant units in case of missing data in the Units table for units existing in respectively the historical reference period and the simulation year.

### 1.6.1 O Set G (Set of Unit Groups)

The set of unit groups in the simulation is generated with the query “O Set G”.

### 1.6.2 O Parameter GKFXELEC and O Parameter GKFXHEAT (Electricity and heat capacity)

The electricity production capacities of all unit groups in a simulation are generated using query “O Parameter GKFXELEC”. “O Parameter GKFXELEC” adds the electricity production capacities of all units in a unit group. Likewise “Subquery GKFXHEAT 1” adds the heat production capacities of all units in a unit group for backpressure and extraction type of units. “Subquery GKFXHEAT 2” does the same for heat boilers, heat pumps including electrical boilers, and heat storages. The union query “O Parameter GKFXHEAT” then collects the heat production capacities of all unit groups.



### 1.6.3 O Parameter GDATA and O Parameter GDATA 1

The parameter GDATA contains all the parameters describing the technical and economical properties of a unit group (all parameters with the Joint Market Model name starting with GD as shown in Table 1). Each parameter is aggregated using a separate query named “Subquery GDATA xxxxx” where xxxxx is the name of the technology parameter in the Joint Market Model. All these sub-queries are added into one using two union queries “O Parameter GDATA” and “O Parameter GDATA1”.

Different aggregation rules are used for the parameter GDOMVCOST (VarOaMCosts) according to the technology type in question (one rule for backpressure and another rule for the rest of the technologies). This situation has been resolved by introducing a dummy parameter TotalPower in the queries “Default Data to Units - HistRef” and “Default Data to Units - YearSim” where TotalPower is defined as:

$$TotalPower = \begin{cases} MaxPower + CHP\_MaxHeat & \text{for } Type = 2 \\ MaxPower & \text{for } Type \neq 2 \end{cases}$$

Type=2 indicates that the technology type is CHP backpressure. Using TotalPower instead of MaxPower+CHP\_MaxHeat or MaxPower, the two equations in

Table 4 for the parameter VarOaMCosts will be the same. The same method has been used to handle the two equations for GDFE\_SECTION where a dummy parameter MinEffFactor has been defined in the query “Default Data to Units”:

$$MinEffFactor = \begin{cases} 1 + \frac{1}{CHP\_CB} & \text{for } Type = 2 \\ 1 & \text{for } Type \neq 2 \end{cases}$$

### 1.7 Time series

Time series data can have hourly, daily, weekly or yearly resolution. The time series that have hourly, daily or weekly resolution cover only historical data. Yearly time series have also future values or hypothesis dependant values. To create time series for a future year, historical data is converted into future data by selecting the historical year and a hypothesis for the future year. The historical time series data is then multiplied with the factor between the historical year and hypothesis.

## 1.8 Hourly Time Series

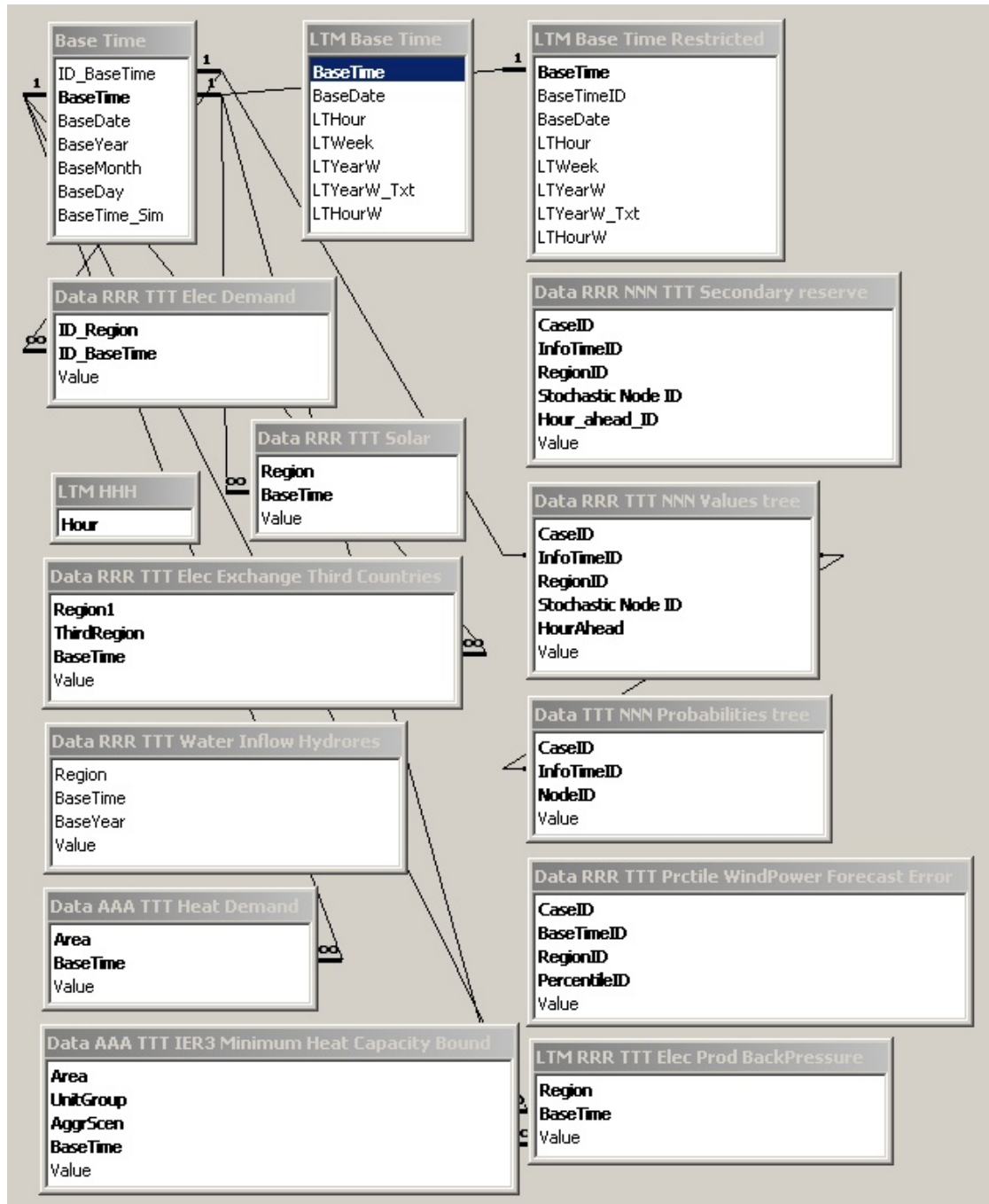


Figure 4 The tables used to store hourly time-series data in the Planning tool input database.

