UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER'S DEGREE IN THE ELECTRIC POWER INDUSTRY

Master’s Thesis

MOTHBALLING MECHANISMS IN THE SPANISH POWER SYSTEM: ECONOMIC AND OPERATIONAL ASSESSMENT

Author:	**Irene Campos Blanco**
Supervisor:	**Javier García González**

Madrid, July 2015

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SUMMARY

During the last years, combined cycles have been significantly displaced from the Spanish market due to the lower demand and its higher coverage with renewable energy sources. Their production decline, combined with low wholesale electricity prices and higher operating costs than other generation technologies, have contributed to reduce the economic profitability of these facilities. As a result, the industry started to consider the convenience of closing (either permanently or temporarily) those power plants with low market share and not enough incomes to cover their operating expenses.

The electricity reform approved in 2013 establishes the regulatory framework to enable the mothballing of power plants in Spain, introducing the possibility of temporary closure of facilities and entitling the system operator to forecast the maximum capacity that may be withdrawn from the system, as well as to report on the need of reinstating mothballed power, when applicable.

The main objective of this thesis is to analyse what would be the economic and operational impacts derived from the introduction of power plant mothballing in the Spanish Power System, taking into account that the generation capacity could be adapted to the evolution of demand, thus, saving the costs associated with unnecessary plants being opened for commercial operation.

A midterm planning model, based in a centralised approach, is used to address the issue of generation planning, subject to ensure a desirable security of supply margin. The model provides a reference to determine what would be the expected outcome of mothballing in terms of decisions related to temporary closure and later restoring of facilities and their impact in the generation mix structure, operating costs and level of security of supply.

Three scenarios for the years 2015 and 2020 are defined in order to analyse the impact of mothballing in the Spanish Power System. The main results are 11.7 GW of mothballed power, reduction of operation costs in 379 M€ and lack of impact on the energy mix or CO_2 emissions in the year 2015. Additionally, the increase in demand considered for the scenario in 2020 do not reveal the need to reinstate mothballed power in the horizon 2015-2020.

RESUMEN

Durante los últimos años, los ciclos combinados se han visto significativamente desplazados del mercado español debido a la menor demanda y su mayor cobertura con fuentes de energía renovables. La reducción de su producción, combinada con bajos precios del mercado eléctrico y mayores costes de operación que otras tecnologías de generación, han contribuido a reducir la rentabilidad económica de estas instalaciones. Como resultado, el sector empezó a considerar la conveniencia de cerrar (permanentemente o temporalmente) aquellas centrales con baja cuota de mercado y sin suficientes ingresos para cubrir sus gastos de operación.

La reforma eléctrica aprobada en 2013 establece el marco regulatorio para permitir la hibernación de centrales eléctricas en España, introduciendo la posibilidad del cierre temporal de instalaciones y habilitando al operador del sistema a estimar la capacidad que puede ser retirada del sistema, así como informar de la necesidad de reincorporar potencia hibernada, cuando sea aplicable.

El principal objetivo de esta tesis es analizar cuáles serían los impactos económicos y de operación derivados de la introducción de la hibernación de centrales en el Sistema Eléctrico Español, teniendo en cuenta que la capacidad de generación podría ser adaptada a la evolución de la demanda, evitando así los costes asociados a la operación comercial de las plantas que no sean necesarias.

Se ha utilizado un modelo de planificación a medio plazo, basado en una perspectiva centralizada, para abordar la planificación de generación, garantizando un margen de seguridad de suministro deseable. El modelo proporciona una referencia para determinar cuál sería el resultado esperado de la hibernación en términos de decisiones relacionadas con el cierre temporal y posterior reincorporación y su impacto en la estructura del mix de generación, los costes de operación y la seguridad de suministro.

Se han definido tres escenarios para los años 2015 y 2020 con el fin de analizar el impacto de la hibernación en el Sistema Eléctrico Español. Los principales resultas son 11.7 GW de potencia hibernada, reducción de los costes de operación en 379 M€ y ausencia de impacto en el mix de energía o las emisiones de CO_2 en el año 2015. Además, el incremento de demanda considerado para el escenario en 2020 no muestra la necesidad de reincorporar potencia hibernada en el horizonte 2015-2020.

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1 Introduction

1.1 Motivation and problem description

The current state of the Spanish power industry is defined to a great extent by the drop of electricity consumption, the large penetration of renewable generation and the reduced interconnection capacity with adjacent countries. This context, together with the excess of installed capacity, has revealed a lower involvement of some agents in the wholesale electricity market (especially those who operate the peak power plants).

This is the case of the combined cycle power plants, which have been significantly displaced from the Spanish market due to the lower demand and its higher coverage with renewable energy sources. As a consequence, these facilities have experienced an important reduction in operation hours and contribution to demand coverage, declining their share in the generation mix from 32% in 2008 to 8.5% in 2014.

The production decline described above, combined with low wholesale electricity prices and higher operating costs than other generation technologies, have contributed to reduce the economic profitability of the combined cycles. As a result, the industry started to consider the convenience of closing (either permanently or temporarily) those facilities with low market share and not enough incomes to cover their operating expenses.

In case that a power plant is permanently retired before its expected decommission date, the situation is irreversible: the owner would be unable to recover some of the investment costs and the system would face a permanent capacity withdrawal. On the other hand, the temporary shut-down of the facility (also called mothballing) could represent an alternative to the freedom of exit the market that may entail some benefit for both producers and consumers.

In other words, power plant mothballing may act as a mechanism to cope with the cyclical behaviour of power systems, providing market agents with some flexibility to adapt their generation portfolio to the projected demand. This means that capacity could be withdrawn from the system in periods of oversupply (allowing producers to safe some operating costs) and it could be restored when market conditions are more favourable (and agents are able to recover their investments). Consumers, in turn, could benefit from the reduction of some regulated costs when there is overcapacity and plants do not need to be available, as well as from the rapid entry of de-mothballed capacity in periods of supply scarcity.

In this context, the electricity reform approved in 2013, the Act 24/2013 of the Power Sector, establishes the regulatory framework to enable the mothballing of power plants in Spain. The Act introduces the possibility of temporary closure of facilities (subject to administrative authorisation) and entitles the system operator to forecast the maximum capacity that may be withdrawn from the system, as well as to report on the need of reinstating mothballed power, when applicable.

The aim of this master thesis is to assess the economical and operational effects of the introduction of power plant mothballing in the Spanish Power System. The main issue is to address the question of generation planning, subject to ensure a desirable security of supply margin, taking into account that the generation capacity could be adapted to the evolution of demand, thus, saving the costs associated with unnecessary plants being opened for commercial operation.

A centralised generation planning model is used to tackle the problem from the perspective of the system operator. This approach provides a reference to determine what would be the expected outcome of the implementation of mothballing mechanisms in the current Spanish System in terms of decisions related to temporary closure and later restoring of facilities and their impact in the generation mix structure, operating costs and level of security of supply.

The work presented in the thesis is supported by the analysis of different scenarios developed to explore the influence of mothballing on operational costs and generation structure.

1.2 Objectives

The main objective of this thesis is to analyse what would be the economic and operational impacts derived from the introduction of power plant mothballing in the Spanish Power System.

It is proposed a decision support model, based in a centralised generation planning approach, to accomplish this objective and to address the following questions:

- How much power should be mothballed considering the current state of the system?
- How would security of supply be affected?
- What technologies would replace the capacity withdrawal in the energy mix?
- What would be the impact on operating costs?
- How much should demand increase in order to reinstate mothballed plants?

1.3 Methodology

The objective of the master thesis is to assess the impact on costs and operation of the future implementation of mothballing mechanisms in Spain. The proposed methodology to perform this assessment is indicated below:

- Analysis of the current situation in the Spanish Power System:

The Spanish case is studied, looking at current market conditions which jeopardize the economic viability of combined cycles and examining the new regulation that allows their temporary closure.

- Development of decision support model:

The "Midterm planning model" studied during the course "Decision support models for the electric power industry" is adapted to incorporate mothballing decisions to the dynamics of generation planning. The proposed model considers such decisions based on the projected savings in operating costs and subject to ensure a sufficient level of security of supply.

The main features of the proposed model are:

- Centralised approach based on minimisation of operating costs from the system operator's perspective
- Medium term scope adopting a time horizon of one year
- Main assumptions: transmission grid is not modelled, system evolution is represented by load blocks instead of chronologically, single reservoirs are used to model the behaviour of all hydro units, uncertainty of input data is neglected
- Deterministic approach using estimated values of input data (demand, production of renewable energy sources, fuel costs, hydrology, etc.)
- Incorporation of fixed operating costs in the objective function
- Consideration of constraints related to security of supply and dispatchable capacity

During this stage, the thesis problem is conceptualised and formalised through the proposed model and the required input data is collected. The data is introduced in the model for its implementation, validation and use.

- Scenarios generation:

Three scenarios for the years 2015 and 2020 are selected to infer the evolution of mothballing decisions over time, as well as to analyse their impact on operation costs and scheduling.

2 An approach to the Spanish case

In this chapter, it is presented the case of mothballing in the Spanish System framework, introducing some considerations of the Spanish market, the situation of combined cycles and the related regulation.

2.1 Market considerations

The Spanish Power System has observed a decrease in electricity demand (see Figure 1) during the past years, mainly derived from the macroeconomic scenario of economic crisis that started in 2007.

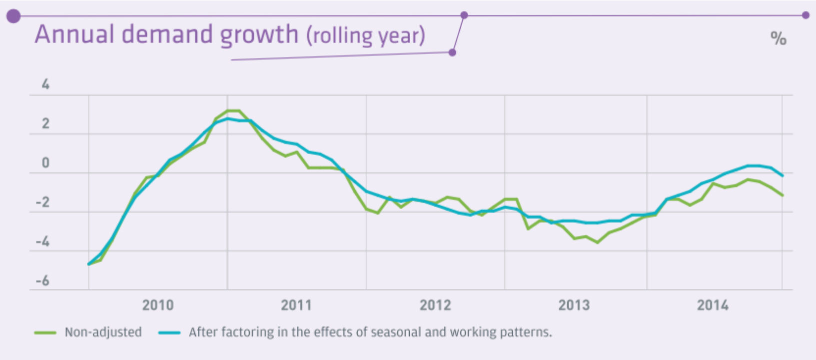

Figure 1: Evolution of electricity demand. Years 2010-2014 (Source REE)

The actual demand experienced during these last years was significantly below the values foreseen in the planning scenarios and, therefore, there are more generation facilities than the actual needs of the system.

Together with the drop in demand, it has been a progressive increase in integration of renewable resources (see Figure 2), that has also resulted in a market share reduction for other conventional generation technologies.

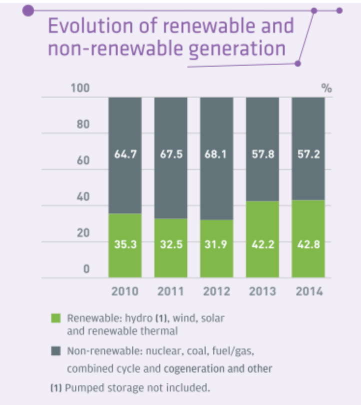

Figure 2: Evolution of renewable and non-renewable energy production. Years 2010-2014 (Source REE)

Additionally, the Spanish Power System has limited interconnection capacity with adjacent systems. Even though there are projects to increase the interconnection facilities (see Figure 3), they will not ensure significant energy exchanges with other markets.

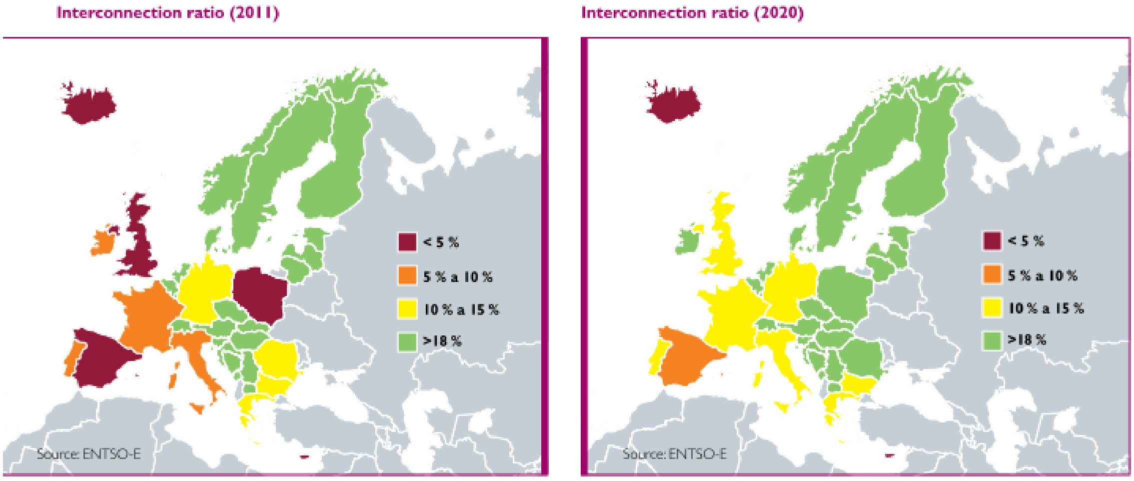

Figure 3: European interconnection ratios. Year 2011 and Year 2020 (Source ENTSO-E)

As a result of the drop in demand, the high level of renewable sources integration and the limited interconnection capacity, the current environment in the Spanish System is characterized by the overcapacity of installed power (see Figure 4).

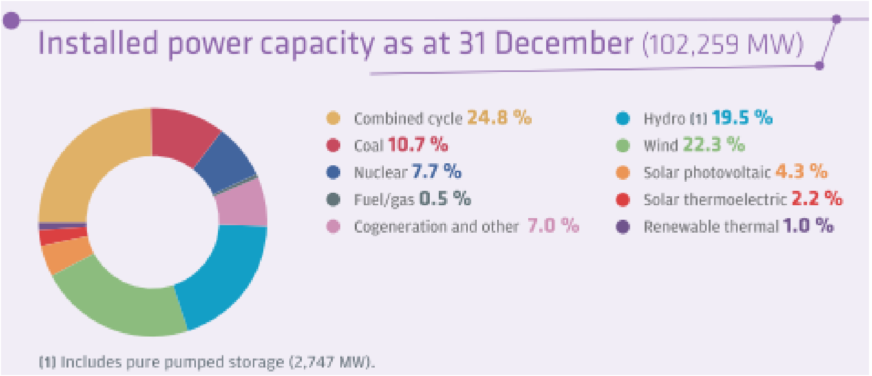

Figure 4: Installed power. Year 2014 (Source REE)

At the end of 2014, the installed capacity was around 102 GW, while the maximum peak demand was below 39 GW and the coverage index (relationship between the available power and the peak demanded) accounted for 1.4, which is significantly higher than the desirable coverage index (1.1).

In Figure 5 they are also included the coverage indexes for years 2007 to 2014, indicating an increasing evolution.

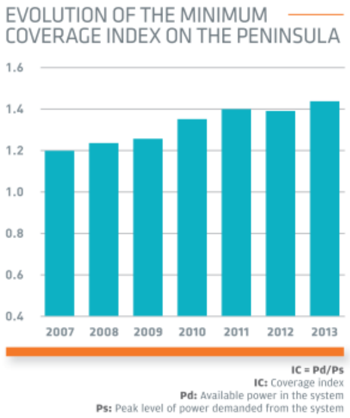

Figure 5: Evolution of coverage index. Years 2007-2013 (Source REE)

2.2 Current situation of combined cycles

As a result of the existing overcapacity some of the generation facilities are under-use, with the consequent negative impact in their economic profitability. This situation is amplified in the case of combined cycles where the evolution of fuel, electricity and CO_2 prices, as well as the regulations for domestic coal consumption, decrease even more their contribution to the energy mix.

See Figure 6 and Figure 7 where the evolution of the Spanish energy mix is represented, and Figure 8 that shows the changes in the spark spreads (margin between electricity and fuel price) for coal and gas.

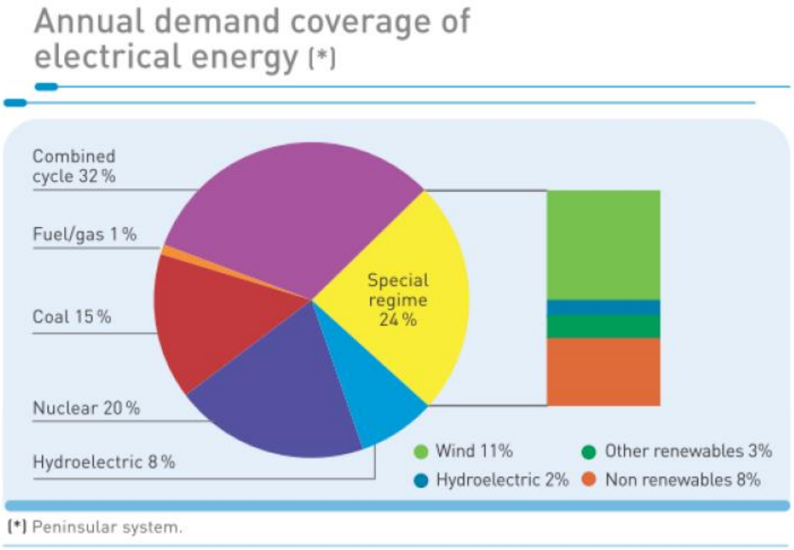

Figure 6: Energy mix. Year 2008 (Source REE)

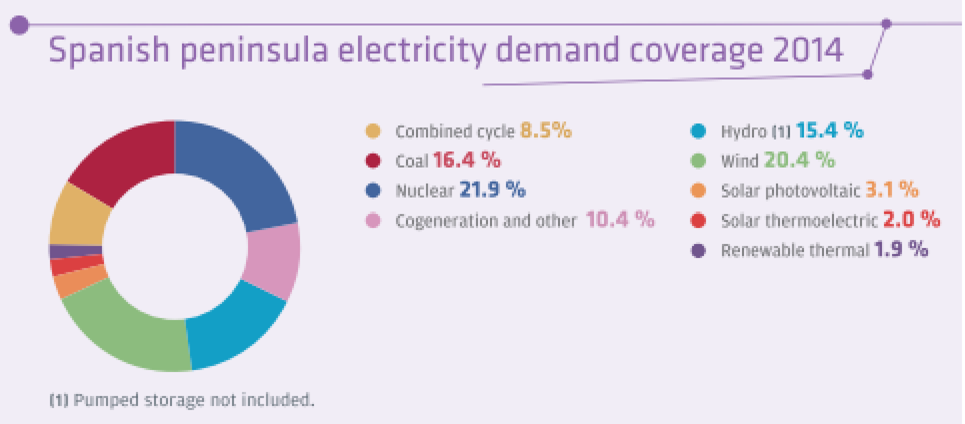

Figure 7: Energy mix. Year 2014 (Source REE)

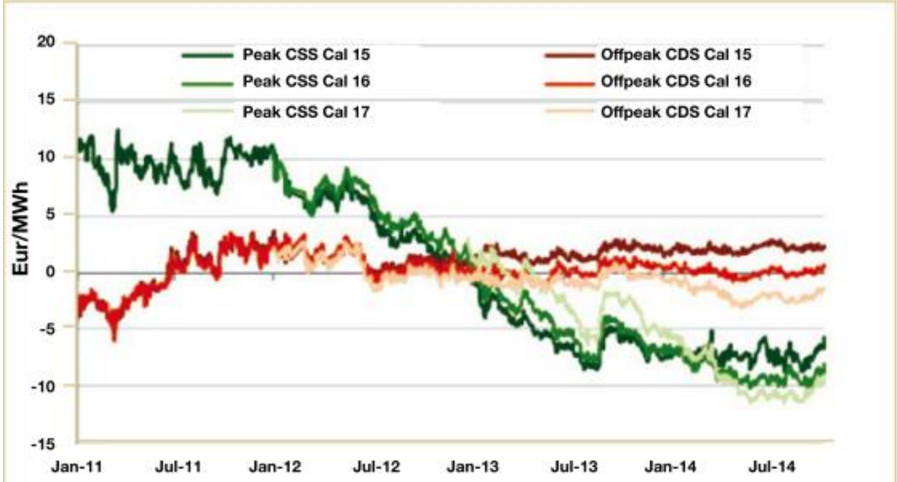

Figure 8: Spark spreads for coal (during off-peak hours) and gas (during peak hours) in the German market (Source Platts from (Velázquez, 2014))

Consequently, the number of operation hours of the combined cycles is significantly curtailed (see Figure 9 below), accounting for less than 1000 hours in 2014 according to data reported by CNMC (CNMC, 2015).

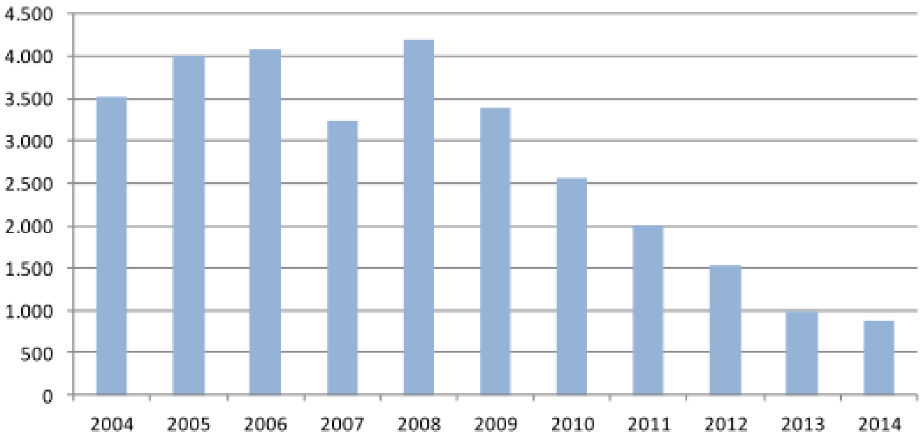

Figure 9: Evolution of equivalent operating hours at full load for combined cycles (Source CNMC)

The Spanish regulator has also indicated in its proposal for mechanisms for security of supply (CNE, 2012) that the overcapacity, together with the lack of mechanisms to exit the market, would have contributed to jeopardize the economic situation of combined cycles, with some of them unable to recover their fixed operating costs. See Figure 10 where the estimations from the CNMC are included.