Figure 4 shows the tables involved in the storage of hourly time series and the field names of each table. Four tables are linked from the scenario tree database, i.e. the data are stored in the scenario tree database, but through the linking the tables are available in the Planning tool input database. These tables are “Data TTT NNN Probabilities tree”, “Data RRR TTT NNN Values tree”, “Data RRR NNN TTT Secondary reserve” and “Data RRR TTT Prctile WindPower Forecast Error”. The content of these tables are documented in section 3.

### **1.8.1 BaseTime**

This table contains the basic set of time periods specified as a text string in the form YYYY-MM-DD-HH as well as separate fields for date, year, month, day, hour and ID as well as a field to indicate the period selected for modelling.

### **1.8.2 LTM BaseTime**

This table contains the basic set of time periods specified as a text string in the form YYYY-MM-DD-HH as well as fields used when generating the input for the LTM.

### **1.8.3 LTM BaseTime Restricted**

Same as LTM BaseTime but with data restricted to the time period 2000-2002 to save time in the generation of the input to the LTM.

### **1.8.4 Data RRR TTT Elec Demand**

This table contains historical, hourly values for the electricity demand in each region. The values have been scaled such that the yearly sum is 1. They are multiplied with the yearly electricity consumption before being used.

### **1.8.5 Data RRR TTT Elec Exchange Third Countries**

This table contains historical, hourly values for the electricity exchange between a region within the simulated geographical area and a region outside the simulated area in MWh.

### **1.8.6 Data RRR TTT Solar**

Hourly values for the solar power production in each region (not in use currently) in MWh.

### **1.8.7 Data AAA TTT Heat Demand**

Hourly values for the heat demand in each area in MWh.

### **1.8.8 Data AAA TTT IER3 Minimum Heat Capacity Bound**

Hourly minimum heat production levels in MW for some of the heat plants in Germany obtained from the IER3 model. German district heating areas are treated separately from the Nordic areas and have code that needs these minimum limits.

### **1.8.9 Data RRR TTT Water Inflow Hydrores**

The hourly water inflow to hydropower reservoirs in each region in MWh. Derived from daily and weekly inflow data, but stored in a separate table instead of being generated with a query, because it reduces the generation time of the input data to the JMM.

### **1.8.10 LTM RRR TTT Elec Prod BackPressure**

Hourly electricity production in MWh from back pressure CHP plants in each region. Used in the long term model.

## 1.9 Daily Time Series

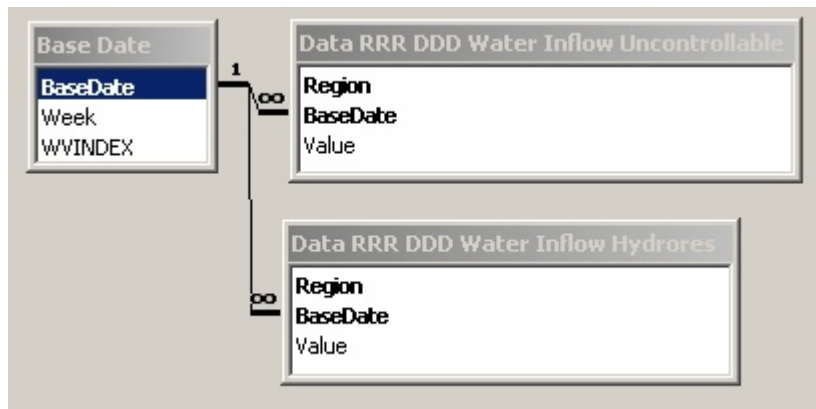


Figure 5 The tables involved in the storage of daily time series.

### 1.9.1 Base Date

Set of dates represented as a text string: YYYY-MM-DD. The associated week number is also saved in the table.

### 1.9.2 Data RRR DDD Water Inflow Uncontrollable

Daily values for uncontrollable (run of river) hydropower production in MWh.

### 1.9.3 Data RRR DDD Water Inflow Hydrores

Daily values for hydro inflow into hydropower reservoirs in MWh.

## 1.10 Weekly Time Series

Figure 6 shows the tables involved in the storage of weekly time series data.

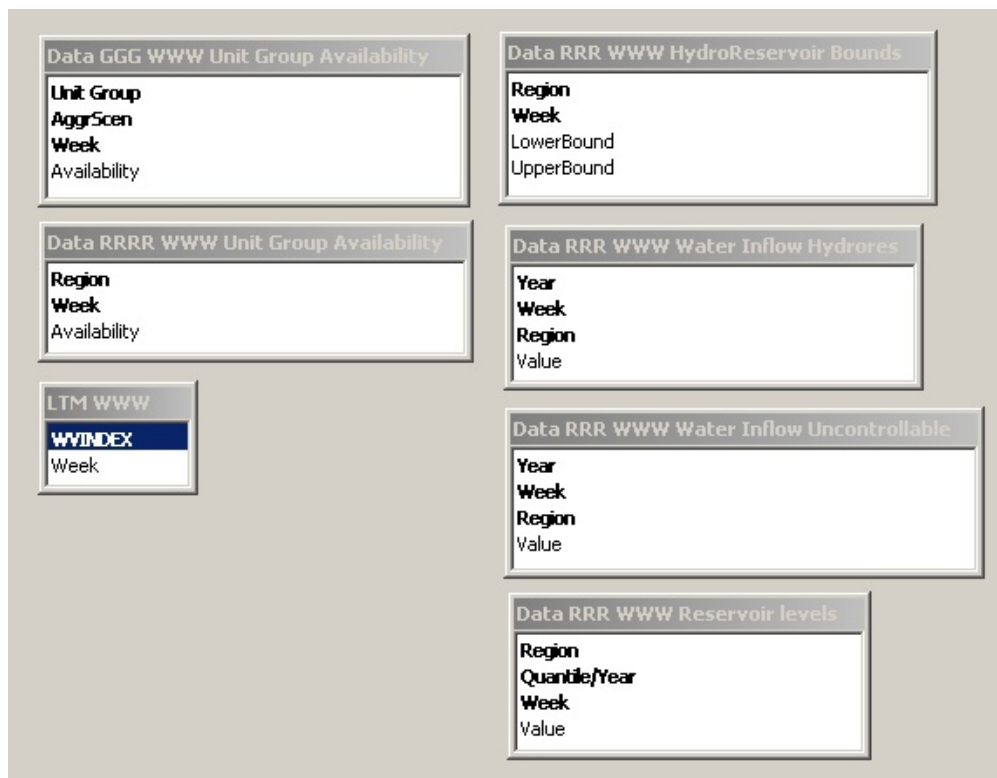


Figure 6 The tables and relations involved in the storage of weekly time series.