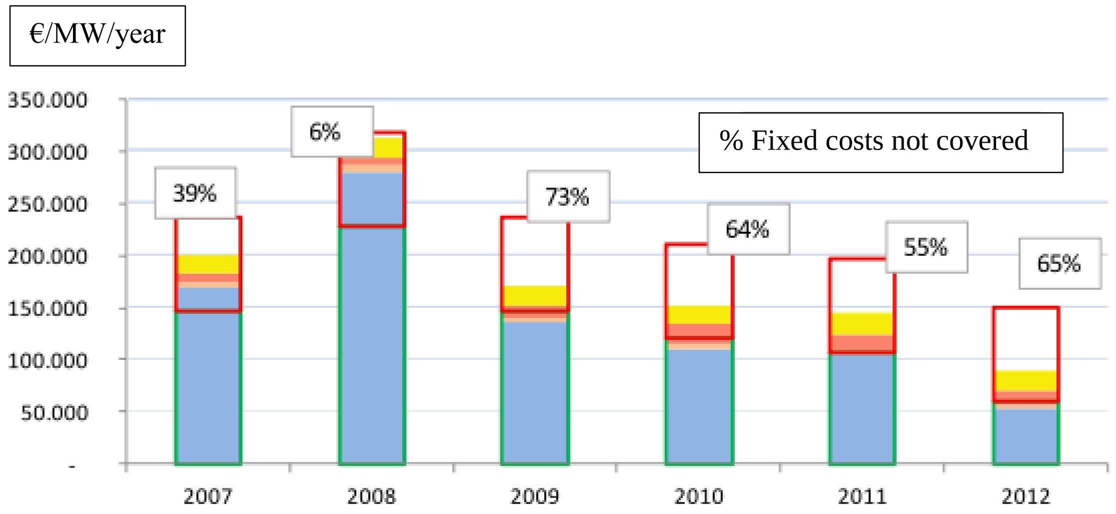

Figure 10: Evolution of non-recovery of fixed operating costs for combined cycles (Source CNMC)

2.3 The new regulatory framework

In this context, the Act 24/2013 of the Power Sector (BOE, 2013) enables the temporary closure of combined cycles (mothballing). The law establishes that the mothballing process will be subject to administrative authorisation and that the system operator will be entitled to forecast requirements for mothballing and power restoring.

The proposed mothballing mechanism is further developed on the Draft Royal Decree on capacity payments and mothballing (Secretaría de Estado de Energía, 2013). The relevant considerations for the aim of this thesis are indicated below:

- The mothballing mechanism would be allowed for combined cycles over 50 MW.
- The system operator would determine the amount of power to be mothballed (based on forecasts on security of supply, including evolution of coverage index, local/zonal constraints and any other issue relevant for security). Its forecasts would be based on scenarios with low hydraulicity and high demand.
- The mechanism included in the draft RD establishes the mothballing assignment through a decreasing auction for the power to be mothballed on the following year.

- The period for mothballing is established in one year (even though the first auction could be arranged for a longer period).

- Additionally, it is defined an incentive for dispatchable power, in order to recognise the value of available thermal power to face variations in demand and as back-up for renewable generation.

- The incentive for dispatchable power would be allowed for combined cycles and coal power plants, but not for hydropower or pumping stations. The requirements on dispatchable power for each year would be based on the maximum thermal gap occurred during the previous three years.

3 Generation planning model with mothballing. Application to the Spanish Power System

This chapter includes the characteristics of the model presented in the thesis, as well as the definition of the scenarios that are used to support the results and conclusions of this work.

It is considered a midterm temporal scope with time horizon of one year, in accordance with the regulatory proposals for mothballing mechanisms in Spain (refer to section 2.3). The temporal structure used in the model divides the yearly time horizon in periods (weeks), subperiods (working and non-working days) and load levels (five levels for working days and four levels for non-working days).

The proposed model is a midterm planning model based on a centralised approach and with mothballing decisions for combined cycles. The model is used to determine the optimal generation schedule over the considered time horizon (one year) and taking into account potential mothballing decisions for combined cycle units.

The mothballing decisions are incorporated in the model based on the projected savings in operating costs (introduction of fixed operating costs in the objective function) and subject to provide a sufficient level of security of supply (introduction of requirements for dispatchable generation in the model constraints).

Three scenarios are defined in order to analyse the impact on operation and costs derived from mothballing decisions, namely year 2015 without mothballing, year 2015 with mothballing and year 2020 with mothballing.

3.1 Characteristics of the proposed model

3.1.1 Formulation

The formulation of the optimization problem is presented below:

$$\begin{aligned} Min \sum_t \sum_p \sum_s \left\{ f_t \cdot \left[\gamma_t \cdot y_{t,s,p} + \theta_t \cdot z_{t,s,p} + \sum_n a_{n,s,p} \cdot \left[\alpha_t \cdot \frac{q_{t,n,s,p}}{k_t} + \beta_t \cdot u_{t,s,p} \right] \right] \right\} \\ + \sum_g \left\{ \left[o_g + pco2 \cdot emis_g \right] \cdot \sum_p \sum_s \sum_n \left[a_{n,s,p} \cdot \frac{q_{g,n,s,p}}{k_g} \right] \right\} \\ + \sum_{gccgt} \mathrm{foc} \cdot m_{gccgt} \cdot q_{gccgt}^{max} \end{aligned} \qquad (1)$$

s.t.

$$a_{n,s,p} \cdot \left[\sum_{t} q_{t,n,s,p} + \sum_{h}\left(q_{h,n,s,p} - b_{h,n,s,p}\right) + \sum_{res} q_{res,n,s,p} + \right] = a_{n,s,p} \cdot d_{n,s,p} \;\; \forall n,s,p \tag{2}$$

$$q_{t,n,s,p} \leq u_{t,s,p} \cdot k_t \cdot q_t^{max} \quad \forall t,n,s,p \tag{3}$$

$$q_{h,n,s,p} \leq k_h \cdot q_h^{max} \quad \forall h,n,s,p \tag{4}$$

$$b_{h,n,s,p} \leq k_h \cdot b_h^{max} \quad \forall h,n,s,p \tag{5}$$

$$q_{t,n,s,p} \geq u_{t,s,p} \cdot k_t \cdot q_t^{min} \quad \forall t,n,s,p \tag{6}$$

$$q_{h,n,s,p} \geq q_h^{min} \quad \forall h,n,s,p \tag{7}$$

$$b_{h,n,s,p} \geq 0 \quad \forall h,n,s,p \tag{8}$$

$$w_{h,p} + \sum_{n,s} a_{n,s,p}\left(q_{h,n,s,p} - \eta_h b_{h,n,s,p}\right) \leq w_{h,p-1} + i_{h,p} \quad \forall h,p \tag{9}$$

$$w_{h,p} \leq w_{h,p}^{max} \quad \forall h,p \tag{10}$$

$$w_{h,p} \geq w_{h,p}^{min} \quad \forall h,p \tag{11}$$

$$q_{gccgt,n,s,p} \leq m_{gccgt} \cdot k_{gccgt} \cdot q_{gccgt}^{max} \quad \forall gccgt,n,s,p \tag{12}$$

$$\sum_{gccgt} u_{gccgt,s,p} \cdot k_{gccgt} \cdot q_{gccgt}^{max} + \sum_{gcg} u_{gcg,s,p} \cdot k_{gcg} \cdot q_{gcg}^{max} \geq thgap \; \forall n,s,p \tag{13}$$

$$u_{t,lab,p} - u_{t,fes,p-1} = y_{t,lab,p} - z_{t,lab,p} \quad \forall t,p \tag{14}$$

$$u_{t,fes,p} - u_{t,lab,p} = y_{t,fes,p} - z_{t,fes,p} \quad \forall t,p \tag{15}$$

The objective of the problem is to determine the optimal generation schedule that minimises the objective function (1) in order to supply the electrical demand (2) and satisfy the technical constraints included in the model, (3)-(15), at minimum cost.

The proposed formulation incorporates the mothballing decisions as follows: on the one hand, fixed operating costs for combined cycles are included in the objective function (1), on the other hand, the available dispatchable generation is constrained to be able to cover the thermal gap required by the system (13).

Mothballing decisions will be made as long as the savings in fixed operating costs are greater than the variable costs incurred by the substitute technology, if any, and the available dispatchable generation is enough to satisfy the requirements of the system.

3.1.2 Input data

The set of input data used in the model is presented below, as well as the considerations followed to obtain the required information and to estimate the related parameters.

a) Generation units $g, t, h, res, gccgt, gcg$

The set of generators (g) considered in the model is comprised by thermal generators (t), hydraulic generators (h) and renewable, cogeneration and waste-to-energy units (res).

- Thermal generators include nuclear, coal, combined cycle and gas units installed in the Spanish Power System.
- Hydraulic generation is modelled through two aggregated reservoirs, one for hydraulic units connected to the hydro network and other for isolated units (closed-cycle pumped storage plants). Run-of-river plants are considered within the connected reservoir.
- Renewable generators comprise the following technologies: wind, solar photovoltaic, solar thermoelectric and renewable thermal (biogas and biomass). Each technology is represented in the model through an equivalent unit with the production associated to all generators of the aforementioned technology.
- Cogeneration and waste-to-energy units are also modelled with an equivalent unit with aggregated production.

Additionally, two subsets of generators are specifically defined to consider dispatchable generation such as combined cycle units ($gccgt$) and coal/gas plants (gcg) in the model.

The generation units are introduced in the model according to data available from REE (REE, 2014) and they are summarized in Annex A.

b) Generation mix and power limits for generation and pumping units $q_g^{max}, q_g^{min}, b_g^{max}$

The generation mix is defined in order to set the amount and type of generation available to meet demand in each scenario (refer to section 3.2).

Additionally, gross power limits (expressed in GW) are necessary to establish the feasible range for the operation of generation and pumping units:

- Maximum gross power for thermal generators is extracted from the information reported by REE (REE, 2014).
- Minimum gross power for thermal generators is estimated as 30% of the maximum gross power limit.
- Maximum gross power for hydraulic units connected to the hydro network is limited below the installed power due to physical constrains (turbines cannot operate all simultaneously at maximum capacity in order to avoid floods downstream). Therefore, the maximum limit for hydraulic generation in the connected reservoir is established as 10 GW according to data for maximum hydraulic production in 2014 (REE, 2015b).
- Since run-of-river plants are modelled within the connected reservoir, average production of these plants may be used to determine the minimum gross power for hydraulic generation in the aforementioned reservoir. According to data of run-of-river production in 2014 (REE, 2015b), 0.4 GW is considered as the minimum gross power for hydraulic generation in the connected reservoir.
- Maximum gross power for closed-cycle pumped storage units is extracted from the information reported by REE (REE, 2014).
- Minimum gross power for closed-cycle pumped storage units is set to zero.
- Maximum power consumed (pumping mode) by hydraulic generators in the connected reservoir and by closed-cycle pumped storage units is estimated as 2.9 GW and 2.7 GW, respectively, according to data from REE (REE, 2009).
- Minimum power consumed (pumping mode) is set to zero for both aggregated reservoirs considered in the model.

Following the guidelines explained above, these input data are collected for each scenario (refer to section 3.2) and presented in Annex A.

c) Reservoir limits $w_{h,p}^{max}$, $w_{h,p}^{min}$

Maximum and minimum limits for the hydraulic reservoirs are included in the model according to data available in references (REE, 2015b), (Consejería de Economía y Hacienda Comunidad de Madrid, 2011) and (EURELECTRIC, 2011), and they are summarized in Table 1.

Reservoir level	Connected reservoir	Isolated reservoir
Maximum [GWh]	18538	70
Minimum [GWh]	4000	0

Table 1: Maximum and minimum limits for hydraulic reservoirs in the model

d) Inflows $i_{h,p}$

Inflows are introduced in the model to represent the hydraulicity during a specific period, this is, the amount of available hydroelectric production once that water supplies for irrigation or other uses than electric production are deducted.

In the model, data from average hydroelectric producible per month and hydraulicity reported by REE (REEAvance14) are used to determine the inflows received by the connected reservoir during each period (week). The average producible (monthly values) is scaled by the producible hydroelectric index considered in each scenario and distributed over the periods considered in the model (proportionally to the number of days per month assigned to each period), see Table 2 and Table 3 below and refer to section 3.2.

Month	Average producible [GWh/day]
January	124
February	145
March	108
April	99
May	89
June	71
July	29
August	14
September	20
October	46
November	71
December	98

Table 2: Average producible hydroelectric energy in Spain

Year	GWh	Index	Probability of being exceeded (%)
2010	36174	1.29	16
2011	22506	0.81	74
2012	12722	0.46	100
2013	32631	1.18	25
2014	32655	1.18	25

Table 3: Annual producible hydroelectric energy in Spain

The inflows received by the isolated reservoir are neglected.

e) Fuel consumption terms for thermal units $\alpha_t, \beta_t, \gamma_t, \theta_t$

The different terms of fuel consumption for thermal units (incremental term α_t, fixed term β_t, start-up fuel consumption γ_t and shut-down fuel consumption θ_t) are considered in the model according to reference (Soler, 2012) and presented in Annex B.

These parameters intend to model the amount of fuel consumed by thermal generators: the incremental term (MTh per GWh) represents the quantity required to produce one unit of energy, the fixed term (MTh per hour) expresses the amount required during one hour of operation and the start-up and shut-down terms (MTh) indicate the quantity spent to start and stop the machines.

f) Gross to net power conversion factor k_g

These factors are used to internalise the amount of power consumed by the auxiliary systems of the plant, in order to determine the net power that is actually delivered by generators. The conversion factors for the different technologies used in the model are obtained from references (MINETUR, 2012) and (IDAE, 2014), and they are summarized in Table 4.

Technology	Conversion factor
Nuclear	0.96
Coal	0.95
Combined cycle	0.95
Gas	0.95
Hydraulic	0.98
Others	0.96

Table 4: Gross to net power conversion factors per technology

g) Efficiency of the pumping-turbine cycle k_g

This value is used to model the losses in the pumping-turbine cycle, this is, not all the energy consumed in the pumping stage can be delivered by the hydraulic units. These values are estimated as 0.7 for both reservoirs.

h) Fuel costs for thermal units f_t

Fuel costs (expressed in k€ per MTh) for uranium, coal and gas are obtained from market data and projections available in references (Bureau of Resources and Energy Economics, 2014), (MIBEL, 2015), (European Commission, 2014). The resulting prices for each scenario are summarized in section 3.2.

Some additional considerations are indicated below:

- The relationship between the uranium price and the associated cost in nuclear plant is derived from data reported by Word Nuclear Association (WNA, 2015), see Figure 11.

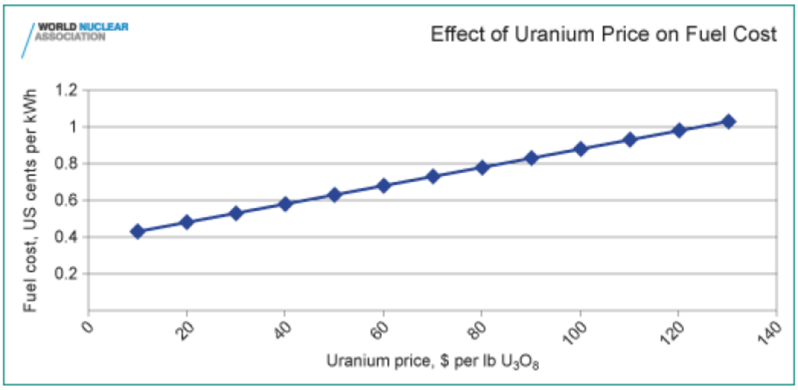

Figure 11: Effect of uranium price on fuel cost for a typical US plant (Source WNA)

- Average fuel prices are obtained from market data in the first quarter of 2015 for API2 and TTF indexes for coal and gas (or from projections from the European Commission (European Commission, 2013) in case of future scenarios).

- Additional logistic cost for coal is considered 10 €/ton according to information available in reference (IEA, 2014).

i) Variable operation and maintenance costs o_g

These values (expressed in k€ per GWh) incorporate other variable costs different from fuel in the objective function. The variable O&M costs for the different technologies used in the model are indicated in Table 5. They are obtained from the following references:

- (UNESA, 2007) for costs for nuclear, coal, combined cycle and integrated gasification combined cycle (IGCC) units.
- (CNE, 2010) for costs for hydraulic, small hydro, wind, solar photovoltaic, solar thermoelectric, non-renewable thermal and renewable thermal units.

Technology	**O&M cost [k€/GWh]**
Nuclear	10.2
Coal	4.9
Combined cycle	4.5
IGCC	12.9
Hydraulic	12.29
Wind	17.4
Solar photovoltaic	44.9
Solar thermoelectric	114.2
Small hydro	17.1
Non-renewable thermal	63.2
Renewable thermal	36

Table 5: Variable operation and maintenance costs per technology

j) Emission allowance price $pco2$

CO_2 price (expressed in k€ per ton) is obtained from market data available in EEX (EEX, 2015), and from projections published by the European Commission (European Commission, 2013), see section 3.2.

k) CO_2 emissions per technology $emis_g$

CO_2 emissions (expressed in ton per GWh) are introduced in the model in order to internalize the environmental costs associated with the production of electricity with each type of technology, since power plants are required to purchase the emission allowances equivalent to the amount of CO_2 generated during production.

The resulting values considered in the model, extracted from data reported by REE (REE, 2015a), are indicated in Table 6.

Technology	CO_2 emissions [ton/GWh]
Nuclear	0
Coal	950
Combined cycle	370
Gas	700
Hydraulic	0
Wind	0
Solar photovoltaic	0
Solar thermoelectric	0
Small hydro	0
Non-renewable thermal	370
Renewable thermal	0

Table 6: CO_2 emissions per technology

l) Fixed operation and maintenance costs for combined cycles foc

Fixed operation costs (expressed in k€ per GW) are used to model the potential savings derived from mothballing decisions for combined cycles. These costs are due to the fixed expenses required for the availability of facilities for operation and they are incurred even if they do not produce any power.

Fixed O&M cost for combined cycles is considered an annualized value equal to 31300 k€/GW (13000 k€/GW for the fixed term of operation and maintenance expenses plus 18300 k€/GW corresponding to the gas access tariff) in accordance with data reported by CNMC (CNE, 2012).

Fixed operation costs for other technologies are not taken into account in the model since they do not impact on mothballing decisions.

m) Demand $d_{n,s,p}$

Input data to determine electricity demand (GW) is obtained from the information system of the Spanish System Operator (REE, 2015b). Data for the year 2014 was collected and processed in order to distribute the hourly values in load blocks that represent the behaviour of demand during each period (week). The process is explained below:

- Hourly demand values for 2014 are assigned to the different weeks (periods) of the year and scaled by a demand growth factor that represent the variation of electricity consumption considered in each scenario, see section 3.2.

- Weeks are divided in working days and non-working days (sub-periods)
- Days are subsequently divided in blocks according to the value of demand (load level). In this thesis they are used five load levels for working days (super-peak, peak, plateau, valley, super-valley) and four load levels for non-working days (peak, plateau, valley, super-valley).
- Demand values are rearranged (ordered) within the two sub-periods of the week according to their load level.
- Average demand values for each period, sub-period and level are computed taking into account the number of hours of each level. The length of load blocks considered in the model is included in Table 7 of the following section.
- The variation of the shape of demand curve over the years is neglected and, therefore, the assignment of periods, subperiods and levels is the same for all the scenarios considered in the model.

According to this, demand values for each scenario (refer to section 3.2) are obtained and included in Annex C.

n) Length of load blocks $a_{n,s,p}$

The length of load blocks (expressed in hours) for the scenarios considered in the thesis is presented below in Table 7.

Period	**Sub-period/Load level**								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
1	8	28	32	12	16	24	26	11	11
2	8	28	32	12	16	24	26	11	11
3	10	35	40	15	20	14	20	7	7
4	10	35	40	15	20	14	20	7	7
5	10	35	40	15	20	14	20	7	7
6	10	35	40	15	20	14	20	7	7
7	10	35	40	15	20	14	20	7	7
8	10	35	40	15	20	14	20	7	7
9	10	35	40	15	20	14	20	7	7
10	10	35	40	15	20	14	20	7	7

Period	**Sub-period/Load level**								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
11	10	35	40	15	20	14	20	7	7
12	10	35	40	15	20	14	20	7	7
13	10	35	40	15	20	14	20	7	7
14	10	35	40	15	20	14	20	7	7
15	10	35	40	15	20	14	20	7	7
16	6	21	24	9	12	34	32	15	15
17	10	35	40	15	20	14	20	7	7
18	8	28	32	12	16	24	26	11	11
19	10	35	40	15	20	14	20	7	7
20	10	35	40	15	20	14	20	7	7
21	10	35	40	15	20	14	20	7	7
22	10	35	40	15	20	14	20	7	7
23	10	35	40	15	20	14	20	7	7
24	10	35	40	15	20	14	20	7	7
25	10	35	40	15	20	14	20	7	7
26	10	35	40	15	20	14	20	7	7
27	10	35	40	15	20	14	20	7	7
28	10	35	40	15	20	14	20	7	7
29	10	35	40	15	20	14	20	7	7
30	10	35	40	15	20	14	20	7	7
31	10	35	40	15	20	14	20	7	7
32	10	35	40	15	20	14	20	7	7
33	8	28	32	12	16	24	26	11	11
34	10	35	40	15	20	14	20	7	7
35	10	35	40	15	20	14	20	7	7
36	10	35	40	15	20	14	20	7	7
37	10	35	40	15	20	14	20	7	7
38	10	35	40	15	20	14	20	7	7
39	10	35	40	15	20	14	20	7	7
40	10	35	40	15	20	14	20	7	7
41	10	35	40	15	20	14	20	7	7
42	10	35	40	15	20	14	20	7	7

Period	Sub-period/Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
43	10	35	40	15	20	14	20	7	7
44	10	35	40	15	20	14	20	7	7
45	10	35	40	15	20	14	20	7	7
46	10	35	40	15	20	14	20	7	7
47	10	35	40	15	20	14	20	7	7
48	10	35	40	15	20	14	20	7	7
49	10	35	40	15	20	14	20	7	7
50	8	28	32	12	16	24	26	11	11
51	10	35	40	15	20	14	20	7	7
52	8	28	32	12	16	24	26	11	11

Table 7: Length of load blocks for each period, sub-period and load block

o) Thermal gap $thgap$

The thermal gap (expressed in GW) is required in order to constraint the minimum dispatchable generation required by the system. The values used in the model are estimated according to historical values for CCGT, coal and gas production available in (REE, 2015b).

p) Renewable, cogeneration and waste-to-energy generation res

The methodology followed to determine the production patterns for renewable, cogeneration and waste-to-energy generation (expressed in GW) is explained below:

- Hourly production values during the year 2014 (obtained from (REE, 2015b)) are assigned to the different weeks (periods) of the year and multiplied by a scale factor that represent the variation of installed power considered for each generation technology and scenario, see section 3.2. This step is applicable for cogeneration, waste-to-energy and all renewable generation except solar photovoltaic.

- In case of solar photovoltaic, hourly production is obtained multiplying the scale power factor considered for each scenario by the hourly duty factors defined in Annex IV of RD 413/2014 (RD 413/2014, 2014). The values considered in the model are the ones that correspond to the climatic zone 4.

- Scaled hourly production values are rearranged according to the load blocks defined in the model, and the average values for each period, sub-period and level are computed taking into account the length of each block.

Production patterns for renewable, cogeneration and waste-to-energy generation for each scenario (refer to section 3.2) are included in Annex D.

3.1.3 Objective function

The objective function of the “Midterm planning model” proposed in this thesis (refer to equation (1) in section 3.1.1) computes the operation costs incurred by the units of the system to satisfy demand and technical constraints. The objective is to determine the optimal generation schedule that minimize the aforementioned operation costs.

The operation costs (expressed in k€) comprise fuel costs of the thermal units, variable operation costs for all generators (associated with CO_2 emissions and with operation and maintenance) and fixed operation costs for combined cycles that are available (not mothballed).

3.1.4 Constraints

The set of constraints considered in the model (refer to equations (3)-(15) in section 3.1.1) are summarized below:

- Demand balance constraint: expresses the equilibrium between supply (production of thermal, hydraulic and renewable generators) and demand, for each period, sub-period and level of the time horizon considered (one year).

- Power limits constraints: define the feasible range of production for generation units between their operation limits.

- Reservoir management constraints: expresses the energy balance in the reservoirs during each period. The energy stored at the end of the period depends on the energy available in the previous period, the inflows received, the energy produced and the energy returned to the reservoir by pumping.

- Reservoir limits constraints: define the maximum and minimum levels in the reservoir according to their physical capacity.

- Mothballing constraints: define the relationship between mothballing decisions and production. This is, in case of one unit is mothballed, its production is set to zero.

- Thermal gap constraint: expresses the requirements for dispatchable generation. This is, the available generation obtained from dispatchable sources (combined cycles, coal and gas) shall be above the thermal gap considered in the model.

- Relationship between commitment state and start-up/shut-down decisions for thermal generators: defines the dynamics associated with start-up/shut-down decisions within subperiods and in the transition between subperiods. Start-ups and shut-downs are only allowed in the transitions from working days to non-working days.

3.1.5 Variables

The following variables are considered in the model:

- Decision variables $q_{g,n,s,p}$, $b_{h,n,s,p}$: positive variables that determine the power (expressed in GW) produced and pumped by the generators in each period, sub-period and level.

- State variables $w_{h,p}$: positive variables that represent the energy (expressed in GWh) stored in the reservoirs at the end of each period.

- Decision variables $y_{t,s,p}, z_{t,s,p}$: binary variables that decide the commitment of thermal units representing their start-ups and shut-downs, respectively.

- State variables $u_{t,s,p}$: binary variables that represent the commitment state of thermal units. They are linked with the start-up and shut-down decisions stated above.

- Decision variables m_{gccgt}: binary variables that determine mothballing decisions for combined cycles. Its value is 0 for the facilities that are mothballed and 1 for the ones that are available for production (not mothballed).

3.1.6 Model assumptions

The assumptions used in the model are indicated below:

- Centralised environment, where decisions are taken by a central agent (i.e. system operator) who is responsible for the exploitation of generation resources and whose decisions are aimed to minimize the operational costs incurred by the system.

- Single node approach, where transmission network is not modelled and grid constraints are not considered.

- Events are modelled through load blocks instead of chronologically, with start-ups and shut-downs of units limited to the transitions between working days and non-working days.

- The shape of demand curve is considered constant over the time horizon, this is, the distribution of load levels and sub-periods within each period of the horizon is assumed to be the same in different scenarios and, therefore, a unique distribution of periods, sub-periods and load levels is used.

- Two aggregated reservoirs (instead of detail representation of water basins) to model the behaviour of all hydro units.

- Fuel consumption for thermal units is assumed to be linear.

- Deterministic approach: uncertainty related to input data is neglected. Instead, they are used forecasts or estimations for input data such as technical characteristics of generation units, demand, fuel and emission allowance costs, hydrology and production for renewable, cogeneration and waste-to-energy units.

- Evolution of input data over the time horizon is also estimated, when applicable.

- Availability of units in terms of scheduled maintenance or unexpected outage is not taken into account.

- International electricity exchanges or with extra-peninsular systems are not included in the model.

- Fixed operation costs incurred by other technologies different than combined cycles are not taken into account, since they would not impact on the mothballing decisions or scheduling.

3.2 Development of alternative scenarios

In this section the different scenarios considered in the model are defined. The main guidelines are explained below:

- Two yearly time horizon are considered corresponding to the years 2015 and 2020, respectively.

- Three scenarios are generated for the aim of this thesis. In the base case scenario the midterm generation planning model is used to determine the optimal scheduling in 2015, assuming that combined cycles are not allowed to mothball capacity. The other two scenarios consider the problem of generation planning for the years 2015 and 2020, taking into account that mothballing decisions are allowed.

Scenario
2015 without mothballing
2015 with mothballing decisions
2020 with mothballing decisions

Table 8: Base case and alternative scenarios

- Generation mixes for each scenario are indicated in Table 9 and Table 10. They are based on data from (REE, 2014) and projections from (Ministerio de Industria, Turismo y Comercio , 2014).

Technology	Installed power [GW]
Nuclear	7.865
Coal	10.635
Combined cycle	25.357
IGCC	0.32
Hydraulic (including mixed pumping)	15.039
Closed-cycle pumping	2.747
Wind	22.845
Solar photovoltaic	4.428
Solar thermoelectric	2.3
Small hydro	2.105
Non-renewable thermal	7.075
Renewable thermal	1.01

Table 9: Generation mix. Scenarios 2015

Technology	Installed power [GW]
Nuclear	7.865
Coal	10.635
Combined cycle	25.357
IGCC	0.32
Hydraulic (including mixed pumping)	15.288
Closed-cycle pumping	3.77
Wind	27.65
Solar photovoltaic	5.79
Solar thermoelectric	2.3
Small hydro	2.3
Non-renewable thermal	7.39
Renewable thermal	1.254

Table 10: Generation mix. Scenario 2020

- In all scenarios, the operation of Garoña nuclear power plant is not considered (even though the facility is included within the generation mixes).

- Additionally, power reductions in coal power plants foreseen in reference (Ministerio de Industria, Turismo y Comercio , 2014) for year 2020 are not taken into account since they are considered of low relevance.

- Annual demand values for each scenario are based on projections from the Spanish System Operator available at (CNMC, 2015) and they are indicated in Table 11 together with their corresponding growth factor.

Year	Demand [GWh]	Demand growth factor
2014	242282	-
2015	251600	1.0385
2020	277700	1.1462

Table 11: Annual demand. Year 2014 and scenarios 2015 and 2020

- All scenarios consider low hydraulicity (in accordance with proposed regulation for mothballing mechanisms in Spain) in order to take into account the restrictive conditions that are faced during dry years.

Therefore, according to the methodology explained in section 3.1.2, the average producible values are scaled by the producible hydroelectric index of a year with low hydraulicity and distributed over the periods considered in each scenario, see Table 12 and Table 13.

Month	Producible [GWh/day]
January	1768.2
February	1867.6
March	1540.1
April	1366.2
May	1269.1
June	979.8
July	413.5
August	199.6
September	276
October	657
November	979.8
December	1397.5

Table 12: Monthly producible hydroelectric energy (index 0.46). Scenarios 2015 and 2020

Week	Inflows [GWh]	Week	Inflows [GWh]
1	375	2	399
3	399	4	399
5	419	6	467
7	467	8	467
9	433	10	348
11	348	12	348
13	348	14	323
15	319	16	319
17	319	18	300
19	287	20	287
21	287	22	278
23	229	24	229
25	229	26	229
27	113	28	93

Week	Inflows [GWh]	Week	Inflows [GWh]
29	93	30	93
31	73	32	45
33	45	34	45
35	45	36	64
37	64	38	64
39	64	40	124
41	148	42	148
43	148	44	171
45	229	46	229
47	229	48	229
49	316	50	316
51	316	52	316

Table 13: Inflows received per period. Scenarios 2015 and 2020

- Fuel costs for uranium, coal and gas in each scenario are indicated in Table 14, Table 15 and Table 16 below. For the purpose of units’ conversion, a euro/dollar exchange rate of 1.12 has been considered.

Year	Fuel price [$/lb U_3O_8]	Fuel cost [US cent/ kWh]	Fuel cost [k€/MTh]
2015	32	0.53	5.50
2020	60	0.67	6.96

Table 14: Uranium cost. Scenarios 2015 and 2020

Year	Fuel price	Logistic cost	Fuel cost
2015	54.03 €/ton	10 €/ton	9.15 k€/MTh
2020	110.15 €/ton (23 €/boe)	10 €/ton	17.16 k€/MTh

Table 15: Coal cost. Scenarios 2015 and 2020

Year	Fuel price	Fuel cost
2015	21.58 €/MWh	25.09 k€/MTh
2020	36.47 €/MWh (62 €/boe)	42.41 k€/MTh

Table 16: Gas cost. Scenarios 2015 and 2020

- CO_2 emission allowance prices are based on projections from the European Commission (European Commission, 2013), see Figure 12. Prices for the considered scenarios are summarized in Table 17.

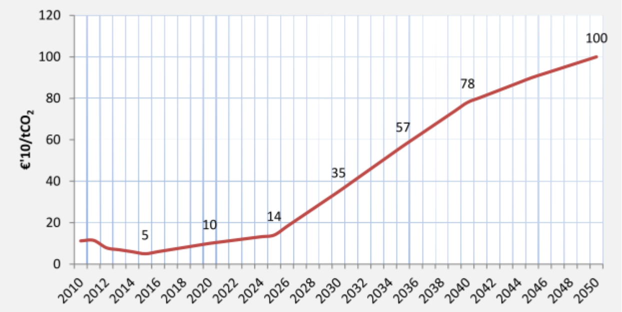

Figure 12: Projections for ETS price (Source European Commision)

Year	CO_2 price
2015	5 €/tCO_2
2020	10 €/tCO_2

Table 17: CO2 emission allowance price. Scenarios 2015 and 2020

- Finally, minimum dispatchable generation (thermal gap) is considered in order to analyze the behavior of the system depending on the requirements imposed to dispatchable production, see Table 18.

Year	Thermal gap [GW]
2015	23000
2020	23000

Table 18: Thermal gap. Scenarios 2015 and 2020

The thermal gap is used to assess the impact of integration of renewable energy sources on mothballing decisions, since dispatchable production requirements depend on the relationship between renewable generation and demand (available dispatchable generation is required by the system in order to substitute renewable generation in case that this is not available).

4 Results

In this chapter they are presented the results obtained for the application of the model to the three scenarios considered in the thesis. Specifically, the results are focused on the generation schedule, the contribution of each technology to the energy mix, the operation costs, the amount of CO_2 emissions, the quantity of mothballed power and the level of security of supply.

For the aim of this thesis, the relationship between the installed dispatchable power (not mothballed) and the thermal gap has been selected as an indicator of the level of security of supply.

4.1 Model results for the base case

4.1.1 Generation schedule

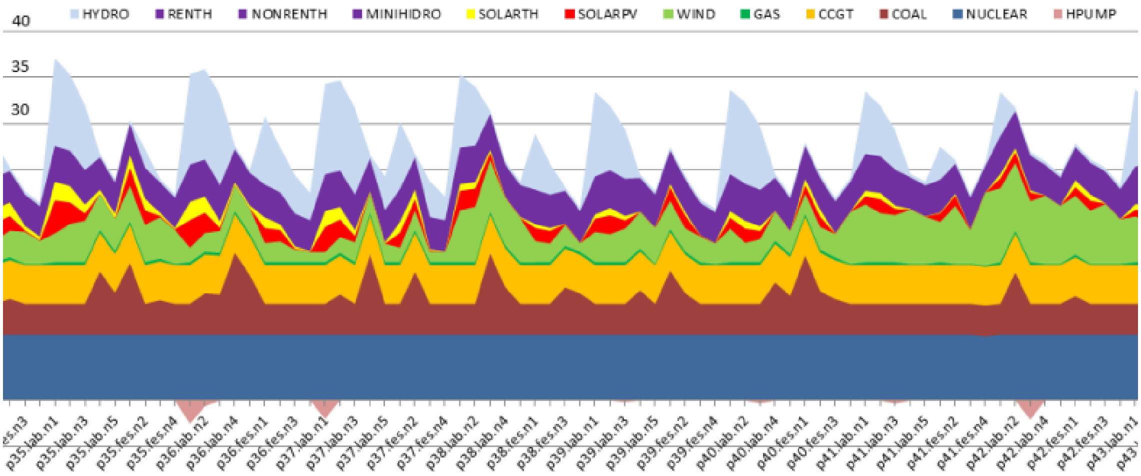

Figure 13: Generation schedule for scenario 2015 without mothballing

4.1.2 Energy mix

Technology	Production [GWh]
Nuclear	61942
Coal	35507
Combined cycle	36680
IGCC	2140
Wind	50067
Solar photovoltaic	8110
Solar thermoelectric	5199
Small hydro	6782
Non-renewable thermal	22152
Renewable thermal	4699
Hydraulic	21016
Pumping	-2562
TOTAL	251732

Table 19: Energy mix for scenario 2015 without mothballing

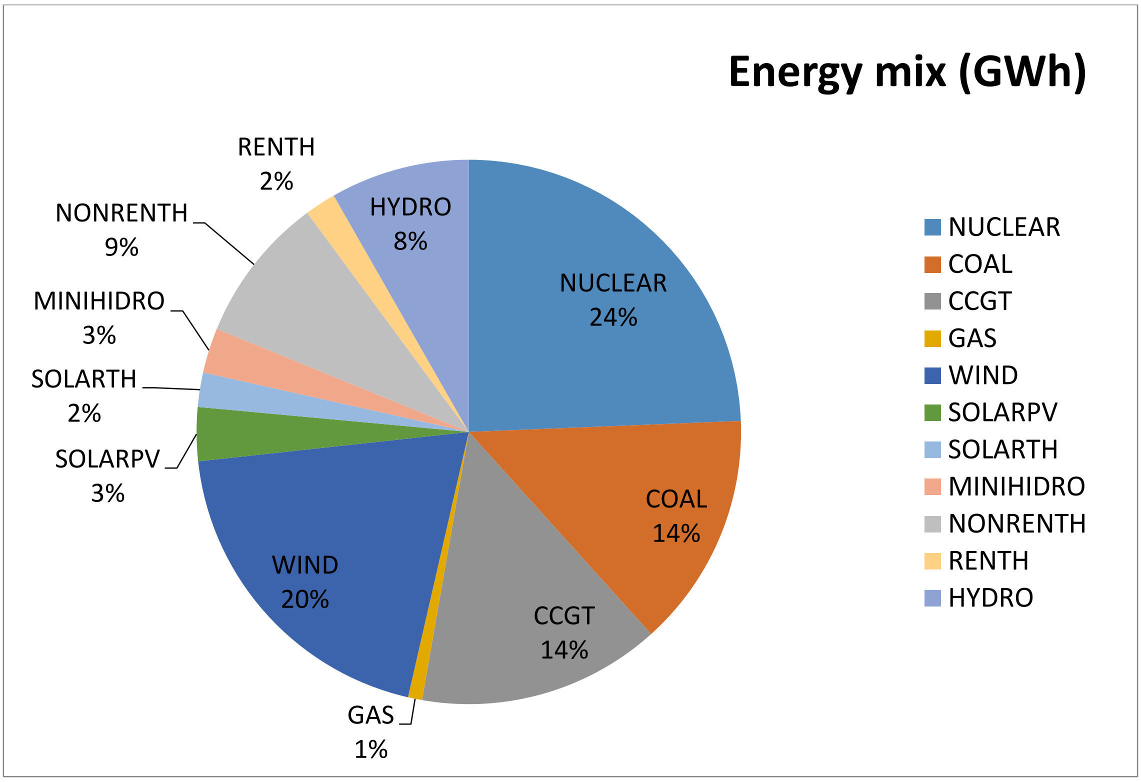

Figure 14: Energy mix for scenario 2015 without mothballing

4.1.3 Operation costs

Operation costs
9434.6 M€

Table 20: Operation costs for scenario 2015 without mothballing

4.1.4 CO_2 emissions

Technology	CO_2 emissions [ton]
Coal	33731417
Combined cycle	13571488
IGCC	1497707
Non-renewable thermal	8196119
TOTAL	**56996731**

Table 21: CO_2 emissions for scenario 2015 without mothballing

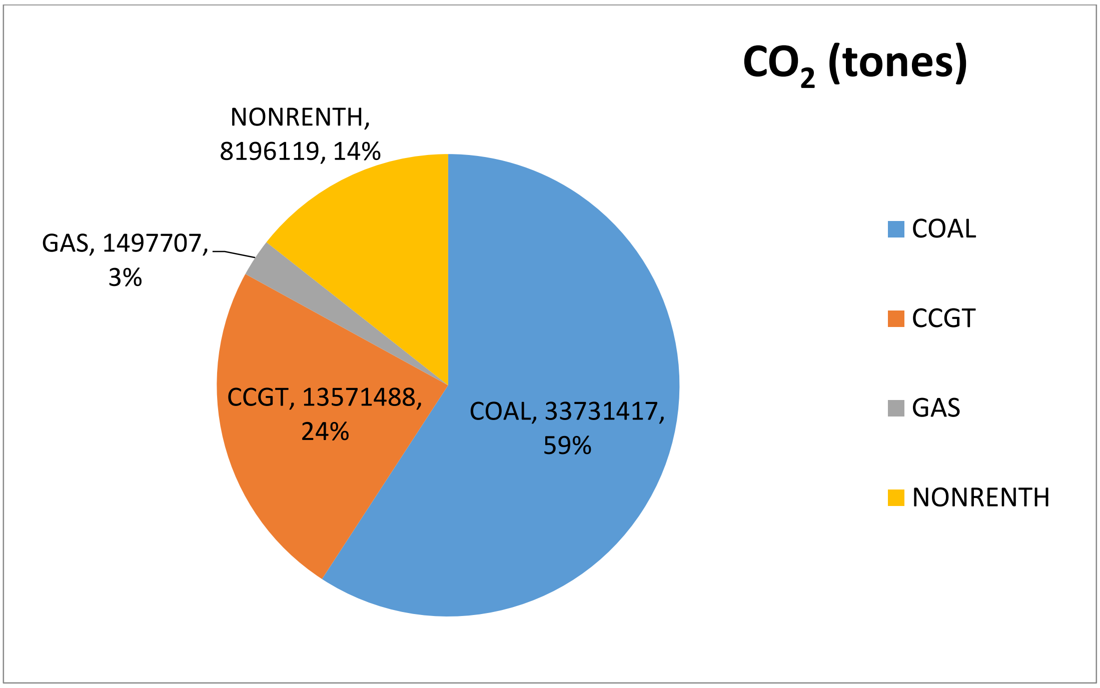

Figure 15: CO_2 emissions for scenario 2015 without mothballing

4.1.5 Mothballed power

Mothballed power
0 GW

Table 22: Mothballed power for scenario 2015 without mothballing

4.1.6 Security of supply

Thermal gap	23 GW
Available thermal power	36.312 GW
RATIO	1.579

Table 23: Available thermal power vs thermal gap for scenario 2015 without mothballing