### **1.10.1 Data RRR WWW Water Inflow Hydrores**

The weekly water inflow to hydro reservoirs in MWh in each relevant region for the years 1980-2002. There are four series based on different hypotheses. Sintef is the original that is the result of Samkjørnignsmodel runs. It has more uncontrollable inflow when some of the reservoirs are full compared to other series. Since this forced production should be modelled by LTM/JMM, new series have been made based on the original Sintef series. Excess uncontrollable inflow has been transferred to inflow into reservoirs. 'Upper' series has the most conservative estimate, 'trend' is a best guess estimate of real situation, and 'lower' holds the least uncontrollable inflow – it has thus most regulative potential for wind power. See memo "WP6 memo on hydro series".

### **1.10.2 Data RRR WWW Water Inflow Uncontrollable**

The weekly water inflow in MWh that must be used immediately in the hydropower stations in each relevant area for the years 1980-2002. There are four series based on different hypotheses (see 1.10.1).

### **1.10.3 Data RRR WWW Reservoir levels**

This table holds historical and statistical data the hydro power reservoir levels in the regions that have hydro power.

### **1.10.4 Data RRR WWW HydroReservoir Bounds**

This table sets the limits relatively to the maximum reservoir capacity for the water content of hydro power reservoirs.

### **1.10.5 LTM WWW**

Set of week numbers used in the LTM model.

### **1.10.6 Data GGG WWW Unit Group Availability**

Weekly availability factors for each unit group.

### **1.10.7 Data RRR WWW Unit Group Availability**

Weekly availability factors for unit groups within a specific region. Data has been distributed on unit groups in table "Data GGG WWW Unit Group Availability".

## **1.11 Yearly Time Series**

*Figure 7* shows the tables involved in the storage of yearly time series. The yearly time series are historical realised values of different parameters with a yearly resolution and forecast of the values of these parameters in future years according to a certain hypothesis.

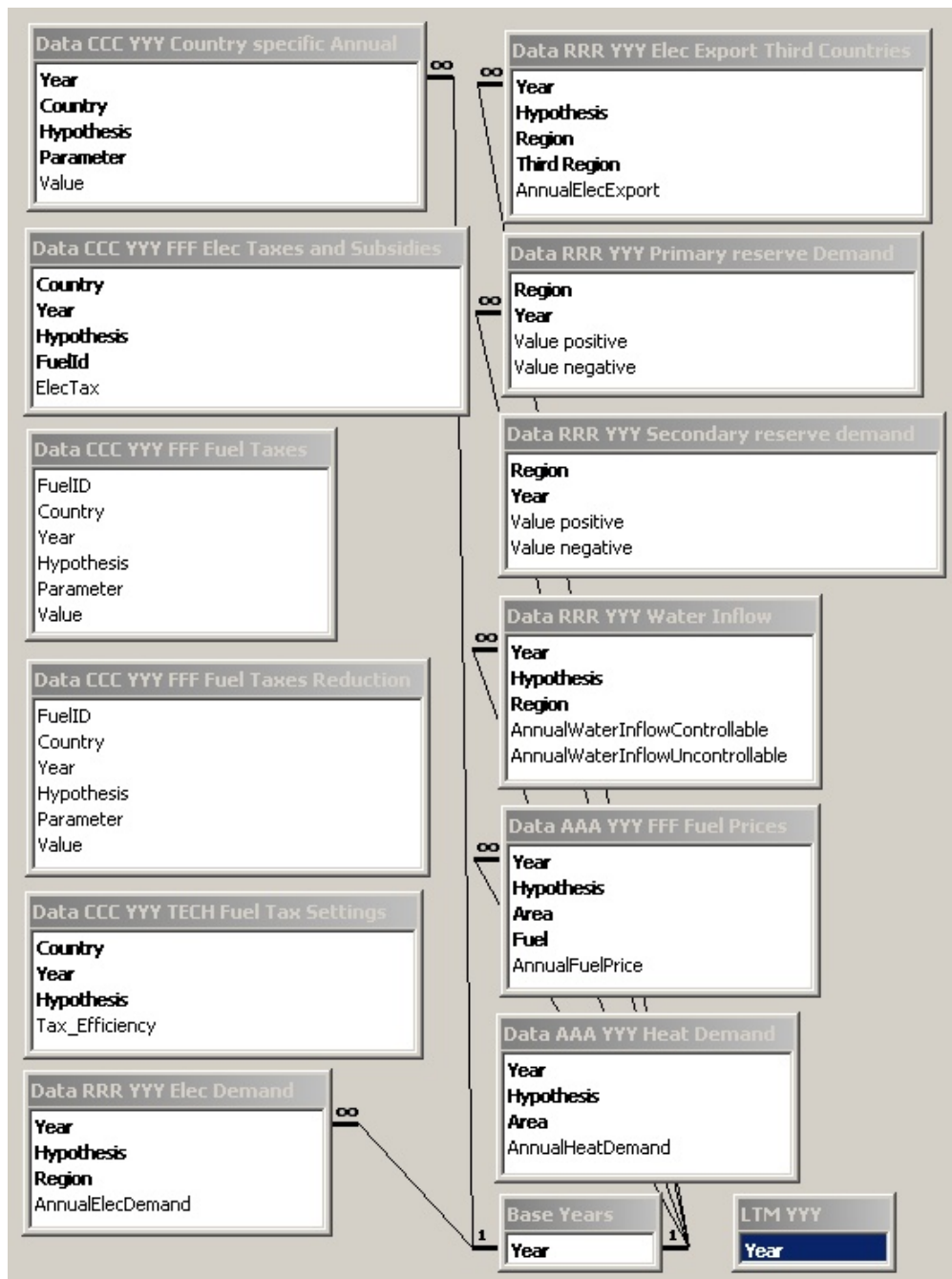


Figure 7 The tables and relationships involved in the storage of yearly time series.