4.2 Scenario analysis

4.2.1 Generation schedule

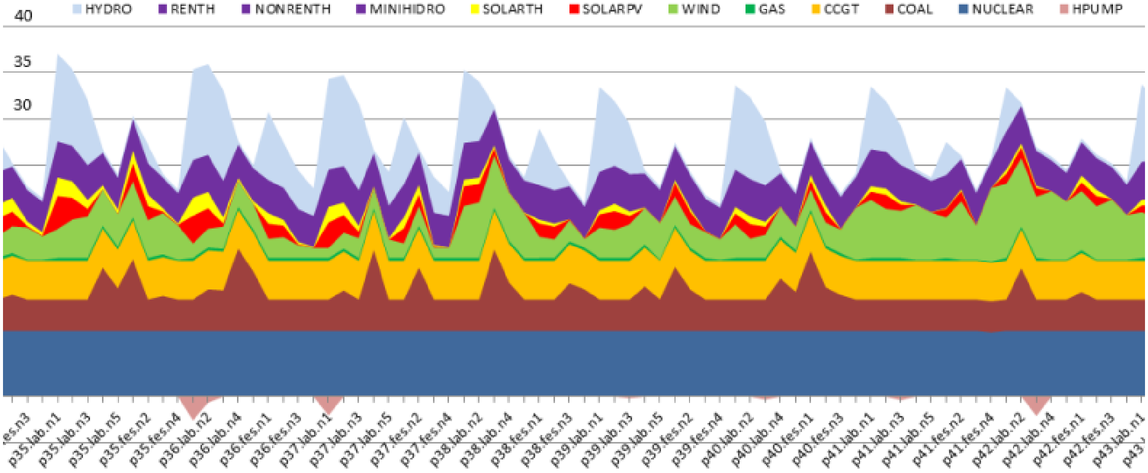

Figure 16: Generation schedule for scenario 2015 with mothballing

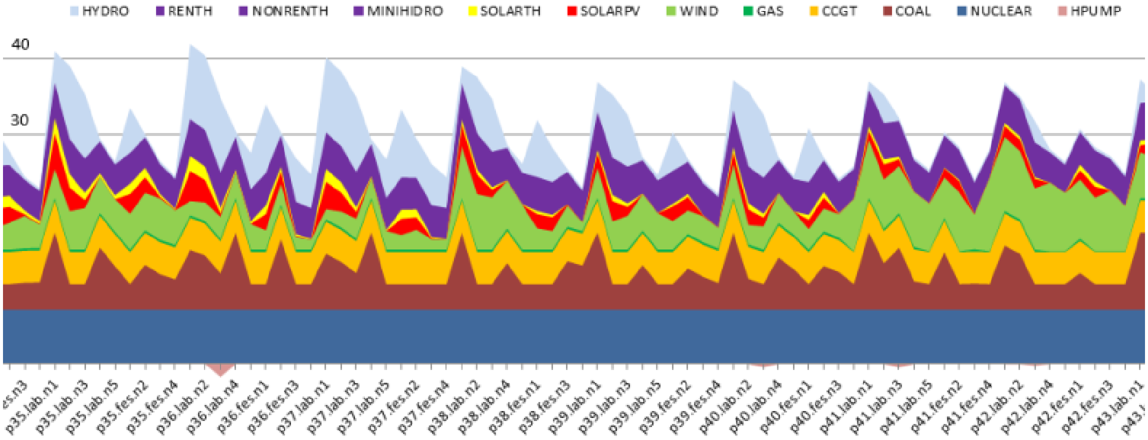

Figure 17: Generation schedule for scenario 2020 with mothballing

4.2.2 Energy mix

Technology	Production [GWh]
Nuclear	61942
Coal	35507
Combined cycle	36680
IGCC	2140
Wind	50067
Solar photovoltaic	8110
Solar thermoelectric	5199
Small hydro	6782
Non-renewable thermal	22152
Renewable thermal	4699
Hydraulic	21016
Pumping	-2562
TOTAL	251732

Table 24: Energy mix for scenario 2015 with mothballing

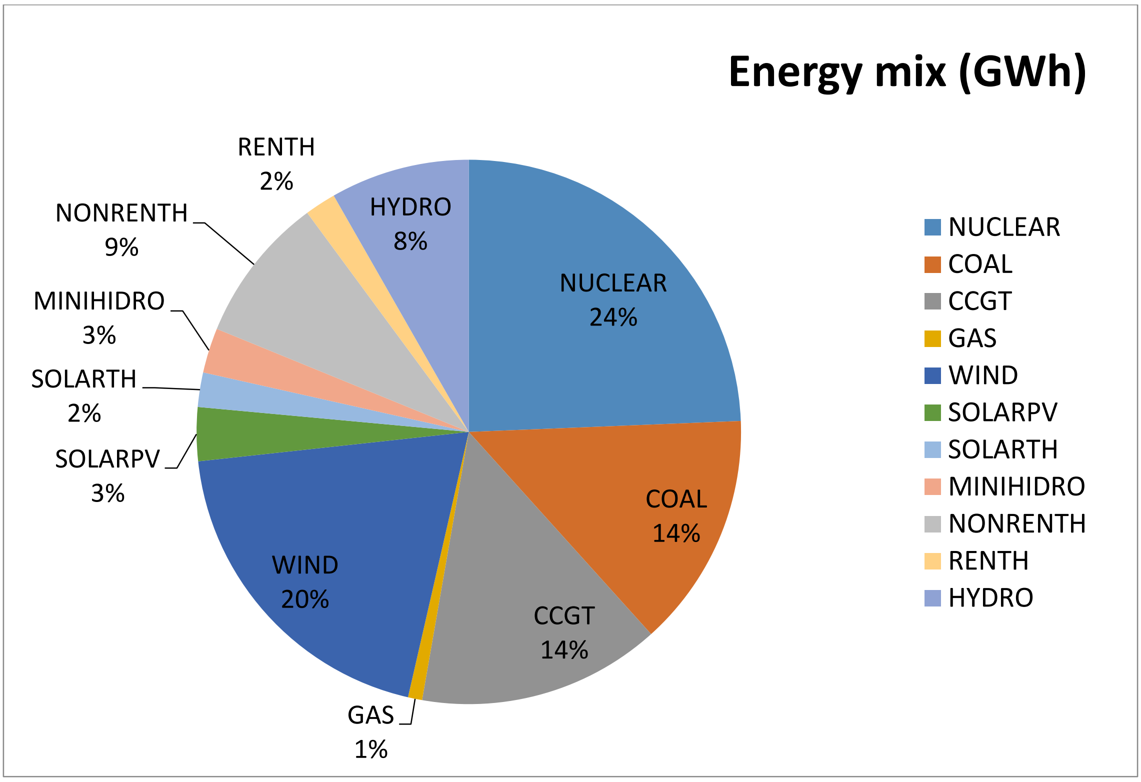

Figure 18: Energy mix for scenario 2015 with mothballing

Technology	Production [GWh]
Nuclear	62000
Coal	42072
Combined cycle	36688
IGCC	2220
Wind	60598
Solar photovoltaic	10604
Solar thermoelectric	5199
Small hydro	7411
Non-renewable thermal	27503
Renewable thermal	4908
Hydraulic	21041
Pumping	-2174
TOTAL	278070

Table 25: Energy mix for scenario 2020 with mothballing

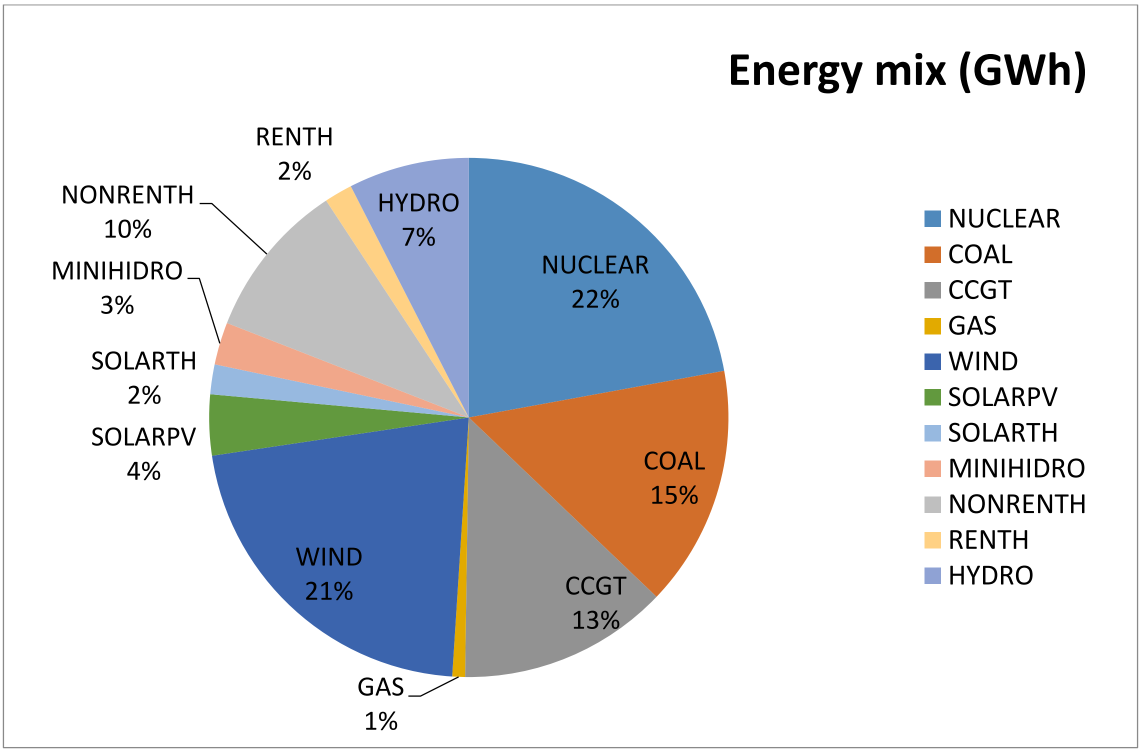

Figure 19: Energy mix for scenario 2020 with mothballing

4.2.3 Operation costs

Operation costs
9056 M€

Table 26: Operation costs for scenario 2015 with mothballing

Operation costs
12608 M€

Table 27: Operation costs for scenario 2020 with mothballing

4.2.4 CO_2 emissions

Technology	CO_2 emissions [ton]
Coal	33731417
Combined cycle	13571488
IGCC	1497707
Non-renewable thermal	8196119
TOTAL	**56996731**

Table 28: CO_2 emissions for scenario 2015 with mothballing

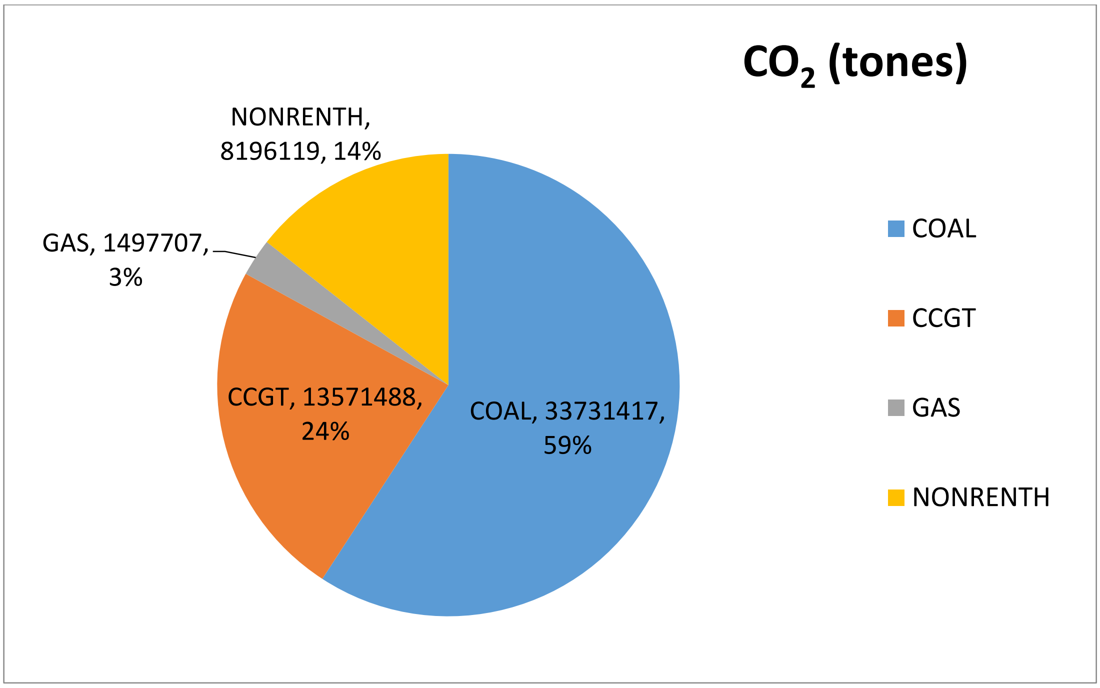

Figure 20: CO_2 emissions for scenario 2015 with mothballing

Technology	CO_2 emissions [ton]
Coal	39968321
Combined cycle	13574559
IGCC	1553851
Non-renewable thermal	10176177
TOTAL	**65272908**

Table 29: CO_2 emissions for scenario 2020 with mothballing

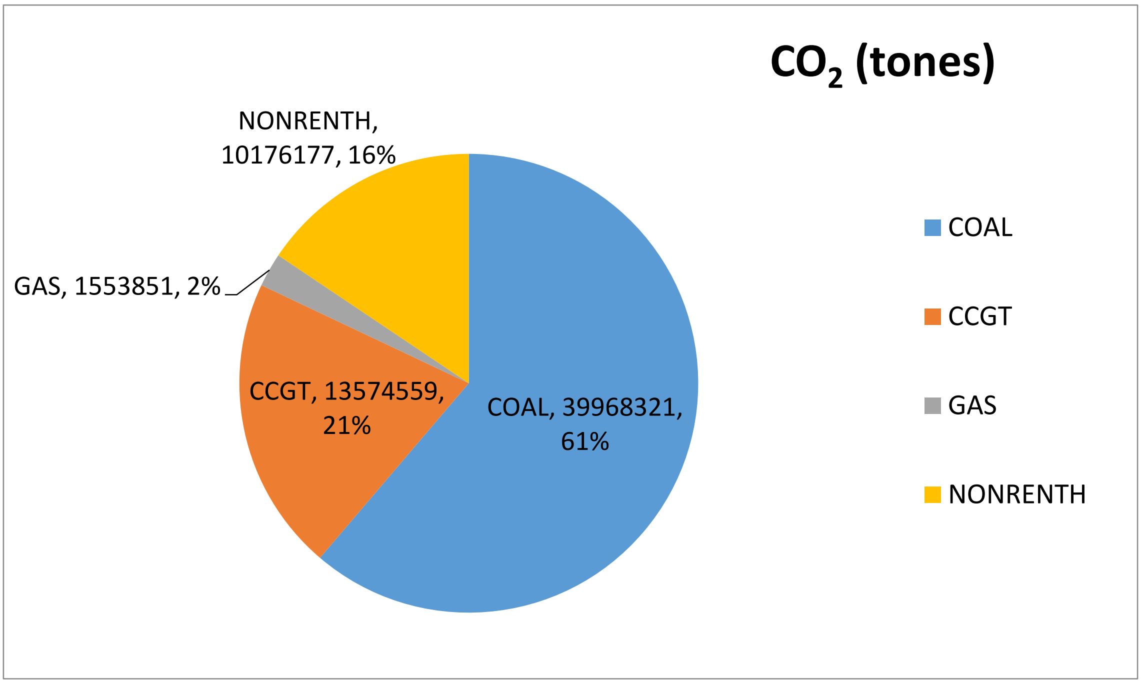

Figure 21: CO_2 emissions for scenario 2020 with mothballing

4.2.5 Mothballed power

Mothballed power
11.7 GW

Table 30: Mothballed power for scenario 2015 with mothballing

Mothballed power
12.1 GW

Table 31: Mothballed power for scenario 2020 with mothballing

4.2.6 Security of supply

Thermal gap	23 GW
Available thermal power	24.6 GW
RATIO	1.070

Table 32: Available thermal power vs thermal gap for scenario 2015 with mothballing

Thermal gap	23 GW
Available thermal power	23.9 GW
RATIO	1.039

Table 33: Available thermal power vs thermal gap for scenario 2020 with mothballing

5 Conclusions

In this chapter they are provided the main findings resulted from the work developed herein, as well as some suggestions for further research.

5.1 Discussion of results

The model proposed in this thesis is able to incorporate the dynamics of mothballing decisions for combined cycles in the midterm generation planning. The process followed intends to model on the one hand, the potential savings in operating costs when facilities are allowed to mothball and, on the other hand, the system requirements on dispatchable generation (not all the facilities are allowed to mothball since they serve as a back-up for other generation sources).

The results obtained with the application of the proposed model to the Spanish Systems (refer to section 4) suggest the following findings:

- The two scenarios considered for the year 2015 (with and without mothballing) obtain the same dispatch results and the mothballing decisions do not impact on scheduling or CO_2 emissions.
- Mothballing decisions in the year 2015 do not result in any technological replacement. This indicates that the mothballed power did not have any contribution in the energy mix (due to the excess of installed capacity present in the system).
- Mothballed power for the scenario 2015 accounts for 11.7 GW (considering a thermal gap of 23 GW).
- Mothballing decisions in the scenario considered for the year 2015 are able to reduce the operating costs in 379 M€, due to the savings in fixed operating costs associated with the plants that are mothballed.
- The two scenarios analysed for the year 2015 indicate that the ratio between dispatchable power and thermal gap is reduced from 1.579 to 1.070 in case of mothballing, indicating that dispatchable generation in the first scenario is more than 50% above system requirements (considering the assumptions followed in the model).
- The scenario 2020 is characterised by the increase in demand and in fuel and emission allowance prices, where higher operating costs and CO_2 emissions are obtained.

- The demand increase considered in the scenario 2020 is covered by the increase in renewable production (estimated in the model proportionally to the projected installed power) and by the cheapest thermal available generation (coal in this case). On the other hand, the contribution of nuclear and hydro is reduced within the total mix.

- Mothballed power for the scenario 2020 accounts for 12.1 GW, with associated ratio between dispatchable power and thermal gap of 1.039. This indicates that, taking into account the assumptions followed within this thesis, the increase of demand projected for 2020 is not enough to reinstate mothballed plants between 2015 and 2020. This result could be affected in case that thermal gap would be increased in the considered horizon.

5.2 Suggestions for further research

Finally, some suggestions for future developments are indicated below:

- Analysis of relevant network constraints for its incorporation in the proposed model (to exclude the mothballing of generators that are required to solve the system constraints).

- Further developments in the estimation of thermal gap, for example, analysis of its evolution with renewable integration, consideration of demand side management (interruptibility service), etc.

- Incorporation of availability of units in the model, as well as alternative approaches to consider security of supply (with the coverage index for example).

- Analysis of the impact of constraints related to domestic coal consumption for its incorporation in the model.

- Adjustment of the model to consider longer periods of mothballing (more than one year).

- Analysis of the impact of considering hydroelectric and pumping stations as dispatchable generation.

- Extension of the model to foresee also seasonal mothballing and possible application to other power systems.

- Sensitivity analysis to variations in demand, fuel and CO_2 prices and hydraulicity.

- Consideration of the problem of mothballing from the perspective of a market agent and its potential effect on competition.

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ANNEX A

GENERATION UNITS

ANNEX A GENERATION UNITS

GENERATION UNITS				
	YEAR 2015		YEAR 2020	
UNIT	Maximum gross power [GW]	Minimum gross power [GW]	Maximum gross power [GW]	Minimum gross power [GW]
NUC_ALM1	1.049	0.350	1.049	0.350
NUC_ALM2	1.044	0.348	1.044	0.348
NUC_ASC1	1.033	0.344	1.033	0.344
NUC_ASC2	1.027	0.342	1.027	0.342
NUC_COF	1.092	0.364	1.092	0.364
NUC_GAR	0.466	0.155	0.466	0.155
NUC_TRI	1.067	0.356	1.067	0.356
NUC_VAN2	1.087	0.362	1.087	0.362
COAL_ABO1	0.36	0.120	0.36	0.120
COAL_ABO2	0.556	0.185	0.556	0.185
COAL_ANL	0.365	0.122	0.365	0.122
COAL_COM2	0.148	0.049	0.148	0.049
COAL_COM3	0.337	0.112	0.337	0.112
COAL_COM4	0.359	0.120	0.359	0.120
COAL_COM5	0.356	0.119	0.356	0.119
COAL_GUA1	0.155	0.052	0.155	0.052
COAL_GUA2	0.361	0.120	0.361	0.120
COAL_LRO1	0.284	0.095	0.284	0.095
COAL_LRO2	0.371	0.124	0.371	0.124
COAL_LAD4	0.358	0.119	0.358	0.119
COAL_LIT1	0.577	0.192	0.577	0.192
COAL_LIT2	0.582	0.194	0.582	0.194
COAL_LBA	0.589	0.196	0.589	0.196
COAL_MEI	0.563	0.188	0.563	0.188
COAL_NAR1	0.065	0.022	0.065	0.022
COAL_NAR2	0.166	0.055	0.166	0.055
COAL_NAR3	0.364	0.121	0.364	0.121
COAL_PNU3	0.324	0.108	0.324	0.108
COAL_PUE1	0.369	0.123	0.369	0.123

GENERATION UNITS				
	YEAR 2015		YEAR 2020	
UNIT	Maximum gross power [GW]	Minimum gross power [GW]	Maximum gross power [GW]	Minimum gross power [GW]
COAL_PUE2	0.366	0.122	0.366	0.122
COAL_PUE3	0.366	0.122	0.366	0.122
COAL_PUE4	0.367	0.122	0.367	0.122
COAL_PLL	0.221	0.074	0.221	0.074
COAL_SOT2	0.254	0.085	0.254	0.085
COAL_SOT3	0.35	0.117	0.35	0.117
COAL_TER1	0.368	0.123	0.368	0.123
COAL_TER2	0.368	0.123	0.368	0.123
COAL_TER3	0.366	0.122	0.366	0.122
CCGT_ACE3	0.392	0.131	0.392	0.131
CCGT_ACE4	0.379	0.126	0.379	0.126
CCGT_ALG3	0.831	0.277	0.831	0.277
CCGT_AMO	0.795	0.265	0.795	0.265
CCGT_ARC1	0.396	0.132	0.396	0.132
CCGT_ARC2	0.379	0.126	0.379	0.126
CCGT_ARC3	0.844	0.281	0.844	0.281
CCGT_ARR1	0.402	0.134	0.402	0.134
CCGT_ARR2	0.397	0.132	0.397	0.132
CCGT_BIZ	0.8	0.267	0.8	0.267
CCGT_BES3	0.419	0.140	0.419	0.140
CCGT_BES4	0.407	0.136	0.407	0.136
CCGT_BES5	0.873	0.291	0.873	0.291
CCGT_GIB1	0.393	0.131	0.393	0.131
CCGT_GIB2	0.388	0.129	0.388	0.129
CCGT_CAR1	0.425	0.142	0.425	0.142
CCGT_CAR2	0.425	0.142	0.425	0.142
CCGT_CAR3	0.419	0.140	0.419	0.140
CCGT_CJN1	0.429	0.143	0.429	0.143
CCGT_CJN2	0.381	0.127	0.381	0.127
CCGT_CJN3	0.426	0.142	0.426	0.142
CCGT_CLN3	0.793	0.264	0.793	0.264

GENERATION UNITS				
	YEAR 2015		YEAR 2020	
UNIT	Maximum gross power [GW]	Minimum gross power [GW]	Maximum gross power [GW]	Minimum gross power [GW]
CCGT_CLN4	0.854	0.285	0.854	0.285
CCGT_CNO	0.798	0.266	0.798	0.266
CCGT_COL4	0.398	0.133	0.398	0.133
CCGT_EFG1	0.409	0.136	0.409	0.136
CCGT_EFG2	0.408	0.136	0.408	0.136
CCGT_EFG3	0.402	0.134	0.402	0.134
CCGT_ESC3	0.818	0.273	0.818	0.273
CCGT_ESCP	0.283	0.094	0.283	0.094
CCGT_ESC6	0.831	0.277	0.831	0.277
CCGT_MAL1	0.421	0.140	0.421	0.140
CCGT_PAL1	0.394	0.131	0.394	0.131
CCGT_PAL2	0.396	0.132	0.396	0.132
CCGT_PAL3	0.398	0.133	0.398	0.133
CCGT_PLV1	0.426	0.142	0.426	0.142
CCGT_PLV2	0.421	0.140	0.421	0.140
CCGT_PUE	0.87	0.290	0.87	0.290
CCGT_PUB1	0.447	0.149	0.447	0.149
CCGT_PUB2	0.445	0.148	0.445	0.148
CCGT_SAB3	0.397	0.132	0.397	0.132
CCGT_SAG1	0.417	0.139	0.417	0.139
CCGT_SAG2	0.42	0.140	0.42	0.140
CCGT_SAG3	0.419	0.140	0.419	0.140
CCGT_SRO1	0.397	0.132	0.397	0.132
CCGT_SRO2	0.402	0.134	0.402	0.134
CCGT_STU4	0.403	0.134	0.403	0.134
CCGT_RIB4	0.432	0.144	0.432	0.144
CCGT_RIB5	0.434	0.145	0.434	0.145
CCGT_TARE	0.4	0.133	0.4	0.133
CCGT_TARP	0.424	0.141	0.424	0.141
GAS_ECG	0.32	0.107	0.32	0.107
WIND	22.845	0.000	27.65	0.000

GENERATION UNITS				
	YEAR 2015		YEAR 2020	
UNIT	**Maximum gross power [GW]**	**Minimum gross power [GW]**	**Maximum gross power [GW]**	**Minimum gross power [GW]**
SOLARPV	4.428	0.000	5.79	0.000
SOLARTH	2.3	0.000	2.3	0.000
MINIHYDRO	2.105	0.000	2.3	0.000
NONRENTH	7.075	0.000	7.39	0.000
RENTH	1.01	0.000	1.254	0.000
HYD_RES	10	0.400	10	0.400
HYD_PUM	2.747	0.000	3.77	0.000

ANNEX B

PARAMETERS OF THERMAL UNITS

ANNEX B PARAMETERS OF THERMAL UNITS

PARAMETERS OF THERMAL UNITS $\alpha_t, \beta_t, \gamma_t, \theta_t$

UNIT	α_t [MTh/GWh]	β_t [MTh/GWh]	γ_t [MTh/GWh]	θ_t[MTh/GWh]
NUC_ALM1	1	0	0	0
NUC_ALM2	1	0	0	0
NUC_ASC1	1	0	0	0
NUC_ASC2	1	0	0	0
NUC_COF	1	0	0	0
NUC_GAR	1	0	0	0
NUC_TRI	1	0	0	0
NUC_VAN2	1	0	0	0
COAL_ABO1	2.6	0.05	2	0.2
COAL_ABO2	2.6	0.07	3.177	0.318
COAL_ANL	2.6	0.05	2.086	0.209
COAL_COM2	2.6	0.02	0.806	0.081
COAL_COM3	2.6	0.04	1.886	0.189
COAL_COM4	2.6	0.04	2	0.2
COAL_COM5	2.6	0.04	2	0.2
COAL_GUA1	2.6	0.02	0.886	0.089
COAL_GUA2	2.6	0.05	2.063	0.206
COAL_LRO1	2.6	0.04	1.623	0.162
COAL_LRO2	2.6	0.05	2.12	0.212
COAL_LAD4	2.6	0.05	2.046	0.205
COAL_LIT1	2.6	0.07	3.297	0.33
COAL_LIT2	2.6	0.07	3.326	0.333
COAL_LBA	2.6	0.08	3.366	0.337
COAL_MEI	2.6	0.07	3.217	0.322
COAL_NAR1	2.6	0.01	0.371	0.037
COAL_NAR2	2.6	0.02	0.949	0.095
COAL_NAR3	2.6	0.05	2.08	0.208
COAL_PNU3	2.6	0.04	1.851	0.185
COAL_PUE1	2.6	0.05	2.109	0.211
COAL_PUE2	2.6	0.05	2.091	0.209

PARAMETERS OF THERMAL UNITS $\alpha_t, \beta_t, \gamma_t, \theta_t$

UNIT	α_t [MTh/GWh]	β_t [MTh/GWh]	γ_t [MTh/GWh]	θ_t[MTh/GWh]
COAL_PUE3	2.60	0.05	2.091	0.209
COAL_PUE4	2.60	0.05	2.097	0.21
COAL_PLL	2.60	0.03	1.263	0.126
COAL_SOT2	2.60	0.03	1.451	0.145
COAL_SOT3	2.60	0.04	2	0.2
COAL_TER1	2.60	0.05	2.103	0.21
COAL_TER2	2.60	0.05	2.103	0.21
COAL_TER3	2.60	0.05	2.091	0.209
CCGT_ACE3	1.30	0.08	1.1	0.11
CCGT_ACE4	1.30	0.075	1.1	0.11
CCGT_ALG3	1.30	0.164	2.2	0.2
CCGT_AMO	1.30	0.15	1.1	0.11
CCGT_ARC1	1.30	0.079	1.1	0.11
CCGT_ARC2	1.30	0.076	1.1	0.11
CCGT_ARC3	1.30	0.169	2.2	0.2
CCGT_ARR1	1.30	0.08	1.1	0.11
CCGT_ARR2	1.30	0.079	1.1	0.11
CCGT_BIZ	1.30	0.16	2.2	0.2
CCGT_BES3	1.30	0.082	1.1	0.11
CCGT_BES4	1.30	0.081	1.1	0.11
CCGT_BES5	1.30	0.175	2.2	0.2
CCGT_GIB1	1.30	0.079	1.1	0.11
CCGT_GIB2	1.30	0.078	1.1	0.11
CCGT_CAR1	1.30	0.085	1.1	0.11
CCGT_CAR2	1.30	0.085	1.1	0.11
CCGT_CAR3	1.30	0.084	1.1	0.11
CCGT_CJN1	1.30	0.086	1.1	0.11
CCGT_CJN2	1.30	0.076	1.1	0.11
CCGT_CJN3	1.30	0.085	1.1	0.11
CCGT_CLN3	1.30	0.16	2.2	0.2
CCGT_CLN4	1.30	0.171	2.2	0.2
CCGT_CNO	1.30	0.16	2.2	0.2

PARAMETERS OF THERMAL UNITS $\alpha_t, \beta_t, \gamma_t, \theta_t$				
UNIT	α_t [MTh/GWh]	β_t [MTh/GWh]	γ_t [MTh/GWh]	θ_t[MTh/GWh]
CCGT_COL4	1.30	0.08	1.1	0.11
CCGT_EFG1	1.30	0.082	1.1	0.11
CCGT_EFG2	1.30	0.082	1.1	0.11
CCGT_EFG3	1.30	0.08	1.1	0.11
CCGT_ESC3	1.30	0.164	2.2	0.2
CCGT_ESCP	1.30	0.057	1.1	0.11
CCGT_ESC6	1.30	0.166	2.2	0.2
CCGT_MAL1	1.30	0.088	1.1	0.11
CCGT_PAL1	1.30	0.08	1.1	0.11
CCGT_PAL2	1.30	0.079	1.1	0.11
CCGT_PAL3	1.30	0.08	1.1	0.11
CCGT_PLV1	1.30	0.082	1.1	0.11
CCGT_PLV2	1.30	0.084	1.1	0.11
CCGT_PUE	1.30	0.17	2.2	0.2
CCGT_PUB1	1.30	0.083	1.1	0.11
CCGT_PUB2	1.30	0.087	1.1	0.11
CCGT_SAB3	1.30	0.078	1.1	0.11
CCGT_SAG1	1.30	0.083	1.1	0.11
CCGT_SAG2	1.30	0.084	1.1	0.11
CCGT_SAG3	1.30	0.084	1.1	0.11
CCGT_SRO1	1.30	0.079	1.1	0.11
CCGT_SRO2	1.30	0.08	1.1	0.11
CCGT_STU4	1.30	0.081	1.1	0.11
CCGT_RIB4	1.30	0.086	1.1	0.11
CCGT_RIB5	1.30	0.087	1.1	0.11
CCGT_TARE	1.30	0.08	1.1	0.11
CCGT_TARP	1.3	0.085	1.1	0.11
GAS_ECG	1.30	0.086	1.1	0.11

ANNEX C

DEMAND LOAD LEVELS

ANNEX C DEMAND LOAD LEVELS

YEAR 2015 - DEMAND [GW]

Period	Sub-period/Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
1	34.5452	32.9853	29.6330	23.6237	20.7176	30.0291	25.9489	22.3809	20.4702
2	37.2465	35.8765	32.9024	26.1437	23.1620	31.1755	26.6830	23.4309	21.3743
3	38.2171	36.9186	34.1497	26.9756	23.9881	32.8313	28.8396	24.2146	22.2518
4	39.2300	37.6239	34.6345	27.5937	24.4096	32.2786	27.9453	24.3270	22.3614
5	38.9528	37.1718	34.3491	27.4735	24.3351	32.9656	28.5962	24.6422	22.6583
6	39.4340	37.5301	34.6243	27.6200	24.6749	32.7507	29.0378	24.2142	22.1011
7	39.3819	37.2507	34.0948	27.7642	24.3032	31.6793	27.7612	24.2407	22.5668
8	37.7440	36.1343	33.3506	27.1569	24.1389	31.5948	27.4026	24.1348	22.1663
9	37.6809	35.9752	33.2972	27.2347	24.1590	32.1607	27.7017	24.0902	22.2634
10	37.0689	35.0977	32.1579	26.4547	23.6848	29.6879	25.7767	23.3375	21.1636
11	35.7271	34.1607	31.3721	25.7049	22.9049	29.6156	25.6522	23.0792	21.1416
12	34.0673	32.2579	29.7099	24.7948	22.4701	29.0881	25.4665	22.4639	20.8345
13	35.9986	34.2994	31.5584	25.8216	23.1936	30.6047	26.7674	23.4965	21.6207
14	35.1993	33.7948	31.1346	25.8352	23.0298	28.8847	25.3503	22.9526	20.7642
15	32.9320	31.6649	29.4544	24.8234	22.2119	27.7678	24.4167	22.3417	20.4477
16	31.9494	30.4694	28.2409	23.9550	21.6800	25.3555	22.6594	20.6690	19.0953
17	32.3297	30.5089	27.5123	23.4400	20.8816	27.9566	24.4826	22.1923	20.4968
18	31.9391	30.4909	27.7034	23.4917	21.1092	26.1039	23.5155	21.1873	20.0248
19	32.5063	31.3506	29.4272	24.7174	22.2949	27.9880	25.0341	22.3480	20.6991
20	32.6573	31.3176	29.3384	24.8052	22.6582	27.2120	24.3278	21.8322	19.8998
21	32.6856	31.3594	29.3205	24.8021	22.5327	27.4458	24.1501	22.0593	20.1494
22	32.5897	31.2694	29.3171	24.7563	22.5189	27.2485	24.3394	21.6800	20.0358
23	33.1493	31.5772	29.7203	24.9303	22.6162	28.1972	25.4063	22.9296	20.9413
24	35.1702	33.3159	30.4913	25.5358	23.3593	29.9334	26.4598	23.6875	21.6441
25	34.1767	32.5264	30.3935	25.9460	23.8729	28.7721	25.9676	23.4150	21.5134
26	33.8272	31.9582	29.3094	25.3540	23.2516	29.3183	25.8959	23.3683	21.3269
27	34.1855	32.3521	30.2350	25.9069	23.7328	28.9989	26.2018	23.0571	21.3513
28	34.0332	32.6469	30.5291	26.1256	23.8519	28.6468	25.8630	23.5030	21.4551
29	37.5542	35.7433	32.5430	27.2979	24.6924	29.7831	26.4963	24.0662	21.9298

YEAR 2015 - DEMAND [GW]

Period	Sub-period/Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
30	36.1703	34.5282	31.7458	26.8809	24.4190	30.2627	27.2262	24.0582	22.2416
31	35.2802	33.5425	30.7778	26.1104	23.8459	28.3263	25.6280	22.8328	21.0340
32	35.0417	33.2939	30.5174	25.2977	22.9537	29.5905	26.5951	23.5593	21.7753
33	33.9321	32.2330	27.6811	24.4010	22.3745	27.0989	24.9623	21.9711	20.7825
34	33.0387	31.7339	29.1854	24.8012	22.6158	27.9875	25.2547	22.2165	20.8712
35	37.0748	35.3317	32.0277	26.7242	24.0155	30.3557	27.2420	24.0436	22.2695
36	37.9203	36.5604	33.1203	27.6069	25.0404	30.7792	27.4597	24.3928	22.5003
37	36.3330	34.7027	31.6604	26.6389	24.2702	30.1699	26.7197	23.7219	22.0996
38	35.3026	34.0381	31.4139	25.9773	23.7309	28.9513	25.6379	23.1318	20.9027
39	33.4333	31.9325	29.5624	24.5044	22.4152	27.4687	24.3472	21.8126	20.1482
40	33.6555	32.3121	29.9754	24.5249	22.2965	27.9635	24.4977	21.9699	20.3675
41	33.5105	31.9356	29.5883	24.5031	22.2970	27.5032	24.2018	21.8423	20.1923
42	33.4110	31.7498	29.0281	24.0704	21.7192	27.8640	24.4174	21.8537	20.1469
43	33.7265	31.9547	29.6437	24.1850	21.9189	27.3581	24.0568	21.3017	19.3918
44	33.5065	31.7602	29.0849	23.8924	21.6520	26.6021	23.5922	20.8936	19.3133
45	34.4605	32.8426	29.9350	24.3405	21.9268	29.2538	25.5234	22.0512	20.3523
46	35.9418	34.2853	31.2782	25.4005	22.6800	29.7398	25.8139	22.8713	21.1709
47	36.4185	34.5009	31.7837	25.5738	23.0987	29.4692	26.1567	22.5124	20.8580
48	35.7311	34.2387	31.4242	25.1273	22.6796	30.0556	26.5163	22.3957	20.6555
49	36.4054	34.7427	32.1769	25.6854	22.8680	31.0548	27.4835	23.4134	22.1410
50	38.8752	36.9301	34.3246	27.1593	23.9217	32.4288	28.4152	24.0089	21.8559
51	38.2337	36.4031	33.5678	26.7970	23.7283	31.6349	27.7336	23.4343	21.7536
52	35.4811	33.1674	29.0553	23.7813	21.2035	30.0245	25.4272	21.4483	19.7528

	YEAR 2020 - DEMAND [GW]								
Period	**Sub-period/Load level**								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
1	38.1288	36.4071	32.707	26.0743	22.8668	33.1442	28.6407	24.7026	22.5937
2	41.1103	39.5982	36.3156	28.8557	25.5647	34.4095	29.451	25.8615	23.5916
3	42.1816	40.7484	37.6923	29.7739	26.4765	36.2371	31.8313	26.7265	24.5601
4	43.2996	41.5269	38.2273	30.4562	26.9418	35.6271	30.8442	26.8506	24.6811
5	42.9936	41.0279	37.9123	30.3235	26.8595	36.3853	31.5627	27.1985	25.0088
6	43.5247	41.4233	38.2161	30.4852	27.2346	36.1481	32.0501	26.7261	24.3938
7	43.4672	41.1149	37.6317	30.6443	26.8243	34.9656	30.641	26.7553	24.9078
8	41.6594	39.8827	36.8103	29.9741	26.643	34.8723	30.2452	26.6384	24.4657
9	41.5898	39.7071	36.7513	30.0599	26.6652	35.4969	30.5754	26.5892	24.5729
10	40.9143	38.7386	35.4938	29.199	26.1418	32.7676	28.4507	25.7584	23.359
11	39.4333	37.7044	34.6265	28.3714	25.281	32.6878	28.3133	25.4733	23.3347
12	37.6013	35.6042	32.7919	27.3669	24.8011	32.1056	28.1083	24.7942	22.9958
13	39.733	37.8575	34.8321	28.5002	25.5996	33.7795	29.5441	25.9339	23.8635
14	38.8507	37.3005	34.3644	28.5152	25.4188	31.8811	27.98	25.3336	22.9182
15	36.3482	34.9497	32.5099	27.3985	24.5161	30.6483	26.9496	24.6593	22.5689
16	35.2637	33.6302	31.1705	26.44	23.929	27.9858	25.01	22.8131	21.0762
17	35.6835	33.6738	30.3663	25.8716	23.0478	30.8567	27.0223	24.4944	22.6231
18	35.2523	33.6539	30.5772	25.9286	23.299	28.8118	25.9549	23.3852	22.1021
19	35.8784	34.6028	32.4799	27.2815	24.6077	30.8914	27.631	24.6663	22.8463
20	36.045	34.5664	32.3819	27.3784	25.0087	30.0349	26.8515	24.097	21.9641
21	36.0763	34.6125	32.3621	27.375	24.8702	30.2929	26.6553	24.3476	22.2396
22	35.9704	34.5132	32.3583	27.3244	24.8549	30.0752	26.8643	23.929	22.1142
23	36.5881	34.8529	32.8034	27.5165	24.9623	31.1223	28.0419	25.3082	23.1137
24	38.8186	36.772	33.6543	28.1848	25.7825	33.0386	29.2046	26.1447	23.8894
25	37.7221	35.9006	33.5464	28.6375	26.3494	31.7568	28.6614	25.844	23.7451
26	37.3363	35.2734	32.3498	27.9841	25.6636	32.3597	28.5822	25.7924	23.5393
27	37.7318	35.7082	33.3715	28.5944	26.1947	32.0071	28.9199	25.449	23.5662
28	37.5637	36.0336	33.6961	28.8358	26.3262	31.6185	28.5459	25.9411	23.6808
29	41.4499	39.4512	35.9189	30.1297	27.2539	32.8727	29.2449	26.5627	24.2047
30	39.9225	38.11	35.039	29.6694	26.9521	33.402	30.0505	26.5539	24.5489
31	38.94	37.0221	33.9706	28.819	26.3196	31.2648	28.2865	25.2014	23.216

YEAR 2020 - DEMAND [GW]

Period	Sub-period/Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	38.6768	36.7477	33.6832	27.922	25.3348	32.6601	29.354	26.0032	24.0342
33	37.4521	35.5767	30.5526	26.9323	24.6955	29.91	27.5518	24.2503	22.9384
34	36.466	35.0259	32.213	27.374	24.9619	30.8908	27.8745	24.5212	23.0363
35	40.9208	38.9969	35.3501	29.4965	26.5068	33.5047	30.068	26.5378	24.5797
36	41.854	40.353	36.5561	30.4707	27.638	33.9721	30.3083	26.9232	24.8344
37	40.102	38.3026	34.9447	29.4023	26.7879	33.2996	29.4915	26.1827	24.3921
38	38.9648	37.5691	34.6727	28.6721	26.1927	31.9546	28.2975	25.5314	23.0711
39	36.9015	35.2451	32.6291	27.0464	24.7405	30.3182	26.8729	24.0754	22.2383
40	37.1468	35.664	33.0849	27.069	24.6095	30.8643	27.039	24.249	22.4803
41	36.9867	35.2485	32.6577	27.045	24.61	30.3563	26.7124	24.1081	22.287
42	36.8769	35.0434	32.0394	26.5674	23.9723	30.7545	26.9504	24.1207	22.2369
43	37.2252	35.2696	32.7188	26.6939	24.1927	30.1961	26.5524	23.5115	21.4034
44	36.9823	35.0549	32.1021	26.3709	23.8981	29.3617	26.0396	23.061	21.3168
45	38.0353	36.2496	33.0403	26.8655	24.2014	32.2885	28.1711	24.3387	22.4636
46	39.6703	37.8419	34.5229	28.0354	25.0327	32.8249	28.4917	25.2439	23.3671
47	40.1964	38.0799	35.0808	28.2267	25.4949	32.5262	28.8701	24.8477	23.0217
48	39.4377	37.7905	34.684	27.7339	25.0323	33.1735	29.267	24.7189	22.7982
49	40.182	38.3468	35.5148	28.3499	25.2402	34.2763	30.3345	25.8422	24.4378
50	42.908	40.7611	37.8853	29.9767	26.4032	35.7928	31.3629	26.4995	24.1231
51	42.1999	40.1794	37.05	29.5768	26.1898	34.9166	30.6106	25.8653	24.0102
52	39.1618	36.6081	32.0694	26.2483	23.4031	33.1391	28.0649	23.6733	21.8019