#### 1.11.1 Base Years and LTM YYY

The set of years in the JMM and LTM.

#### 1.11.2 Data AAA YYY Fuel Prices

The average yearly fuel price in Euro 2002/GJ for a certain fuel, year, area and hypothesis.

#### 1.11.3 Data AAA YYY Heat Demand

The yearly heat demand in MWh for a certain area, year and hypothesis.

#### 1.11.4 Data RRR YYY Elec Demand

The yearly electricity demand in MWh for a certain region, year and hypothesis.

### **1.11.5 Data RRR YYY Elec Export Third Countries**

Data for historical (2000-2002) and hypothesis-dependant electricity exports/imports in MWh.

### **1.11.6 Data RRR YYY Primary reserve Demand**

The yearly demand in MW for positive and negative primary (automatically activated) reserves in each region.

### **1.11.7 Data RRR YYY Secondary reserve Demand**

Demand for secondary reserve (minute reserve) in MW, which is based on the fall-out of the largest power plant or transmission line (N-1) criteria. These data are used in the deterministic runs with the JMM. In the stochastic runs with the JMM the demand for secondary reserve calculated in the scenario tree tool and stored in “Data RRR NNN TTT Secondary reserve” are used.

### **1.11.8 Data RRR YYY Water Inflow**

Inflow of water in MWh into hydro power reservoirs and into run-of-river plants. Historical data from 1980 to 2002 and hypothesis-dependant data for future years.

### **1.11.9 Data CCC YYY ...**

These tables hold emission tariffs, the taxes on fuels as well as taxes and subsidies on electricity production. There is a large variety of different tax schemes and for the most part they have been incorporated in the model. The table “Data CCC YYY FFF Elec Taxes and Subsidies” has negative values for subsidies in the electricity production and positive values for taxes. Table “Data CCC YYY FFF Fuel Taxes” has historical data on fuel taxes for heat production and hypothesis dependant taxes for future years. In the table “Data CCC YYY TECH Fuel Tax Settings” one can take into account how the fuel tax on heat production at CHP plants is calculated. For some countries the tax is reduced. “Data CCC YYY FFF Fuel Tax Reduction” is for Germany that has separate code to implement the different taxation between condensing and CHP plants. “Data CCC YYY Country specific annual” has emission permit prices or emission tariffs for SO<sub>2</sub> and CO<sub>2</sub>.

## **1.12 Other Data**

Most of the above-mentioned data tables contain data for one parameter. In contrast, the following tables use a general field “Parameter” that is linked to a basic table “Base Parameters” containing the names of the parameters. This design is more flexible towards the addition of new parameters.

### **1.12.1 Base Parameters**

Contains the definitions of parameters used in the database tables. The short name of the parameter definition (*Parameter*) is completed by a short *description* and the indication in which set this parameter is used mainly (*Referring to*).

### **1.12.2 Data CCC Country General**

Figure 8 depicts the basic data table for country-related information. The table first contains the reference for the described object (*Country*), a reference to the *parameter* described in each entry (as defined in *Base Parameters*) and finally the *value* to this parameter. Through this structure, the data tables can easily be adjusted to new data necessary for the model.

Parameters used in the “Data CCC Country General” table:

*TAX\_DE – consumers tax on electricity consumption (not used presently)*

*TAX\_DH – consumers tax on heat consumption (not used presently)*

*ANNUITYC – discount rate used to calculate the annuity of investments (not used presently)*

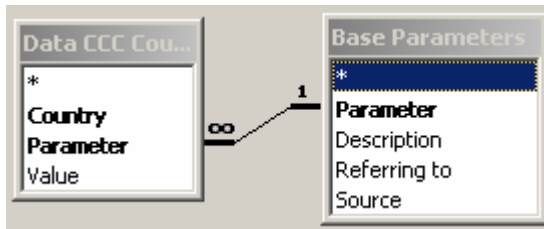


Figure 8: Tables used to store country related information.

### 1.12.3 Data AAA Area General

Contains all data related to a specific area. The relevant parameters:

*DHFP\_BASE – nominal annual average consumer heat price (not used presently)*

*DISCOST\_H – cost of heat distribution (not used presently)*

*DISLOSS\_H – loss in heat distribution*

### 1.12.4 Data RRR Region General

Contains all data related to a specific region. The relevant parameters:

*DEFP\_BASE – nominal annual average electricity price (not used presently)*

*DISCOST\_E – cost of electricity distribution (not used presently)*

*DISLOSS\_E – loss in electricity distribution*

### 1.12.5 Data RRR RRR Region-to-Region

The data table first contains the reference for the two described objects (in this case, *Region\_1* and *Region\_2*), a reference to the *parameter* described in each entry (as defined in *Base Parameters*) and, finally, the *value* to this parameter.

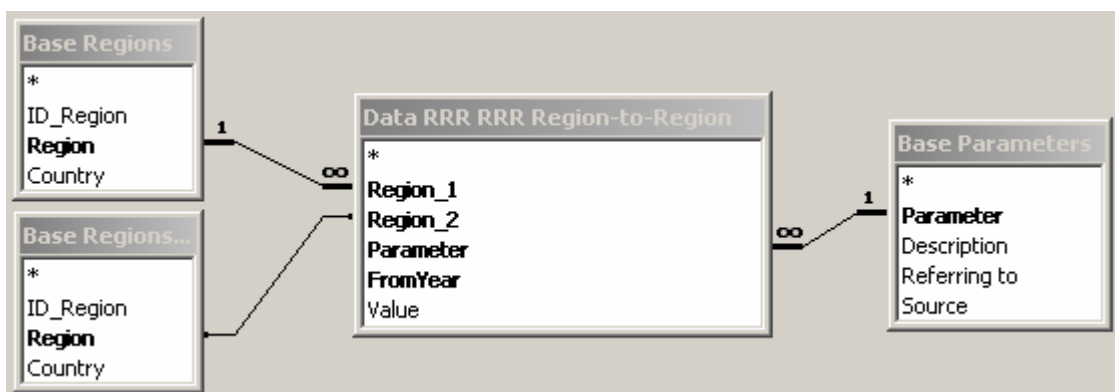


Figure 9: Tables used to store parameters dependent on two regions.