ANNEX D

PRODUCTION PATTERNS FOR RENEWABLE, COGENERATION AND WASTE-TO-ENERGY GENERATION

ANNEX D PRODUCTION PATTERNS FOR RENEWABLE, COGENERATION AND WASTE-TO-ENERGY GENERATION

YEAR 2015 - WIND GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
1	9.3908	8.9879	8.6936	8.9317	7.5715	13.4321	11.2770	9.1023	8.8776
2	4.2890	4.5857	4.6825	4.7713	5.4899	3.2857	5.9807	4.3206	6.6320
3	10.4516	8.6004	9.3724	9.7309	8.5358	7.4147	7.2254	6.1153	4.7708
4	8.0285	8.7578	9.1434	8.1105	8.2815	10.9999	9.9704	11.1952	7.3780
5	12.1362	10.3746	11.7281	10.7080	9.6822	10.4822	8.6327	9.7325	9.1962
6	10.6128	11.8136	12.0148	9.4704	7.8941	11.4422	7.9001	7.0186	4.6328
7	10.7704	11.1515	10.8645	8.5039	6.9078	4.3491	4.0088	3.8773	2.1357
8	6.8767	6.2310	7.2670	5.7380	5.5314	6.0930	5.8677	6.2570	5.0720
9	8.7955	8.7761	9.3583	8.4409	7.1745	11.5433	9.6407	8.3369	6.3468
10	12.8692	7.7979	7.2938	7.5149	6.2615	5.1306	5.0987	4.6800	5.1392
11	4.4879	3.2413	4.1666	4.0472	3.8849	6.1157	5.8331	6.1882	7.5334
12	4.8542	2.9578	3.7194	4.2673	3.4420	8.4345	8.7878	7.3404	8.9519
13	11.9749	9.5985	9.7611	9.4702	7.5087	8.7603	7.4352	7.7439	6.2191
14	8.3868	7.8297	9.5270	7.6554	7.5279	6.4554	5.1083	6.5612	4.3780
15	4.0797	4.1310	4.6649	4.2073	4.0052	5.1525	4.3943	4.9286	3.6856
16	2.5306	1.6201	2.1472	2.5460	2.8681	3.7420	3.9087	3.9444	4.9774
17	8.8224	7.5157	4.8662	5.2260	4.0580	10.1791	9.2218	9.8521	8.9654
18	3.7702	4.4483	6.9703	4.7374	5.3652	5.6416	4.6317	6.2776	5.6540
19	2.0848	2.5147	3.4886	3.4059	3.2962	2.9018	3.9875	2.1654	3.0560
20	5.9473	7.0825	8.7400	8.0653	7.0500	7.2242	5.8011	7.2118	3.9761
21	9.2078	9.1150	8.2047	8.0853	7.6958	3.2489	3.0655	1.9905	2.3780
22	3.4853	4.0582	4.9011	3.2948	3.3193	6.0802	6.0300	6.0241	6.6523
23	7.2714	5.2219	4.5901	4.2868	3.9323	6.3957	5.4180	6.1660	2.3997
24	2.9591	2.9670	3.9174	3.2689	3.0510	9.0162	9.1858	8.1967	9.0243
25	3.0392	3.7037	4.3070	5.1175	5.4839	2.6990	2.2839	1.6212	1.6497
26	1.8518	3.1878	3.2350	2.9353	3.1985	7.4964	5.5496	4.7056	6.2771
27	3.3536	4.6314	4.4016	4.0571	3.3928	5.6997	5.1675	4.8791	5.5948
28	6.3701	7.0381	6.9635	6.6275	5.9155	4.5832	3.4080	4.5589	2.4977

YEAR 2015 - WIND GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
29	4.5772	4.7999	4.1503	3.7490	3.7213	7.2651	6.8901	5.3979	6.5830
30	1.3661	3.0235	3.9356	3.9535	3.9416	3.4344	3.8657	4.0332	4.0801
31	3.8458	4.5346	5.4592	5.0505	4.7860	4.3906	2.9191	4.5622	1.5884
32	1.9643	2.5081	2.8679	2.7730	2.5559	4.4495	3.9329	2.9141	5.1249
33	3.3897	4.8692	4.5289	4.4926	4.0957	5.5698	4.7767	5.1919	5.7041
34	2.4770	3.4387	4.3888	4.0306	4.1619	2.3237	2.8904	3.5044	2.5376
35	3.1251	4.1521	4.4821	3.9413	3.5335	3.8893	4.0589	4.4775	3.7318
36	1.5599	2.0473	2.3818	2.8333	2.7732	2.0843	2.2628	1.3552	1.1028
37	1.0975	1.7324	2.1596	2.1923	2.0128	1.5847	2.1400	1.1182	1.1151
38	5.6292	5.9993	5.6445	5.1800	4.8416	2.3014	2.0149	2.2890	0.9415
39	3.2783	3.0530	3.6516	3.9770	3.9362	3.0907	2.5477	2.8207	2.2207
40	3.6477	2.0959	2.5171	3.2273	2.5210	2.2130	2.4792	2.5508	5.6299
41	6.2728	5.3186	5.1123	5.9154	5.1359	4.3734	6.3148	3.7188	7.9618
42	8.0160	7.3890	6.6320	7.4006	6.2962	6.3950	5.7857	6.5206	4.8610
43	4.9529	4.3762	4.4914	5.6262	5.1656	2.6488	2.3742	2.6985	2.3985
44	3.3962	3.5537	3.6905	3.8707	3.5365	2.6158	3.3698	2.5156	4.7633
45	9.4602	9.0607	9.4599	9.5151	8.4891	7.0016	5.6159	4.9138	5.1229
46	10.3073	9.1528	9.0109	9.8199	8.4618	12.8410	12.5170	11.4703	11.6874
47	5.8468	5.2329	5.5089	5.8565	6.4560	6.3095	7.2402	5.3805	9.2261
48	5.7260	5.1953	4.7443	4.5725	4.8499	7.9867	8.9840	5.1931	8.2377
49	8.2355	7.4260	8.7205	7.9297	8.0987	9.6139	9.4794	9.5986	10.0660
50	6.6226	6.9526	6.7884	6.6990	7.8296	7.5222	6.6810	7.3285	6.1741
51	7.7121	5.8477	5.2804	6.4685	6.3414	3.3528	3.1588	4.1688	4.2569
52	2.8995	2.5764	2.6989	3.4481	3.5695	11.5046	7.6624	6.4823	5.1080

YEAR 2020 - WIND GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
1	11.366	10.8783	10.5221	10.8103	9.164	16.2573	13.6489	11.0168	10.7448
2	5.1911	5.5502	5.6674	5.7748	6.6446	3.9768	7.2386	5.2294	8.0269
3	12.6499	10.4093	11.3437	11.7776	10.3311	8.9742	8.7451	7.4015	5.7742
4	9.7171	10.5998	11.0665	9.8164	10.0234	13.3135	12.0675	13.5499	8.9298
5	14.6888	12.5567	14.1949	12.9602	11.7187	12.6869	10.4484	11.7795	11.1304
6	12.845	14.2984	14.5419	11.4623	9.5545	13.8488	9.5617	8.4948	5.6072
7	13.0357	13.497	13.1496	10.2925	8.3607	5.2638	4.852	4.6928	2.5849
8	8.3231	7.5416	8.7955	6.9449	6.6948	7.3745	7.1019	7.573	6.1388
9	10.6455	10.622	11.3266	10.2163	8.6835	13.9712	11.6684	10.0904	7.6817
10	15.576	9.438	8.8279	9.0955	7.5785	6.2097	6.1711	5.6643	6.2201
11	5.4318	3.923	5.043	4.8984	4.702	7.402	7.06	7.4898	9.1179
12	5.8752	3.5799	4.5017	5.1648	4.166	10.2085	10.6361	8.8843	10.8348
13	14.4936	11.6174	11.8142	11.4621	9.088	10.6029	8.999	9.3727	7.5272
14	10.1508	9.4765	11.5308	9.2656	9.1112	7.8132	6.1827	7.9412	5.2988
15	4.9378	4.9999	5.6461	5.0922	4.8476	6.2362	5.3186	5.9652	4.4608
16	3.0629	1.9609	2.5988	3.0815	3.4713	4.5291	4.7308	4.774	6.0243
17	10.678	9.0965	5.8897	6.3252	4.9115	12.3201	11.1614	11.9243	10.8511
18	4.5632	5.3839	8.4364	5.7338	6.4937	6.8282	5.6059	7.598	6.8432
19	2.5233	3.0436	4.2224	4.1223	3.9895	3.5121	4.8262	2.6208	3.6988
20	7.1982	8.5722	10.5783	9.7617	8.5328	8.7437	7.0212	8.7287	4.8124
21	11.1445	11.0322	9.9304	9.7859	9.3145	3.9322	3.7103	2.4092	2.8782
22	4.2184	4.9118	5.932	3.9878	4.0174	7.3591	7.2983	7.2912	8.0515
23	8.8008	6.3202	5.5555	5.1884	4.7594	7.7409	6.5576	7.4629	2.9044
24	3.5815	3.5911	4.7413	3.9564	3.6927	10.9126	11.1179	9.9207	10.9224
25	3.6784	4.4827	5.2129	6.1939	6.6373	3.2667	2.7643	1.9622	1.9967
26	2.2413	3.8583	3.9154	3.5527	3.8712	9.0731	6.7169	5.6953	7.5974
27	4.059	5.6055	5.3274	4.9104	4.1064	6.8985	6.2544	5.9053	6.7716
28	7.7099	8.5184	8.4281	8.0215	7.1597	5.5472	4.1248	5.5178	3.023
29	5.5399	5.8095	5.0232	4.5375	4.504	8.7932	8.3393	6.5332	7.9676
30	1.6534	3.6594	4.7634	4.785	4.7706	4.1568	4.6788	4.8815	4.9383
31	4.6547	5.4884	6.6074	6.1128	5.7926	5.3141	3.5331	5.5218	1.9225

YEAR 2020 - WIND GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	2.3775	3.0356	3.4711	3.3562	3.0935	5.3854	4.7601	3.527	6.2028
33	4.1027	5.8933	5.4815	5.4375	4.9572	6.7413	5.7814	6.2839	6.9038
34	2.998	4.162	5.3119	4.8784	5.0373	2.8124	3.4983	4.2415	3.0713
35	3.7824	5.0254	5.4248	4.7703	4.2767	4.7073	4.9126	5.4193	4.5167
36	1.888	2.4779	2.8828	3.4292	3.3565	2.5227	2.7387	1.6402	1.3348
37	1.3283	2.0968	2.6138	2.6534	2.4362	1.918	2.5901	1.3534	1.3496
38	6.8132	7.2611	6.8317	6.2695	5.8599	2.7855	2.4387	2.7704	1.1395
39	3.9678	3.6951	4.4196	4.8135	4.7641	3.7408	3.0836	3.414	2.6878
40	4.4149	2.5367	3.0465	3.9061	3.0512	2.6785	3.0007	3.0873	6.814
41	7.5922	6.4373	6.1876	7.1596	6.2161	5.2933	7.643	4.501	9.6364
42	9.702	8.9431	8.0269	8.9572	7.6205	7.7401	7.0026	7.8921	5.8834
43	5.9946	5.2966	5.4361	6.8096	6.2521	3.2059	2.8736	3.2661	2.903
44	4.1105	4.3012	4.4667	4.6848	4.2803	3.166	4.0786	3.0447	5.7652
45	11.45	10.9664	11.4496	11.5164	10.2746	8.4742	6.7971	5.9473	6.2004
46	12.4752	11.0779	10.9062	11.8853	10.2416	15.5419	15.1497	13.8829	14.1456
47	7.0766	6.3335	6.6676	7.0883	7.8139	7.6366	8.763	6.5122	11.1666
48	6.9304	6.288	5.7422	5.5342	5.87	9.6665	10.8736	6.2854	9.9703
49	9.9677	8.9879	10.5547	9.5976	9.8021	11.636	11.4732	11.6175	12.1832
50	8.0155	8.4149	8.2162	8.108	9.4764	9.1043	8.0862	8.8699	7.4727
51	9.3342	7.0776	6.391	7.829	7.6752	4.058	3.8232	5.0456	5.1523
52	3.5094	3.1183	3.2666	4.1733	4.3203	13.9244	9.274	7.8457	6.1824

YEAR 2015 - SOLAR PHOTOVOLTAIC GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
1	0.4926	0.8287	0.5383	0.0000	0.0000	0.7177	0.4922	0.3502	0.1328
2	0.0000	1.1228	0.4898	0.0000	0.0000	0.5517	0.7596	0.1731	0.0403
3	0.1904	1.1412	0.4262	0.0000	0.0000	0.6326	0.7129	0.0633	0.0000
4	0.1506	1.1652	0.4151	0.0000	0.0000	0.6326	0.7129	0.0000	0.0633
5	0.0000	1.1045	0.5059	0.0000	0.0000	0.8635	0.9830	0.2151	0.1455
6	0.6819	1.3031	0.8314	0.0000	0.0000	0.8635	1.0494	0.0253	0.1455
7	0.9963	1.3284	0.7306	0.0000	0.0000	0.8635	0.9830	0.2151	0.1455
8	0.4694	1.5764	0.6454	0.0000	0.0000	0.9710	0.9742	0.0253	0.1455
9	0.0000	1.7472	0.6133	0.0000	0.0000	1.0975	1.1070	0.2657	0.2341
10	0.8236	1.8167	0.7672	0.0000	0.0000	1.0975	1.0826	0.3353	0.2341
11	0.2435	1.9787	0.7705	0.0000	0.0000	1.0975	1.1181	0.2341	0.2341
12	0.0000	2.0521	0.7672	0.0000	0.0000	1.0975	1.1756	0.0696	0.2341
13	0.8635	1.8256	0.7494	0.0000	0.0000	1.2304	0.9897	0.3353	0.2341
14	1.4745	1.5384	1.2996	0.0000	0.0000	1.2398	1.4325	0.5377	0.0380
15	1.7933	1.7168	1.1767	0.0000	0.0000	1.2398	1.4325	0.5377	0.0380
16	2.1992	1.7923	1.0092	0.0000	0.0000	1.3974	1.5913	0.0915	0.0177
17	1.7933	1.6877	1.1956	0.0177	0.0000	1.2398	1.5099	0.3163	0.0380
18	2.1199	1.6478	1.3104	0.0480	0.0000	1.7177	1.8478	0.1650	0.0523
19	2.7808	2.2848	1.1247	0.0000	0.0000	1.8123	1.6959	0.1771	0.0822
20	2.9446	2.2254	1.1358	0.0000	0.0000	1.7522	1.7380	0.1771	0.0822
21	3.0465	2.0710	1.2454	0.0000	0.0000	1.5783	1.7269	0.5567	0.0822
22	3.4140	2.0344	1.1856	0.0000	0.0000	1.7680	1.7956	0.1961	0.1202
23	3.3918	2.3721	1.1136	0.0089	0.0000	1.5719	2.0834	0.0190	0.1202
24	3.4228	2.5025	0.9919	0.0089	0.0000	2.1507	1.6096	0.2151	0.1202
25	3.4096	2.6935	0.8247	0.0177	0.0000	2.1001	1.6450	0.2151	0.1202
26	3.2811	2.6138	0.9266	0.0177	0.0000	2.1507	1.6096	0.2151	0.1202
27	3.4007	2.6707	1.1203	0.0089	0.0000	2.1286	1.8952	0.2214	0.1139
28	3.8524	2.9301	0.8446	0.0177	0.0000	1.7048	2.1919	0.2214	0.1139
29	3.9144	2.9490	0.8103	0.0236	0.0000	2.1792	1.8598	0.2214	0.1139
30	3.7461	2.7732	1.0085	0.0177	0.0000	2.3405	1.7468	0.2214	0.1139
31	3.8169	3.0376	0.6365	0.0118	0.0000	1.7111	1.7291	0.1581	0.0569

YEAR 2015 - SOLAR PHOTOVOLTAIC GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
32	3.6398	2.3494	0.7871	0.0000	0.0000	1.9578	1.4612	0.4301	0.0569
33	3.5978	1.9736	1.0198	0.2509	0.0249	1.7343	1.7746	0.1731	0.0362
34	3.6221	2.2469	0.8812	0.0000	0.0000	1.9104	1.5897	0.1581	0.0569
35	3.5778	2.3418	0.8092	0.0000	0.0000	1.9578	1.5564	0.1581	0.0569
36	3.0066	2.2051	0.3410	0.0000	0.0000	1.6194	1.2443	0.1012	0.0127
37	2.7409	1.8964	0.6775	0.0000	0.0000	1.6194	1.2443	0.1012	0.0127
38	2.1299	1.9799	0.7572	0.0000	0.0000	1.4201	1.3838	0.1012	0.0127
39	1.4391	2.0242	0.8911	0.0000	0.0000	1.4518	1.3616	0.1012	0.0127
40	1.1734	1.5523	0.8756	0.0000	0.0000	0.9267	1.0959	0.0380	0.0000
41	0.8856	1.5106	0.6542	0.0000	0.0000	0.9267	1.0959	0.0380	0.0000
42	1.0627	1.1488	0.9266	0.0000	0.0000	0.9267	1.0959	0.0380	0.0000
43	0.7173	1.3018	0.8790	0.0000	0.0000	0.9077	1.1092	0.0380	0.0000
44	0.2834	1.4638	0.8457	0.0000	0.0000	0.6389	0.7328	0.0000	0.0696
45	0.0000	1.1778	0.4749	0.0000	0.0000	0.6389	0.7328	0.0000	0.0696
46	0.2037	1.1197	0.4749	0.0000	0.0000	0.5282	0.8103	0.0000	0.0696
47	0.0000	1.2221	0.4362	0.0000	0.0000	0.6389	0.7328	0.0000	0.0696
48	0.2037	1.1336	0.4627	0.0000	0.0000	0.6389	0.7328	0.0000	0.0696
49	0.0000	0.9210	0.5358	0.0000	0.0000	0.4681	0.6952	0.0506	0.0000
50	0.0000	0.9710	0.4511	0.0000	0.0000	0.4945	0.7170	0.0644	0.0000
51	0.0000	0.9223	0.4937	0.0000	0.0000	0.5662	0.5823	0.1771	0.0000
52	0.5535	0.6942	0.5549	0.0000	0.0000	0.5092	0.6216	0.2254	0.0322

YEAR 2020 - SOLAR PHOTOVOLTAIC GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
1	0.6441	1.0836	0.7039	0	0	0.9385	0.6436	0.4579	0.1736
2	0	1.4682	0.6405	0	0	0.7214	0.9932	0.2263	0.0527
3	0.249	1.4922	0.5573	0	0	0.8272	0.9322	0.0828	0
4	0.1969	1.5236	0.5428	0	0	0.8272	0.9322	0	0.0828
5	0	1.4442	0.6615	0	0	1.1291	1.2854	0.2813	0.1903
6	0.8916	1.7039	1.0871	0	0	1.1291	1.3722	0.0331	0.1903
7	1.3028	1.737	0.9553	0	0	1.1291	1.2854	0.2813	0.1903
8	0.6138	2.0613	0.8439	0	0	1.2697	1.2739	0.0331	0.1903
9	0	2.2846	0.8019	0	0	1.4351	1.4475	0.3474	0.3061
10	1.0769	2.3755	1.0032	0	0	1.4351	1.4156	0.4384	0.3061
11	0.3184	2.5873	1.0075	0	0	1.4351	1.462	0.3061	0.3061
12	0	2.6833	1.0032	0	0	1.4351	1.5372	0.091	0.3061
13	1.1291	2.3871	0.9799	0	0	1.6089	1.2941	0.4384	0.3061
14	1.928	2.0116	1.6993	0	0	1.6211	1.8731	0.7031	0.0497
15	2.3449	2.2449	1.5386	0	0	1.6211	1.8731	0.7031	0.0497
16	2.8756	2.3436	1.3196	0	0	1.8272	2.0808	0.1196	0.0231
17	2.3449	2.2068	1.5634	0.0231	0	1.6211	1.9743	0.4136	0.0497
18	2.772	2.1546	1.7135	0.0628	0	2.246	2.4162	0.2158	0.0684
19	3.6361	2.9876	1.4706	0	0	2.3697	2.2175	0.2316	0.1075
20	3.8503	2.9099	1.4852	0	0	2.2912	2.2726	0.2316	0.1075
21	3.9836	2.708	1.6285	0	0	2.0638	2.2581	0.7279	0.1075
22	4.4641	2.6602	1.5503	0	0	2.3118	2.3479	0.2564	0.1572
23	4.4351	3.1017	1.4561	0.0116	0	2.0554	2.7242	0.0248	0.1572
24	4.4756	3.2722	1.297	0.0116	0	2.8122	2.1047	0.2813	0.1572
25	4.4584	3.522	1.0784	0.0231	0	2.7461	2.151	0.2813	0.1572
26	4.2903	3.4178	1.2116	0.0231	0	2.8122	2.1047	0.2813	0.1572
27	4.4467	3.4922	1.4649	0.0116	0	2.7833	2.4781	0.2895	0.1489
28	5.0374	3.8314	1.1044	0.0231	0	2.2292	2.8661	0.2895	0.1489
29	5.1184	3.8561	1.0595	0.0309	0	2.8495	2.4319	0.2895	0.1489
30	4.8984	3.6262	1.3187	0.0231	0	3.0604	2.2841	0.2895	0.1489
31	4.9909	3.9719	0.8323	0.0154	0	2.2374	2.261	0.2067	0.0744

YEAR 2020 - SOLAR PHOTOVOLTAIC GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	4.7594	3.072	1.0292	0	0	2.56	1.9106	0.5624	0.0744
33	4.7044	2.5807	1.3335	0.3281	0.0326	2.2678	2.3204	0.2263	0.0473
34	4.7362	2.938	1.1522	0	0	2.498	2.0787	0.2067	0.0744
35	4.6783	3.0621	1.0581	0	0	2.56	2.0351	0.2067	0.0744
36	3.9314	2.8834	0.4459	0	0	2.1175	1.627	0.1323	0.0166
37	3.584	2.4797	0.8859	0	0	2.1175	1.627	0.1323	0.0166
38	2.785	2.5889	0.9901	0	0	1.8569	1.8094	0.1323	0.0166
39	1.8818	2.6468	1.1652	0	0	1.8984	1.7804	0.1323	0.0166
40	1.5343	2.0298	1.1449	0	0	1.2117	1.433	0.0497	0
41	1.158	1.9752	0.8554	0	0	1.2117	1.433	0.0497	0
42	1.3896	1.5022	1.2116	0	0	1.2117	1.433	0.0497	0
43	0.9379	1.7022	1.1494	0	0	1.1869	1.4504	0.0497	0
44	0.3706	1.914	1.1058	0	0	0.8354	0.9582	0	0.091
45	0	1.5401	0.621	0	0	0.8354	0.9582	0	0.091
46	0.2664	1.4641	0.621	0	0	0.6907	1.0595	0	0.091
47	0	1.598	0.5704	0	0	0.8354	0.9582	0	0.091
48	0.2664	1.4823	0.605	0	0	0.8354	0.9582	0	0.091
49	0	1.2043	0.7006	0	0	0.6121	0.909	0.0662	0
50	0	1.2697	0.5899	0	0	0.6466	0.9375	0.0842	0
51	0	1.206	0.6456	0	0	0.7404	0.7614	0.2316	0
52	0.7238	0.9077	0.7256	0	0	0.6658	0.8128	0.2947	0.0421

YEAR 2015 AND YEAR 2020 - SOLAR THERMOELECTRIC GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
1	0.0159	0.1048	0.1330	0.0053	0.0088	0.1035	0.0702	0.0070	0.0001
2	0.0397	0.1605	0.2342	0.0088	0.0041	0.1848	0.1687	0.0457	0.0029
3	0.0261	0.0635	0.0776	0.0085	0.0032	0.0391	0.1072	0.0016	0.0000
4	0.0281	0.2726	0.3145	0.0035	0.0035	0.3548	0.3103	0.0000	0.0007
5	0.0113	0.1725	0.2028	0.0029	0.0006	0.0827	0.3603	0.0101	0.0014
6	0.0566	0.0840	0.0863	0.0021	0.0006	0.0405	0.0527	0.0000	0.0000
7	0.0367	0.1088	0.1304	0.0024	0.0000	0.0865	0.3941	0.0140	0.0017
8	0.1235	0.4071	0.3842	0.0198	0.0075	0.5375	0.4542	0.1161	0.0309
9	0.0456	0.3184	0.2838	0.0224	0.0327	0.0045	0.0169	0.0024	0.0000
10	0.3054	0.7262	0.7358	0.0995	0.0449	0.9772	0.5711	0.0913	0.0381
11	0.5675	1.1803	1.0313	0.1533	0.1173	1.0804	1.0372	0.2762	0.0629
12	0.3661	1.0101	0.8829	0.1440	0.1262	0.5228	1.0557	0.0096	0.0112
13	0.6811	0.8171	0.5146	0.0951	0.0838	0.1412	0.3136	0.0038	0.0018
14	0.2773	0.1981	0.2182	0.0310	0.0095	0.2571	0.6850	0.1859	0.0085
15	1.1174	1.0997	0.9998	0.2622	0.3066	0.8992	1.0604	0.5540	0.0118
16	1.0075	1.0993	0.7799	0.1981	0.1843	0.8139	0.8674	0.1487	0.1010
17	1.1544	0.9489	0.4333	0.0512	0.0290	0.7889	0.9167	0.4122	0.1131
18	1.6051	1.4242	1.2195	0.4179	0.5168	1.3836	1.6043	0.5314	0.3999
19	1.6278	1.5892	1.0534	0.3635	0.4898	1.3159	1.2896	0.3995	0.1458
20	1.9490	1.7485	1.1396	0.5151	0.5651	1.4207	1.4772	0.4060	0.2804
21	0.8920	0.7873	0.5116	0.1082	0.2122	1.1257	1.2001	0.5016	0.1937
22	1.5095	1.2818	0.9574	0.2987	0.2923	1.3368	1.3943	0.5384	0.3575
23	1.4828	1.5912	1.0925	0.4076	0.4495	1.0272	1.5929	0.1573	0.2273
24	1.8072	1.3630	0.7545	0.3181	0.3667	1.6778	1.3340	0.5708	0.3196
25	1.8491	1.5620	0.7603	0.2811	0.3300	1.3037	1.0695	0.3604	0.2024
26	1.7628	1.4636	0.5384	0.2189	0.1193	1.7532	1.4480	0.6794	0.5039
27	1.7981	1.6096	0.9388	0.3334	0.3787	1.5466	1.0392	0.6101	0.2739
28	2.1231	1.9943	1.0660	0.4958	0.4071	1.4874	1.7191	0.6884	0.5204
29	2.1056	1.9726	1.0380	0.3873	0.5740	0.7707	1.2111	0.2273	0.0445
30	2.0844	1.9468	1.0980	0.4303	0.4915	1.7551	1.4221	0.5789	0.4539

YEAR 2015 AND YEAR 2020 - SOLAR THERMOELECTRIC GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
31	1.9786	1.9190	0.9051	0.3928	0.5112	1.3132	1.3584	0.2557	0.1873
32	2.1021	1.8948	1.0585	0.4562	0.5156	1.6164	1.3864	0.7955	0.3824
33	2.0991	1.7512	1.0568	0.6508	0.5255	1.4774	1.6121	0.5102	0.4233
34	2.0444	1.7081	1.0200	0.3137	0.4441	1.4942	1.4736	0.4885	0.3729
35	2.0042	1.7732	0.9614	0.4302	0.5115	1.3569	1.2664	0.3522	0.1323
36	1.9611	1.7586	0.6867	0.2861	0.2980	1.1447	0.6160	0.2682	0.0825
37	1.6972	1.3584	0.6195	0.1658	0.1304	1.1785	1.0372	0.1794	0.0350
38	0.7167	0.6963	0.3376	0.0816	0.0883	0.4069	0.3198	0.0164	0.0116
39	0.4554	0.7897	0.4768	0.0542	0.0257	0.3432	0.3815	0.0329	0.0163
40	0.7075	0.8291	0.5068	0.0241	0.0054	0.6520	0.7453	0.0423	0.0207
41	0.5987	0.6738	0.3549	0.0581	0.0277	0.0935	0.1993	0.0101	0.0015
42	0.4567	0.4266	0.2359	0.0250	0.0092	0.7446	0.6774	0.0290	0.0129
43	0.6101	0.8162	0.6612	0.0167	0.0158	0.6687	0.5398	0.0593	0.0197
44	0.3647	0.8139	0.6200	0.0159	0.0095	0.3954	0.5121	0.0114	0.0000
45	0.1440	0.5202	0.4006	0.0129	0.0070	0.2198	0.3314	0.0000	0.0003
46	0.0277	0.1365	0.1444	0.0065	0.0036	0.1611	0.3461	0.0094	0.0007
47	0.0400	0.3532	0.3059	0.0025	0.0020	0.0300	0.0458	0.0000	0.0000
48	0.0234	0.0590	0.0526	0.0037	0.0019	0.1046	0.1118	0.0044	0.0007
49	0.0316	0.2146	0.2436	0.0009	0.0003	0.3085	0.4727	0.0066	0.0056
50	0.0385	0.3557	0.3852	0.0057	0.0044	0.0557	0.2889	0.0026	0.0040
51	0.0172	0.1789	0.3463	0.0017	0.0031	0.1502	0.2945	0.0008	0.0000
52	0.0958	0.3523	0.3407	0.0006	0.0000	0.2580	0.1889	0.1757	0.0000

YEAR 2015 – SMALL HYDRO GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
1	0.9760	0.9850	0.9677	0.8642	0.8321	0.9748	0.8834	0.7956	0.7968
2	1.0824	1.0374	1.0502	0.9719	0.9280	1.0481	0.9846	0.9673	0.8705
3	1.0308	1.0436	1.0183	0.9561	0.9520	1.0400	1.0089	0.9952	0.9905
4	1.1245	1.1073	1.0890	1.0399	1.0123	1.0717	0.9882	0.9480	0.9385
5	1.1311	1.1095	1.0726	0.9862	0.9274	1.0526	1.0361	0.9811	1.0155
6	1.1196	1.1071	1.0738	0.9581	0.9396	0.9534	0.8917	0.8087	0.7374
7	1.0867	1.0665	1.0361	0.8985	0.7728	1.1724	1.1053	0.9158	0.9964
8	1.1584	1.1515	1.1073	1.0547	0.9804	1.1394	1.0334	1.0438	1.0205
9	1.1852	1.1221	1.1056	1.0019	0.9622	1.0568	0.9598	0.9202	0.8137
10	1.0968	1.0879	1.0733	0.9455	0.8774	1.1831	1.0168	0.9529	0.8039
11	1.2103	1.1866	1.1627	1.0320	1.0130	1.0177	0.9707	0.9632	0.9017
12	1.1172	1.0759	1.0269	0.9293	0.9086	0.9604	0.9686	0.8453	0.9340
13	1.0122	0.9860	0.9536	0.8899	0.8809	0.9663	0.9333	0.9019	0.8949
14	1.1871	1.1244	1.0925	1.0332	0.9775	1.1741	1.1220	1.0766	1.0579
15	1.2009	1.1914	1.1694	1.1530	1.0778	1.1675	1.0617	1.0286	1.0022
16	1.1520	1.1300	1.0921	1.0132	0.9623	0.9779	0.9304	0.9595	0.8940
17	0.9632	0.9419	0.9448	0.9120	0.8816	1.0393	0.8839	0.8803	0.8089
18	1.0527	1.0021	0.9709	0.9519	0.9266	0.9252	0.8957	0.8884	0.8873
19	0.9079	0.8965	0.8739	0.8080	0.7997	0.8600	0.7926	0.7544	0.7582
20	0.8060	0.7977	0.7819	0.7301	0.7106	0.7153	0.7031	0.6956	0.6824
21	0.7758	0.7631	0.7588	0.6743	0.6536	0.7741	0.7312	0.7458	0.6808
22	0.8834	0.8657	0.8252	0.7767	0.7277	0.7722	0.7591	0.7301	0.6977
23	0.7351	0.7638	0.7476	0.7147	0.6870	0.7895	0.7896	0.7033	0.7901
24	0.8482	0.8150	0.7771	0.7056	0.6810	0.7018	0.6765	0.6411	0.6218
25	0.8117	0.7461	0.6774	0.5943	0.5871	0.6659	0.6576	0.5713	0.5775
26	0.8285	0.7862	0.7368	0.6814	0.6356	0.7004	0.6829	0.6560	0.6266
27	0.7433	0.6892	0.6745	0.6172	0.6052	0.6938	0.7101	0.6146	0.5756
28	0.7072	0.6926	0.6719	0.6037	0.6025	0.6740	0.5899	0.5331	0.5116
29	0.6662	0.6270	0.6251	0.5116	0.5061	0.5967	0.5429	0.4975	0.5022
30	0.7181	0.6509	0.5940	0.4886	0.4735	0.5472	0.5069	0.4476	0.4261
31	0.5960	0.5606	0.5187	0.4436	0.4350	0.5461	0.5369	0.4678	0.4622

YEAR 2015 – SMALL HYDRO GENERATION [GW]									
Period	**Sub-period /Load level**								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	0.6928	0.6349	0.5858	0.4800	0.4687	0.5463	0.5366	0.4914	0.4742
33	0.6051	0.5871	0.5285	0.4806	0.4673	0.5544	0.5090	0.4500	0.4258
34	0.6546	0.6019	0.5374	0.4929	0.4577	0.5761	0.5196	0.4760	0.4512
35	0.6271	0.5762	0.5329	0.4710	0.4536	0.5002	0.4678	0.4186	0.4049
36	0.6146	0.5609	0.5078	0.4507	0.4364	0.4813	0.4639	0.4311	0.4198
37	0.5789	0.5476	0.5075	0.4525	0.4346	0.4940	0.4587	0.4372	0.4159
38	0.5384	0.5244	0.4944	0.4164	0.4107	0.5805	0.5027	0.4410	0.4229
39	0.5790	0.5586	0.5239	0.4435	0.4179	0.5153	0.4702	0.3825	0.3724
40	0.4885	0.4844	0.4544	0.3950	0.4005	0.4220	0.3814	0.3562	0.3518
41	0.4927	0.4738	0.4551	0.3855	0.3808	0.5560	0.4817	0.4719	0.4198
42	0.6540	0.6204	0.5732	0.5455	0.4798	0.6582	0.6167	0.6280	0.5798
43	0.5857	0.5512	0.5138	0.4526	0.4649	0.4443	0.4041	0.3693	0.3410
44	0.4859	0.4564	0.4213	0.3457	0.3372	0.4105	0.3552	0.3179	0.3119
45	0.6433	0.6266	0.5814	0.5351	0.4584	0.7399	0.7136	0.6909	0.6955
46	0.7608	0.7463	0.7254	0.6656	0.6472	0.8143	0.7855	0.7580	0.7698
47	0.8920	0.8604	0.8468	0.8213	0.8063	0.8417	0.8173	0.7936	0.7589
48	0.8469	0.8408	0.8114	0.7666	0.7613	0.8977	0.8911	0.8400	0.8690
49	0.9948	0.9853	0.9612	0.9232	0.8980	0.9642	0.8837	0.8978	0.8886
50	0.9714	0.9518	0.9181	0.8390	0.7816	0.9996	0.9315	0.8048	0.8209
51	1.0562	1.0356	1.0027	0.9024	0.8677	0.9352	0.8921	0.8233	0.7469
52	0.9310	0.8953	0.8413	0.7390	0.7228	0.7349	0.6926	0.6317	0.6238

YEAR 2020 – SMALL HYDRO GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
1	1.0664	1.0762	1.0573	0.9443	0.9092	1.0651	0.9652	0.8693	0.8706
2	1.1827	1.1335	1.1475	1.0619	1.014	1.1452	1.0758	1.0569	0.9511
3	1.1263	1.1403	1.1126	1.0447	1.0402	1.1363	1.1024	1.0874	1.0823
4	1.2287	1.2099	1.1899	1.1362	1.1061	1.171	1.0797	1.0358	1.0254
5	1.2359	1.2123	1.172	1.0776	1.0133	1.1501	1.1321	1.072	1.1096
6	1.2233	1.2097	1.1733	1.0469	1.0266	1.0417	0.9743	0.8836	0.8057
7	1.1874	1.1653	1.1321	0.9817	0.8444	1.281	1.2077	1.0006	1.0887
8	1.2657	1.2582	1.2099	1.1524	1.0712	1.245	1.1291	1.1405	1.115
9	1.295	1.226	1.208	1.0947	1.0513	1.1547	1.0487	1.0054	0.8891
10	1.1984	1.1887	1.1727	1.0331	0.9587	1.2927	1.111	1.0412	0.8784
11	1.3224	1.2965	1.2704	1.1276	1.1068	1.112	1.0606	1.0524	0.9852
12	1.2207	1.1756	1.122	1.0154	0.9928	1.0494	1.0583	0.9236	1.0205
13	1.106	1.0773	1.0419	0.9723	0.9625	1.0558	1.0198	0.9854	0.9778
14	1.2971	1.2286	1.1937	1.1289	1.0681	1.2829	1.2259	1.1763	1.1559
15	1.3121	1.3018	1.2777	1.2598	1.1776	1.2757	1.1601	1.1239	1.095
16	1.2587	1.2347	1.1933	1.1071	1.0514	1.0685	1.0166	1.0484	0.9768
17	1.0524	1.0292	1.0323	0.9965	0.9633	1.1356	0.9658	0.9618	0.8838
18	1.1502	1.0949	1.0608	1.0401	1.0124	1.0109	0.9787	0.9707	0.9695
19	0.992	0.9795	0.9549	0.8829	0.8738	0.9397	0.866	0.8243	0.8284
20	0.8807	0.8716	0.8543	0.7977	0.7764	0.7816	0.7682	0.76	0.7456
21	0.8477	0.8338	0.8291	0.7368	0.7141	0.8458	0.7989	0.8149	0.7439
22	0.9652	0.9459	0.9016	0.8487	0.7951	0.8437	0.8294	0.7977	0.7623
23	0.8032	0.8346	0.8169	0.7809	0.7506	0.8626	0.8627	0.7685	0.8633
24	0.9268	0.8905	0.8491	0.771	0.7441	0.7668	0.7392	0.7005	0.6794
25	0.8869	0.8152	0.7402	0.6494	0.6415	0.7276	0.7185	0.6242	0.631
26	0.9052	0.859	0.8051	0.7445	0.6945	0.7653	0.7462	0.7168	0.6846
27	0.8122	0.753	0.737	0.6744	0.6613	0.7581	0.7759	0.6715	0.6289
28	0.7727	0.7568	0.7341	0.6596	0.6583	0.7364	0.6445	0.5825	0.559
29	0.7279	0.6851	0.683	0.559	0.553	0.652	0.5932	0.5436	0.5487
30	0.7846	0.7112	0.649	0.5339	0.5174	0.5979	0.5539	0.4891	0.4656
31	0.6512	0.6125	0.5668	0.4847	0.4753	0.5967	0.5866	0.5111	0.505

YEAR 2020 – SMALL HYDRO GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	0.757	0.6937	0.6401	0.5245	0.5121	0.5969	0.5863	0.5369	0.5181
33	0.6612	0.6415	0.5775	0.5251	0.5106	0.6058	0.5562	0.4917	0.4652
34	0.7152	0.6577	0.5872	0.5386	0.5001	0.6295	0.5677	0.5201	0.493
35	0.6852	0.6296	0.5823	0.5146	0.4956	0.5465	0.5111	0.4574	0.4424
36	0.6715	0.6129	0.5548	0.4925	0.4768	0.5259	0.5069	0.471	0.4587
37	0.6325	0.5983	0.5545	0.4944	0.4749	0.5398	0.5012	0.4777	0.4544
38	0.5883	0.573	0.5402	0.455	0.4487	0.6343	0.5493	0.4819	0.4621
39	0.6326	0.6103	0.5724	0.4846	0.4566	0.563	0.5138	0.4179	0.4069
40	0.5338	0.5293	0.4965	0.4316	0.4376	0.4611	0.4167	0.3892	0.3844
41	0.5383	0.5177	0.4973	0.4212	0.4161	0.6075	0.5263	0.5156	0.4587
42	0.7146	0.6779	0.6263	0.596	0.5242	0.7192	0.6738	0.6862	0.6335
43	0.64	0.6023	0.5614	0.4945	0.508	0.4855	0.4415	0.4035	0.3726
44	0.5309	0.4987	0.4603	0.3777	0.3684	0.4485	0.3881	0.3473	0.3408
45	0.7029	0.6846	0.6353	0.5847	0.5009	0.8084	0.7797	0.7549	0.7599
46	0.8313	0.8154	0.7926	0.7273	0.7072	0.8897	0.8583	0.8282	0.8411
47	0.9746	0.9401	0.9252	0.8974	0.881	0.9197	0.893	0.8671	0.8292
48	0.9254	0.9187	0.8866	0.8376	0.8318	0.9809	0.9736	0.9178	0.9495
49	1.087	1.0766	1.0502	1.0087	0.9812	1.0535	0.9656	0.981	0.9709
50	1.0614	1.04	1.0031	0.9167	0.854	1.0922	1.0178	0.8794	0.8969
51	1.154	1.1315	1.0956	0.986	0.9481	1.0218	0.9747	0.8996	0.8161
52	1.0172	0.9782	0.9192	0.8075	0.7898	0.803	0.7568	0.6902	0.6816

YEAR 2015 – NON-RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
1	3.6692	3.6035	3.2561	2.5220	2.3077	2.5130	2.3066	2.2009	2.0789
2	3.9541	3.8924	3.8079	2.9721	2.7759	2.8745	2.8915	2.8218	2.5067
3	3.9023	3.8697	3.7703	2.8883	2.8386	2.8390	2.7931	2.8364	2.8192
4	3.9252	3.8691	3.7786	2.9834	2.9148	2.7467	2.6623	2.7264	2.7590
5	3.7716	3.7204	3.6088	2.7431	2.6665	2.6092	2.5923	2.4718	2.6026
6	3.6544	3.5824	3.3806	2.6013	2.5319	2.1932	2.1076	2.0374	1.9420
7	3.0765	2.9770	2.7026	2.1347	1.9278	2.0613	1.9718	1.8399	1.8271
8	2.9183	2.8643	2.7272	2.1567	2.0100	1.9568	1.8962	1.9540	1.9704
9	2.7824	2.5859	2.5494	2.0239	1.9614	1.7605	1.6635	1.6188	1.5401
10	2.1708	2.4804	2.4448	1.8512	1.7417	1.6400	1.5601	1.5515	1.3796
11	2.9226	2.8320	2.7756	2.1580	2.0236	1.9426	1.8511	1.8741	1.6947
12	2.8984	2.8174	2.7462	2.2211	2.1273	1.7095	1.6674	1.6925	1.4873
13	2.4590	2.5184	2.4741	1.9880	1.9194	1.8782	1.8706	1.8709	1.8499
14	2.4634	2.4765	2.3640	1.9636	1.8792	1.7160	1.6537	1.6285	1.6868
15	2.5298	2.5382	2.4619	2.0180	1.9264	1.5725	1.5200	1.5184	1.4866
16	2.3630	2.3828	2.2849	1.8561	1.7340	1.7137	1.6258	1.5995	1.5166
17	2.2805	2.2760	2.1517	1.8974	1.7314	1.5388	1.4856	1.4549	1.3424
18	2.6087	2.5632	2.2029	1.9281	1.7479	1.6839	1.6962	1.6549	1.6297
19	2.6736	2.6805	2.6064	2.1214	1.9742	2.0175	2.0350	2.0561	2.0098
20	2.7702	2.7837	2.7153	2.1522	2.0915	1.9924	2.0239	1.9696	2.0339
21	2.7437	2.7429	2.7209	2.1537	2.0841	2.2988	2.2010	2.2014	2.1402
22	2.8832	2.9058	2.8485	2.3824	2.2655	2.2838	2.2627	2.2620	2.1916
23	2.7930	2.9491	2.9284	2.4971	2.3554	2.3332	2.2885	2.3825	2.3184
24	3.0143	3.0013	2.9507	2.5998	2.4993	2.3403	2.1924	2.2888	2.0929
25	2.9633	2.9650	2.9186	2.5736	2.4425	2.3792	2.3753	2.3993	2.3298
26	2.8779	2.8776	2.8483	2.5568	2.4781	2.2808	2.2806	2.3458	2.1376
27	2.8393	2.8430	2.8177	2.4824	2.3944	2.2982	2.2886	2.3398	2.0781
28	2.8699	2.8636	2.8068	2.4387	2.2989	2.4696	2.4049	2.3858	2.3371
29	2.9983	2.9881	2.9673	2.7158	2.5941	2.3686	2.2562	2.3796	2.2060
30	2.8891	2.8735	2.8078	2.5324	2.4636	2.2663	2.2237	2.2834	2.1963
31	2.7070	2.6674	2.6430	2.3840	2.3328	2.3298	2.1987	2.3352	2.1610