The relevant parameters used comprise:

*XCAPACITY – transmission capacity between regions*

*XLOSS – transmission loss between regions*



## **1.13 Using the Planning tool input database**

Tables beginning with “Case...” specify which data will be included in the output files which the JMM will use. Only exception to this is the wind power scenarios which are selected according to which database the four scenario tables are linked. The table “Access-Excel Link” contains the directories for the JMM, LTM, and WP5. All of these settings are easiest to select and change in the user shell, which will then automatically update the database.

The table “Case Definition” holds values for all cases that have been inserted into the system. “Case Selected” and “Case Selected Values” hold the information for the currently selected case. “CaseID” has ID’s for all the cases for the benefit of the output database.

### **1.13.1 Data Import**

The import of new technology data into the database can either be done manually using input forms, which will only be relevant for small amounts of data, or by importing the data in temporary tables and then using append queries to distribute the data in the right tables. Import of technology data should be done in the following order:

1. First import the new default technology data into table “Default Tech”;
2. Then import the unit data into table “Units”;
3. Then make the unit groups in table “Unit Groups”;
4. Then determine the aggregation scheme by completing table “Link Unit – Unit Groups”.

### **1.13.2 Generating Include Files for the JMM**

There is a button in the toolbar, which generates the Include Files to be used in the Joint Market Model when pressed. The include files can be created also from the planning tool. It will open up a log window to show the progress of writing the files. It will also ask for a directory to place the Include Files. All queries starting with “O” will be made into an include file having the extension “inc”.

There are two types of Include Files: those that define members of sets used in the Joint Market Model, and those assigning values to parameters used in the Joint Market Model. The syntax in the first type of Include Files is just a list where each set member is written on a separate line, e.g., for the set C (countries in the simulation):

Denmark  
Finland  
Germany  
Norway  
Sweden

The Include Files assigning values to parameters do this in the form of a list consisting of a label-tuple (in case of parameters with higher dimensions) and a value. Each element in the tuple is separated by dots (.), e.g., the power demand data, which depends on the sets RRR and BaseTime are specified as:

NO\_S . 2000-01-06-00 = 11138.31  
DK\_W . 2000-01-06-00 = 2034  
NO\_M . 2000-01-06-00 = 3088.146  
FI\_R . 2000-01-06-00 = 8850  
NO\_N . 2000-01-06-00 = 764.541  
NO\_S . 2000-01-06-01 = 10768.3  
DK\_W . 2000-01-06-01 = 1950

### **1.13.3 Generating Include Files for the LTM**

There is a button in the toolbar, which generates the include Files to be used in the Long term model when pressed. The include files can be created also from the planning tool. It will open up a log window to show the progress of writing the files. It will also ask for a directory to place the Include Files. All queries starting with “OWV” will be made into an include file having the extension “txt”.

## 2 Joint Market model output database

The Joint Market model output database stores the results of modelling runs and has forms and queries to present the data. It can store several case runs at the same time and has queries for the comparison of different cases. The table structure of the database tries to minimize the size of the database while the query structure tries to minimize the time to retrieve information from the tables. However, when the database holds lot of data, e.g. whole year, some queries will be too slow to use. In these cases it is advisable to use sub-queries and collect the data into Excel sheet for instance.

Basic geographical and time data are linked from the input database. Technology data is imported for each case from JMM, since this data can change from run to run. Variables are recorded at the lowest possible level for each hour, usually at the level of UnitGroups. Recorded variables include production and consumption of electricity and heat, reserve reservations, fuel usage, online status, start ups, and transmission of electricity. Shadow prices of storages as well as marginal prices of the most important equations are also stored.

Most important data can be shown graphically using forms of the database. They utilize the queries that gather the data from the underlying tables. In a form one can choose the object of analysis and the time period for the analysis. There exist forms for electricity prices, wind power forecast vs. realized wind power, power production distributed on fuels, production with consumption and transmission, production from individual UnitGroups, transmission between regions, check for equation balances and a form in which one can compare differences of separate cases.

There are also some queries that do not have their own forms. Their content can usually be best viewed with Access PivotChart functionality.

### 2.1 The tables

Most tables hold data that have ID for the case, ID for the UnitGroup, Region, or Area that the data represents, time stamp, and a value for that particular record. ID's are numeric with smallest viable integer data type. Time stamp, called BaseTime, is a string of 13 characters. Data values are stored as single precision floating point numbers. Some tables have lookup implemented, so that one does not see IDs rather than the real names. In order to save space, tables don't usually hold zero values.

#### 2.1.1 Base tables

“Base Areas”, “Base Fuels”, “Base Regions”, “Base Time”, and “Base UnitGroups” are linked from the input database and are described above. The link has to be updated if the name or the location of the input database changes, although the user shell will also do this.

“BaseDate\_Hour” is a lookup for some queries, which show daily profile.

“BaseTimes” holds the BaseTimes of each case separately.

“CaseNames” holds the current cases in the database.

“Choice” holds user selections, which limit the data retrieved by queries and the data shown by forms.

“TechData” and “TechnologyData” have all technical parameters of UnitGroups for each case.

“UnitGroupsInCase” shows which UnitGroups have been implemented in each case. Used by queries to limit data.

“VariableDef” has description of parameters stored in the database.

“Access-Excel Link” has the directories for the JMM, LTM, and WP5. It should be changed with the user shell.

### **2.1.2 Tables holding marginal values**

“ISDP\_HYDRORES”, “ISDP\_ONLINE”, and “ISDP\_STORAGE” have shadow prices for water in hydropower reservoirs, keeping units online, and for electricity and heat storages respectively. Shadow prices indicate how much one unit (MWh) more of stored water/electricity/heat or online capacity is worth.

Tables starting with letter Q have marginal values of some of the restricting equations in the model. They are named with the name of the restriction in the JMM plus \_M to indicate that it is a marginal value. “QEEQDAY\_M” and “QEEQINT\_M” have marginal values for the electricity balance equations, which is interpreted as the electricity prices in the DayAhead and IntraDay markets for each region in Euro 2002/MWh. “QANCPOSEQ\_M” and “QANCNEGEQ\_M” hold values for primary reserve prices. “QNONSP\_ANCPOSEQ\_M” is for non-spinning reserve. “QESTOVOLT\_M” indicates the marginal value of increasing the storage capacity of electricity storages. “QGONLSTART\_M” has the marginal value for UnitGroup start up, which should be zero if the UnitGroup is already running. “QHEQURBAN\_M” has the price of heat production and “QHSTOVOLT\_M” has the marginal value of increasing the storage content of heat storages.

### **2.1.3 Tables with variables**

If not stated otherwise the unit is MWh.

“VCONTENTHYDRORES” – Content of the hydropower reservoirs in MWh per area. There is at most only one area with reservoir hydro power in each region though.

“VDEMANDELECFLEXIBLE” – The amount (MWh) of price flexible demand activated in the production hour. Positive values indicate increased consumption.

“VGELEC” – Sold electricity production (MWh) in the DayAhead market for each UnitGroup except unregulated production (wind power, run-of-river hydropower). For unregulated production VGELEC contains the realised production from wind power and run-of-river hydropower.

“VGELEC\_DPOS” – Up regulation in the IntraDay market.

“VGELEC\_DNEG” – Down regulation in the IntraDay market.

“VGELEC\_CONSUMED” – Sold electricity consumption (MWh) in the DayAhead market for each UnitGroup that can store electricity or produce heat from electricity.

“VGELEC\_CONSUMED\_DPOS” – Increased loading of electricity storage or heat pump in the IntraDay market.

“VGELEC\_CONSUMED\_DNEG” – Decreased loading of electricity storage or heat pump in the IntraDay market.

“VGELEC\_CONTENTSTORAGE” – Content of each electricity storage (MWh).

“VGE\_ANCPOS” – Electricity capacity reserved in each UnitGroup for providing positive primary reserve.

“VGE\_ANCNEG” – Electricity capacity reserved in each UnitGroup for providing negative primary reserve. UnitGroup has to be producing at certain level in order to provide this.

“VGE\_NONSP\_ANCPOS” – Electricity capacity reserved in each UnitGroup for providing positive non-spinning reserve.

“VGE\_CONSUMED\_ANCPOS” – Reservation of decreased loading capacity of electricity storage or heat pump for providing positive primary reserve. UnitGroup has to be loading (consuming power) at certain level in order to provide this.

“VGE\_CONSUMED\_ANCNEG” – Reservation of increased loading capacity of electricity storage or heat pump for providing positive primary reserve.

“VGE\_CONSUMED\_NONSP\_ANCPOS” – Reservation of decreased loading capacity of electricity storage or heat pump for providing positive non-spinning reserve. UnitGroup has to be loading at certain level in order to provide this.

“VGEFUELUSAGE” – Fuel usage of each UnitGroup that uses fuel.

“VGHEAT” – Heat production (MWh) of each UnitGroup during the production hour.

“VGHEAT\_CONSUMED” – Heat consumption (MWh) of heat storages during the production hour.

“VGHEAT\_CONTENTSTORAGE” – Amount of stored heat in MWh at heat storages.

“VGONLINE” – Online capacity of each UnitGroup except wind power. For hydropower and electricity storage VGONLINE is set equal to the available capacity of these plants.

“VGSTARTUP” – Capacity started up from time T-1 to T.

“VOBJ” – The value of the objective function in the JMM in Euro2002.

“VOBJ\_R\_T” – The cost components distributed on regions and hours in Euro 2002. Only written for the root node hours, i.e. the first three hours of each optimisation loop. Covers cost of fuel consumption, variable O&M costs, start-up costs, transmission costs, CO2 costs, taxes, subsidies and change in consumer surplus.

“VXELEC” – Amount of sold electricity transmission (MWh) from Region1 to Region2 in the DayAhead market.

“VXELEC\_DPOS” – Up regulation from Region1 to Region2 in the IntraDay market.

“VXELEC\_DNEG” – Down regulation from Region1 to Region2 in the IntraDay market.

“VXE\_NONSPIN\_ANCPOS” – Transmission capacity reserved from Region1 to Region2 for providing positive non-spinning reserve.

#### **2.1.4 Other data tables**

“IX3COUNTRY\_T\_Y” has exogenous data on the exports and imports of electricity from countries outside the model.

## 2.2 The queries

Since the tables don't always have zero values, the queries have to be structured in such a way that results are generated even though a zero value for a variable is not in the database. Another qualification for the query structure is that there should be as little data handled as possible since the output database can have huge amounts of data, which would take lot of time to process. Both of these goals are achieved by first selecting the relevant set of analysis and then connecting the data to that set with inner join queries. This means that the set will stay intact and missing values will be represented by empty spaces in the query. These empty spaces are converted into zeroes with help of Nz function. Function CSng around the function Nz ensures that the zero values from Nz function are in numeric format. The relevant set is selected according to the choices made in the "Choice" table or in the "Show\_Results" form as shown in Figure 10.

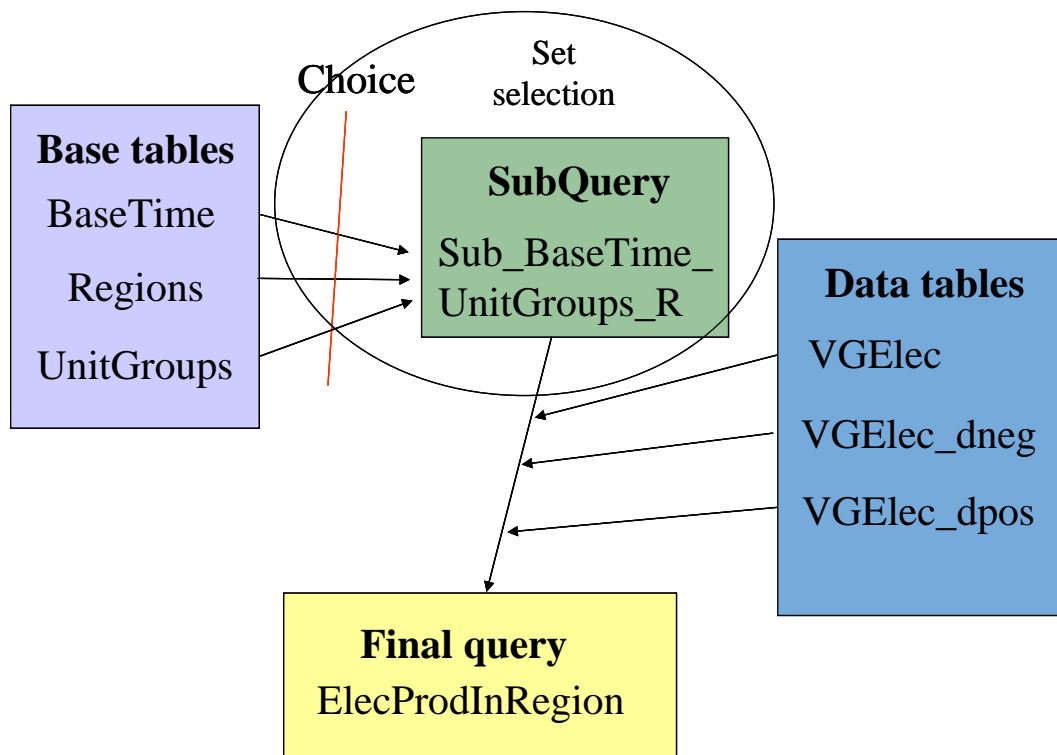


Figure 10. Example of query structure. Subquery *Sub\_BaseTime\_UnitGroups\_R* selects a set that is restricted by the choices made in the "Choice" table. Data from variable tables is connected to this set and final query "ElecProdInRegion" combines the data and does the necessary calculations.