YEAR 2015 – NON-RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	2.5742	2.5721	2.5393	2.3467	2.2737	2.3296	2.2752	2.3350	2.2569
33	2.5721	2.5542	2.3894	2.2974	2.2682	2.2154	2.2007	2.2173	2.1748
34	2.6999	2.6822	2.6499	2.4648	2.3806	2.3340	2.2944	2.3437	2.2749
35	2.6731	2.6784	2.6565	2.4617	2.3721	2.3098	2.2917	2.2823	2.2699
36	2.8308	2.8358	2.8185	2.5663	2.5115	2.4997	2.4212	2.5165	2.3590
37	2.8697	2.8418	2.8117	2.5820	2.5381	2.4857	2.4347	2.4698	2.4008
38	2.8524	2.8548	2.8354	2.5519	2.4717	2.5765	2.5113	2.5662	2.4424
39	2.9303	2.9186	2.8856	2.6163	2.5698	2.5073	2.4729	2.5113	2.3887
40	2.9599	2.9684	2.9182	2.6710	2.5912	2.6047	2.5163	2.5364	2.3578
41	2.9341	2.9401	2.9050	2.5061	2.4432	2.5446	2.3617	2.5077	2.0167
42	2.9703	2.9305	2.7564	2.3336	2.1905	2.4440	2.3210	2.3414	2.1850
43	3.0054	2.9872	2.9529	2.5683	2.4436	2.5967	2.5372	2.4835	2.3611
44	2.9624	2.9447	2.8989	2.5611	2.4820	2.4370	2.3520	2.4352	2.1498
45	2.9208	2.8741	2.8010	2.3651	2.2418	2.4106	2.3727	2.3683	2.2204
46	2.8746	2.8597	2.7741	2.3075	2.2240	2.0056	1.8864	1.9387	1.6885
47	2.7962	2.7808	2.7205	2.3106	2.1878	2.3087	2.1669	2.2631	1.7880
48	2.8912	2.8523	2.7968	2.3868	2.2570	2.3088	2.1152	2.1952	1.8452
49	2.8707	2.7845	2.6193	2.2697	2.0933	2.3046	2.2175	2.1256	2.0012
50	2.9138	2.8692	2.8211	2.4408	2.3088	2.4624	2.3953	2.3145	2.2464
51	2.9090	2.8748	2.8415	2.4701	2.4037	2.5413	2.4846	2.4092	2.3084
52	2.7900	2.6320	2.1691	2.0888	1.9004	1.8223	1.6213	1.5009	1.4205

YEAR 2020 – NON-RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
1	4.5556	4.474	4.0427	3.1313	2.8652	3.1201	2.8638	2.7326	2.5811
2	4.9093	4.8327	4.7278	3.6901	3.4465	3.5689	3.59	3.5035	3.1123
3	4.845	4.8046	4.6811	3.5861	3.5244	3.5249	3.4679	3.5216	3.5003
4	4.8735	4.8038	4.6914	3.7041	3.619	3.4103	3.3055	3.3851	3.4255
5	4.6828	4.6192	4.4806	3.4058	3.3107	3.2395	3.2186	3.0689	3.2313
6	4.5372	4.4479	4.1973	3.2297	3.1436	2.723	2.6168	2.5296	2.4112
7	3.8197	3.6962	3.3555	2.6504	2.3935	2.5593	2.4482	2.2844	2.2685
8	3.6233	3.5563	3.386	2.6777	2.4956	2.4295	2.3543	2.4261	2.4464
9	3.4546	3.2106	3.1653	2.5128	2.4352	2.1858	2.0654	2.0099	1.9122
10	2.6952	3.0796	3.0354	2.2984	2.1625	2.0362	1.937	1.9263	1.7129
11	3.6287	3.5162	3.4461	2.6793	2.5125	2.4119	2.2983	2.3269	2.1041
12	3.5986	3.498	3.4096	2.7577	2.6412	2.1225	2.0702	2.1014	1.8466
13	3.0531	3.1268	3.0718	2.4683	2.3831	2.3319	2.3225	2.3229	2.2968
14	3.0585	3.0748	2.9351	2.438	2.3332	2.1306	2.0532	2.0219	2.0943
15	3.141	3.1514	3.0567	2.5055	2.3918	1.9524	1.8872	1.8852	1.8457
16	2.9339	2.9584	2.8369	2.3045	2.1529	2.1277	2.0186	1.9859	1.883
17	2.8314	2.8258	2.6715	2.3558	2.1497	1.9105	1.8445	1.8064	1.6667
18	3.2389	3.1824	2.7351	2.3939	2.1702	2.0907	2.106	2.0547	2.0234
19	3.3195	3.3281	3.2361	2.6339	2.4511	2.5049	2.5266	2.5528	2.4953
20	3.4394	3.4562	3.3713	2.6721	2.5968	2.4737	2.5128	2.4454	2.5253
21	3.4065	3.4055	3.3782	2.674	2.5876	2.8542	2.7327	2.7332	2.6572
22	3.5797	3.6078	3.5367	2.958	2.8128	2.8355	2.8093	2.8085	2.7211
23	3.4677	3.6616	3.6359	3.1004	2.9244	2.8969	2.8414	2.9581	2.8785
24	3.7425	3.7264	3.6635	3.2279	3.1031	2.9057	2.722	2.8417	2.5985
25	3.6792	3.6813	3.6237	3.1953	3.0326	2.954	2.9491	2.9789	2.8926
26	3.5732	3.5728	3.5364	3.1745	3.0768	2.8318	2.8316	2.9125	2.654
27	3.5252	3.5298	3.4984	3.0821	2.9728	2.8534	2.8415	2.9051	2.5801
28	3.5632	3.5554	3.4849	3.0279	2.8543	3.0662	2.9859	2.9622	2.9017
29	3.7226	3.71	3.6842	3.3719	3.2208	2.9408	2.8013	2.9545	2.7389
30	3.5871	3.5677	3.4861	3.1442	3.0588	2.8138	2.7609	2.835	2.7269
31	3.361	3.3118	3.2815	2.9599	2.8964	2.8926	2.7299	2.8993	2.6831

YEAR 2020 – NON-RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
32	3.1961	3.1935	3.1528	2.9136	2.823	2.8924	2.8249	2.8991	2.8021
33	3.1935	3.1713	2.9666	2.8524	2.8162	2.7506	2.7324	2.753	2.7002
34	3.3522	3.3302	3.2901	3.0603	2.9557	2.8979	2.8487	2.9099	2.8245
35	3.3189	3.3255	3.2983	3.0564	2.9452	2.8678	2.8453	2.8337	2.8183
36	3.5147	3.5209	3.4994	3.1863	3.1182	3.1036	3.0061	3.1244	2.9289
37	3.563	3.5283	3.491	3.2058	3.1513	3.0862	3.0229	3.0665	2.9808
38	3.5415	3.5445	3.5204	3.1684	3.0688	3.1989	3.118	3.1862	3.0324
39	3.6382	3.6237	3.5827	3.2484	3.1906	3.113	3.0703	3.118	2.9658
40	3.675	3.6855	3.6232	3.3163	3.2172	3.234	3.1242	3.1492	2.9274
41	3.6429	3.6504	3.6068	3.1115	3.0334	3.1593	2.9322	3.1135	2.5039
42	3.6879	3.6385	3.4223	2.8974	2.7197	3.0344	2.8817	2.907	2.7129
43	3.7315	3.7089	3.6663	3.1888	3.0339	3.224	3.1501	3.0835	2.9315
44	3.6781	3.6561	3.5992	3.1798	3.0816	3.0257	2.9202	3.0235	2.6692
45	3.6264	3.5684	3.4777	2.9365	2.7834	2.993	2.9459	2.9404	2.7568
46	3.5691	3.5506	3.4443	2.865	2.7613	2.4901	2.3421	2.4071	2.0964
47	3.4717	3.4526	3.3777	2.8688	2.7163	2.8664	2.6904	2.8098	2.22
48	3.5897	3.5414	3.4725	2.9634	2.8023	2.8666	2.6262	2.7255	2.291
49	3.5642	3.4572	3.2521	2.818	2.599	2.8614	2.7532	2.6391	2.4847
50	3.6177	3.5624	3.5026	3.0305	2.8666	3.0573	2.974	2.8736	2.7891
51	3.6118	3.5693	3.528	3.0668	2.9844	3.1552	3.0848	2.9912	2.8661
52	3.464	3.2678	2.6931	2.5934	2.3595	2.2625	2.013	1.8635	1.7637

YEAR 2015 – RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	lab.n1	lab.n2	lab.n3	lab.n4	lab.n5	fes.n1	fes.n2	fes.n3	fes.n4
1	0.5917	0.5915	0.5785	0.5563	0.5153	0.5672	0.5451	0.4776	0.4909
2	0.5973	0.5763	0.5844	0.5576	0.5227	0.6056	0.5856	0.5940	0.5553
3	0.6126	0.6114	0.6106	0.5912	0.5868	0.5623	0.5506	0.5950	0.5641
4	0.5614	0.5637	0.5627	0.5332	0.5304	0.6067	0.5866	0.5965	0.6082
5	0.6034	0.5853	0.5882	0.5639	0.5340	0.5566	0.5109	0.4794	0.4916
6	0.5753	0.5586	0.5340	0.4953	0.4734	0.4265	0.3978	0.3553	0.3190
7	0.4601	0.4641	0.4299	0.3667	0.3047	0.4814	0.4478	0.3499	0.3695
8	0.4896	0.4929	0.4796	0.4419	0.3927	0.5075	0.4520	0.4852	0.4560
9	0.5336	0.4971	0.5049	0.4565	0.4228	0.4172	0.3700	0.3912	0.3301
10	0.4398	0.4465	0.4440	0.3921	0.3649	0.4829	0.4283	0.4202	0.3583
11	0.5255	0.5193	0.5250	0.4964	0.4706	0.5356	0.5171	0.5177	0.4863
12	0.5578	0.5515	0.5485	0.5172	0.5019	0.4769	0.4707	0.4698	0.4505
13	0.4579	0.4634	0.4666	0.4399	0.4215	0.4574	0.4481	0.4542	0.4457
14	0.4706	0.4631	0.4650	0.4505	0.4311	0.4649	0.4575	0.4609	0.4556
15	0.4785	0.4709	0.4737	0.4549	0.4443	0.4506	0.4533	0.4447	0.4294
16	0.4843	0.4816	0.4790	0.4587	0.4415	0.4695	0.4700	0.4577	0.4634
17	0.4984	0.4844	0.4664	0.4682	0.4455	0.4714	0.4461	0.4605	0.4310
18	0.5361	0.5270	0.5204	0.5078	0.4976	0.4947	0.4903	0.5003	0.5006
19	0.5017	0.5036	0.5004	0.4843	0.4803	0.5399	0.5426	0.5282	0.5425
20	0.5616	0.5642	0.5698	0.5546	0.5516	0.5621	0.5722	0.5493	0.5726
21	0.5825	0.5791	0.5783	0.5510	0.5535	0.5809	0.5765	0.5815	0.5813
22	0.6083	0.6171	0.6135	0.6013	0.5882	0.5896	0.5827	0.5840	0.5922
23	0.6182	0.6140	0.6120	0.6067	0.5936	0.6196	0.6176	0.6095	0.6242
24	0.6447	0.6438	0.6421	0.6255	0.6205	0.6136	0.6000	0.6059	0.5923
25	0.6116	0.6080	0.5975	0.5926	0.5915	0.5610	0.5524	0.5606	0.5452
26	0.5156	0.5033	0.4885	0.4934	0.4885	0.5117	0.5164	0.5584	0.4936
27	0.5631	0.5455	0.5606	0.5383	0.5305	0.5989	0.5931	0.5978	0.5762
28	0.6043	0.6127	0.6046	0.5908	0.5913	0.5562	0.5348	0.5449	0.5148
29	0.5564	0.5609	0.5603	0.5485	0.5469	0.5345	0.5506	0.5439	0.5570
30	0.5610	0.5473	0.5550	0.5441	0.5487	0.5397	0.5614	0.5477	0.5579
31	0.5936	0.5959	0.5997	0.5878	0.5855	0.5908	0.5849	0.5844	0.5612

YEAR 2015 – RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	0.6074	0.6129	0.6058	0.5957	0.5926	0.6079	0.5993	0.6034	0.6014
33	0.6083	0.6036	0.5943	0.5960	0.5923	0.5827	0.5818	0.5831	0.5788
34	0.6013	0.6013	0.5970	0.5930	0.5881	0.5851	0.5869	0.5846	0.5826
35	0.5864	0.5863	0.5752	0.5746	0.5701	0.6047	0.6032	0.6010	0.5944
36	0.6105	0.6073	0.6043	0.5999	0.5988	0.5851	0.5868	0.5989	0.5814
37	0.5498	0.5550	0.5471	0.5327	0.5370	0.5901	0.5829	0.5821	0.5823
38	0.5682	0.5733	0.5727	0.5658	0.5636	0.5835	0.5905	0.5754	0.5899
39	0.6161	0.6232	0.6259	0.5987	0.5972	0.6246	0.6194	0.6130	0.6073
40	0.5673	0.5796	0.5718	0.5505	0.5575	0.5836	0.5732	0.5697	0.5709
41	0.5665	0.5704	0.5588	0.5467	0.5464	0.4544	0.4262	0.4633	0.4063
42	0.4951	0.4870	0.4526	0.4437	0.4093	0.4977	0.4915	0.4906	0.4877
43	0.5150	0.5183	0.5218	0.4893	0.4823	0.5296	0.5175	0.5239	0.4963
44	0.5568	0.5503	0.5479	0.5189	0.5223	0.5409	0.5357	0.5294	0.5323
45	0.5530	0.5459	0.5412	0.5244	0.5227	0.5112	0.5134	0.5123	0.5190
46	0.5226	0.5179	0.5132	0.4910	0.4832	0.5220	0.5157	0.5132	0.5128
47	0.5324	0.5148	0.5106	0.4951	0.4891	0.5036	0.4928	0.4884	0.4595
48	0.5438	0.5394	0.5327	0.5201	0.5144	0.5345	0.5239	0.5266	0.5181
49	0.5536	0.5455	0.5345	0.5043	0.4900	0.5840	0.5730	0.5534	0.5494
50	0.5785	0.5714	0.5694	0.5566	0.5519	0.5826	0.5778	0.5523	0.5706
51	0.5932	0.5825	0.5801	0.5598	0.5541	0.5782	0.5688	0.5596	0.5527
52	0.5060	0.5136	0.5135	0.5003	0.4862	0.5120	0.5029	0.4834	0.4652

YEAR 2020 – RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
1	0.618	0.6178	0.6043	0.5811	0.5382	0.5925	0.5694	0.4989	0.5128
2	0.6239	0.602	0.6104	0.5824	0.546	0.6326	0.6117	0.6204	0.58
3	0.6399	0.6386	0.6378	0.6175	0.6129	0.5873	0.5751	0.6215	0.5892
4	0.5864	0.5888	0.5878	0.5569	0.554	0.6337	0.6127	0.6231	0.6353
5	0.6303	0.6114	0.6144	0.589	0.5578	0.5814	0.5336	0.5007	0.5135
6	0.6009	0.5835	0.5578	0.5174	0.4945	0.4455	0.4155	0.3711	0.3332
7	0.4806	0.4848	0.449	0.383	0.3183	0.5028	0.4677	0.3655	0.386
8	0.5114	0.5148	0.501	0.4616	0.4102	0.5301	0.4721	0.5068	0.4763
9	0.5574	0.5192	0.5274	0.4768	0.4416	0.4358	0.3865	0.4086	0.3448
10	0.4594	0.4664	0.4638	0.4096	0.3811	0.5044	0.4474	0.4389	0.3743
11	0.5489	0.5424	0.5484	0.5185	0.4916	0.5594	0.5401	0.5407	0.508
12	0.5826	0.5761	0.5729	0.5402	0.5242	0.4981	0.4917	0.4907	0.4706
13	0.4783	0.484	0.4874	0.4595	0.4403	0.4778	0.4681	0.4744	0.4655
14	0.4916	0.4837	0.4857	0.4706	0.4503	0.4856	0.4779	0.4814	0.4759
15	0.4998	0.4919	0.4948	0.4752	0.4641	0.4707	0.4735	0.4645	0.4485
16	0.5059	0.503	0.5003	0.4791	0.4612	0.4904	0.4909	0.4781	0.484
17	0.5206	0.506	0.4872	0.489	0.4653	0.4924	0.466	0.481	0.4502
18	0.56	0.5505	0.5436	0.5304	0.5198	0.5167	0.5121	0.5226	0.5229
19	0.524	0.526	0.5227	0.5059	0.5017	0.5639	0.5668	0.5517	0.5667
20	0.5866	0.5893	0.5952	0.5793	0.5762	0.5871	0.5977	0.5738	0.5981
21	0.6084	0.6049	0.604	0.5755	0.5781	0.6068	0.6022	0.6074	0.6072
22	0.6354	0.6446	0.6408	0.6281	0.6144	0.6159	0.6086	0.61	0.6186
23	0.6457	0.6413	0.6392	0.6337	0.62	0.6472	0.6451	0.6366	0.652
24	0.6734	0.6725	0.6707	0.6533	0.6481	0.6409	0.6267	0.6329	0.6187
25	0.6388	0.6351	0.6241	0.619	0.6178	0.586	0.577	0.5856	0.5695
26	0.5386	0.5257	0.5102	0.5154	0.5102	0.5345	0.5394	0.5833	0.5156
27	0.5882	0.5698	0.5856	0.5623	0.5541	0.6256	0.6195	0.6244	0.6019
28	0.6312	0.64	0.6315	0.6171	0.6176	0.581	0.5586	0.5692	0.5377
29	0.5812	0.5859	0.5852	0.5729	0.5712	0.5583	0.5751	0.5681	0.5818
30	0.586	0.5717	0.5797	0.5683	0.5731	0.5637	0.5864	0.5721	0.5827
31	0.62	0.6224	0.6264	0.614	0.6116	0.6171	0.6109	0.6104	0.5862

YEAR 2020 – RENEWABLE THERMAL GENERATION [GW]

Period	Sub-period /Load level								
Week	**lab.n1**	**lab.n2**	**lab.n3**	**lab.n4**	**lab.n5**	**fes.n1**	**fes.n2**	**fes.n3**	**fes.n4**
32	0.6344	0.6402	0.6328	0.6222	0.619	0.635	0.626	0.6303	0.6282
33	0.6354	0.6305	0.6208	0.6225	0.6187	0.6086	0.6077	0.6091	0.6046
34	0.6281	0.6281	0.6236	0.6194	0.6143	0.6112	0.613	0.6106	0.6085
35	0.6125	0.6124	0.6008	0.6002	0.5955	0.6316	0.6301	0.6278	0.6209
36	0.6377	0.6343	0.6312	0.6266	0.6255	0.6112	0.6129	0.6256	0.6073
37	0.5743	0.5797	0.5715	0.5564	0.5609	0.6164	0.6089	0.608	0.6082
38	0.5935	0.5988	0.5982	0.591	0.5887	0.6095	0.6168	0.601	0.6162
39	0.6435	0.6509	0.6538	0.6254	0.6238	0.6524	0.647	0.6403	0.6343
40	0.5926	0.6054	0.5973	0.575	0.5823	0.6096	0.5987	0.5951	0.5963
41	0.5917	0.5958	0.5837	0.571	0.5707	0.4746	0.4452	0.4839	0.4244
42	0.5171	0.5087	0.4728	0.4635	0.4275	0.5199	0.5134	0.5124	0.5094
43	0.5379	0.5414	0.545	0.5111	0.5038	0.5532	0.5405	0.5472	0.5184
44	0.5816	0.5748	0.5723	0.542	0.5456	0.565	0.5596	0.553	0.556
45	0.5776	0.5702	0.5653	0.5477	0.546	0.534	0.5363	0.5351	0.5421
46	0.5459	0.541	0.536	0.5129	0.5047	0.5452	0.5387	0.536	0.5356
47	0.5561	0.5377	0.5333	0.5171	0.5109	0.526	0.5147	0.5101	0.48
48	0.568	0.5634	0.5564	0.5433	0.5373	0.5583	0.5472	0.55	0.5412
49	0.5782	0.5698	0.5583	0.5268	0.5118	0.61	0.5985	0.578	0.5739
50	0.6043	0.5968	0.5948	0.5814	0.5765	0.6085	0.6035	0.5769	0.596
51	0.6196	0.6084	0.6059	0.5847	0.5788	0.6039	0.5941	0.5845	0.5773
52	0.5285	0.5365	0.5364	0.5226	0.5078	0.5348	0.5253	0.5049	0.4859