Final queries are not named systematically. However, subqueries that select the set have certain naming convention. They start with "Sub\_". Next is the time resolution: BaseDate or BaseTime. Subqueries, that select a set with single area or region, end with A or R respectively. Sets that have all the regions or areas have plural form. If the set contains many UnitGroups from the selected area, region, or whole case, then the name has plural "UnitGroups". If the set selects only one UnitGroups based on table "Choice", then the form is singular "UnitGroup". The rest of the subqueries are named after their final query with a possible clarification of their role in the final query.

Choice has two fields for cases and regions. When two different cases and regions are selected, some of the queries make comparisons between the selected cases or regions.

### **2.2.1 Base queries**

“Append\_TechData” – When importing new data, this query appends technology data into table “TechData” from table “TechnologyData” in order to speed up queries. If data is imported manually, then this query should be executed.

“AreasInCase” – Shows the areas that are in the current case.

“BaseTime” – Selects the series of BaseTimes that are in the selected case.

“RegionsInCase” – Shows the regions that are in the current case.

“UnitGroupsInCase\_R” – Shows the UnitGroups that are in the selected region of the current case.

### **2.2.2 Queries for validation**

“Bal\_Day” – Consumption plus net export equals production in the DayAhead market in all the regions.

“Bal\_Intraday” – Consumption plus net export equals production in the IntraDay market in all the regions.

“Bal\_ElecStorage” – Loading and unloading result in the correct content of the electricity storage.

“CheckFuelUsage” – JMM reported fuel usage corresponds to the fuel usage calculated from the parameters of the UnitGroup.

“CheckVGE\_ANCNEG” – Amount of reserved negative primary reserve for all UnitGroups in all the cases.

“CheckVGE\_ANCNEG\_Regions” – Amount of reserved negative primary reserve for all regions in all the cases.

“CheckVGE\_ANCPOS” – Amount of reserved negative primary reserve for all UnitGroups in all the cases.

“CheckVGE\_ANCPOS\_Regions” – Amount of reserved negative primary reserve for all regions in all the cases.

“HeatBalance” – Checks that heat consumption and production are in balance in the heat areas.

### **2.2.3 Comparisons between cases**

“CompareCosts” – Comparison of system costs from the table “VOBJ\_R\_T”.

“CompareFuelUsage” – Comparison of fuel usage of UnitGroups in different cases.

“CompareVGONLINE\_R” – Comparison of capacity online in selected region between different cases.

“CompareVGONLINE\_total” – Comparison of capacity online in all regions between different cases.

“Compare\_NONSP\_ANCPOS” – Comparison of reservation of non-spinning reserves between cases.

“Conv\_Prod\_Tot” – Comparison of electricity production in different regions.

“IntraDayPricesRRR” – Average IntraDay prices for different cases.

“TotalCosts” – The total system costs plus change in hydro power reservoir value. Wind power revenues from both DayAhead and IntraDay markets.

“WindPowerCostsBuyUpReg” – For each region and hour costs of buying up regulation on the Intraday market due to the wind power production sold on the day-ahead market being higher than the realised wind power production.

“WindPowerCostsBuyUpRegTotal” – Sum of “WindPowerCostsBuyUpReg” across regions and hours.

“WindPowerRevSellIntraday” – For each region and hour revenue of selling power on the Intraday market due to the wind power production sold on the day-ahead market being lower than the realised wind power production.

“WindPowerRevSellIntraday Total” – Sum of “WindPowerRevSellIntraday” across regions and hours.

“WindRealisedCompare” – Comparison of realised and forecast wind in different cases.

“WindShedding” – Wind shedding in different cases.

#### **2.2.4 Queries for producing results**

“ContentHydroReservoir\_Regions” – Contents of hydro reservoirs in different regions.

“DayaheadPricesRRR” – DayAhead prices in the model regions.

“DownRegulationPrice” – Positive values of DayAhead price – IntraDay price for all regions in the selected time frame.

“DownRegulationPriveAvg” – Average down regulation price for each region.

“ElecConsumption” – Electricity consumption in all regions, restricted to chosen cases and selected time period.

“ElecPrices” – Electricity price in DayAhead and IntraDay markets as well as their price difference.

“ElecProdOnFuels” – Hourly electricity production from different fuel or energy forms for selected region.

“ElecProdOnFuels\_Regions\_Date” – Daily average electricity production from different fuel or energy forms for all regions.

“FuelCosts” – Fuel costs for UnitGroups in the chosen region.

“Heat” – Brings together heat production related activities in the areas of selected region. Heat production and consumption from different production forms: extraction, back-pressure, fuel boilers, heat pumps and heat storages. Heat consumption, heat price and electricity price.

“HeatStorages” – Shows the heat consumption and production as well as storage content of heat storages in the chosen region.

“HeatStorage\_Hourly” –Hourly profile for heat storage operation.

“Hourly\_IntraDay\_prices” – Hourly profile of average IntraDay market prices.

“Hydro\_DayAhead” – Bidded electricity production from hydro power, actual storage content of hydro reservoirs, shadow prices for hydro reservoirs and electricity price at the DayAhead market in the selected region.



“Hydro\_IntraDay” – Realised electricity production from hydro power, storage content of hydro reservoirs, shadow prices for hydro reservoirs and electricity price at the IntraDay market in the selected region.

“Net\_Export\_R” – Net realised transmission from selected region. Exports minus imports, takes regulation into account.

“Primary Reserve” – Primary reserves and content of electricity storage.

“Production” – Data from selected UnitGroup: Online, bidded production, regulations, realised production, negative primary reserve reservation.

“ProductionElecStorage” – Data from selected UnitGroup, if it is electricity storage: Online, bidded production, regulations, and realised production. Takes into account the possible consumption of electricity.

“ProfitUnitGroup” – Revenues, costs, and profits of selected UnitGroup. Costs include fuel costs, start-up costs, and O&M costs. Does not work correctly for electricity storages. Does not include taxes and subsidies!

“Regulation” – Shows up regulation ( $v_{gelec\_dpos} + losses * import\_dpos + export\_dneg + consumed\_dneg$ ) and down regulation ( $v_{gelec\_dneg} + losses * import\_dneg + export\_dpos + consumed\_dpos$ ) as well as realised wind power forecast error in the selected region.

“RegulationTotal” – Total up and down regulation in the selected region.

“RR\_Transmission” – Transmission with regulation from selected region1 to selected region2.

“RR\_Transmission\_Realised” – Same as above, but only the resulting realised transmission.

“UpRegulationPrice” – Negative values of DayAhead price - IntraDay price for all regions in the selected time frame.

“UpRegulationPriveAvg” – Average up regulation price for each region.

“ValueHydroReservoir” – Value of the water in hydro reservoir according to the shadow price of the hydro storage.

“VarUnitGroups\_SumA” – Areawise sum of different variables ( $v_{gheat}, v_{gheat\_consumed}, v_{gelec}, v_{gelec\_dneg}, v_{gelec\_dpos}, v_{gelec\_consumed\_dpos}, v_{gelec\_consumed\_dneg}, v_{gonline}$ ).

“VarUnitGroups\_SumAreas” – Areawise sum of different variables ( $v_{gheat}, v_{gheat\_consumed}, v_{gelec}, v_{gelec\_dneg}, v_{gelec\_dpos}, v_{gelec\_consumed\_dpos}, v_{gelec\_consumed\_dneg}, v_{gonline}$ ) for all areas in the case.

“VarUnitGroups\_SumR” – Regionwise sum of different variables ( $v_{gheat}, v_{gheat\_consumed}, v_{gelec}, v_{gelec\_dneg}, v_{gelec\_dpos}, v_{gelec\_consumed\_dpos}, v_{gelec\_consumed\_dneg}, v_{gonline}$ ).

“WindForecast&Realised” – Forecasted wind power production and realised production.

### **2.2.5 Some useful subqueries**

“SubVariablesUnitGroup” – Gathers together different variables for selected UnitGroup.

“Sub\_VarUnitGroups\_A” – Gathers together different variables for UnitGroups in selected area.

“Sub\_VarUnitGroups\_Areas” – Gathers together different variables for UnitGroups in all areas.

“Sub\_VarUnitGroups\_R” – Gathers together different variables for UnitGroups in selected region.

“Sub\_VarUnitGroups\_Regions\_Cases” – Gathers together different variables for UnitGroups in all regions.

“Sub\_VarUnitGroups\_Regions” – Gathers together different variables for UnitGroups in all regions of selected cases.

## **2.3 The forms**

“BalanceIntraDay” – Shows whether production and consumption have been in balance in the IntraDay market.

“Balance\_DayAhead” – Shows whether production and consumption have been in balance in the DayAhead market.

“CapOnline” – Shows the capacity online with consumption, production, realised wind power production, and net exports.

“Choice” – Shows four forms: ElecPrices, ElecProdOnFuels, WindRealised\_Forecast, and CapOnline.

“Compare cases” – Shows four forms to compare cases: DayAhead Price, IntradayPrices, PriceDiff, and RealisedWind.

“ElecConsumption” – Consumption of electricity in the case.

“ElecPrices” – DayAhead and IntraDay prices of electricity in the selected region.

“ElecPriceCompare” – Comparison of electricity prices between different cases in the selected region.

“ElecProdOnFuels” – Electricity production distributed on fuels in the selected region.

“HeatBalance” – Shows whether production and consumption of heat has been in balance in the selected area.

“IntradayPrices” – IntraDay prices of electricity in the selected cases.

“PriceDiff” – The price difference between DayAhead and IntraDay markets.

“PricesDayAhead” – DayAhead prices of electricity in all model regions.

“Production” – Production, online, and regulation from the selected UnitGroup.

“Realised Wind” – Realised wind power production in the selected region of selected cases.

“RR\_Transmission” – Imports and exports with regulation from Region1 to Region2.

“RR\_Transmission\_Realised” – Net realised exports from Region1 to Region2.

“Show\_Results” – Selection form.

“View\_Balance” – Shows three forms with balances: Balance\_DayAhead, BalanceIntraday, and HeatBalance.

“View\_Production” – Production, online, and regulation from the selected UnitGroup with a selection bar.

“View\_Transmission” – RR\_Transmission and RR\_Transmission\_realised.

“WindRealised\_Forecast” – Realised, forecast, and shedded wind power.

### 3 Scenario database

This database holds some of the data that could be in the input database, but has been separated for two reasons. First, the input database would have been too big with scenario data in it. Second, different wind power scenarios are now in different databases and switching with wind power scenarios is done by switching the database in use. The structure of the tables originates from the way wind scenarios are presented in the model. This is described in the scenario tree tool documentation.

“Base Hour Aheads” is a look-up table for the ID’s of the 36 hours in the model horizon.

“Base Percentiles” is a look-up for percentiles used in calculating the windpower forecast error.

“Base Regions” has the model regions.

“Base Stochastic Progr Nodes” is a look-up for the nodes used in stochastic programming of wind power.

“Base Time” is a look-up list for the base times used in the model (2000-2002).

“Base Wind Case” holds the ID, name, and the description of created wind power scenarios.

“Data RRR NNN TTT Secondary reserve” has the secondary reserve needs calculated by the scenario tree tool for wind power.

“Data RRR TTT NNN Values tree” holds the wind power production in different wind scenarios.

“Data RRR TTT Prctile WindPower Forecast Error” has the value of wind power forecast error for each percentile.

“Data RRR TTT RandomWind\_VAR\_T” is a random serie of prognosed wind power production.

“Data RRR YYY Secondary reserve demand” holds values for needed secondary reserve due to N-1 criteria.

“Data TTT NNN Probabilities tree” has the probability of each wind scenario node.

Risø's research is aimed at solving concrete problems in the society.

Research targets are set through continuous dialogue with business, the political system and researchers.

The effects of our research are sustainable energy supply and new technology for the health sector.