RESEARCH ON THE EFFECTS OF A CARBON PRICE FLOOR

A report for Energie-Nederland

9 July 2018

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EXECUTIVE SUMMARY

On behalf of the Ministry of Economic Affairs and Climate Policy Frontier Economics analysed several scenarios on the introduction of a carbon price floor (CPF) and the ban of coal in the Netherlands (NL).[1] Energie-Nederland has asked Frontier to analyse additional scenarios around the CPF and coal ban in the same framework as the analysis on behalf of the Ministry.

The main results of the scenario with a **regional CPF and coal ban** can be summarised as following (compared to the Reference Case without CPF and coal ban):

Electricity supply

- The regional CPF & coal ban lead to slightly higher exports in 2020 compared to the Reference Case.
- From 2025 onwards, the regional CPF & coal ban lead to lower exports, an earlier conversion from coal to biomass plants and slightly earlier reactivation/less mothballing of gas plants compared to the Reference Case.
- The domestic electricity generation from coal plants is lower than in the Reference Case. The lower generation from coal plants is in earlier years mostly replaced by generation from gas plants (between 2020 and 2030) and later from biomass and imports (between 2025 and 2040).

Emission of CO_2

- The regional CPF & coal ban increase emissions in NL in the short term (2020) slightly compared to the Reference Case.
- In the medium/long term (from 2023 onwards), emissions in NL are lower than in the Reference Case (by up to 19 mn. tCO_2 in 2030).
- The reduction in emissions in the whole model-region is higher than the emission reduction realised in NL.

Impact on Security of Supply and import reliance

- The Adequacy Reserve Margin (reliable generation capacity, including some imports, minus peak demand) decreases in the medium term, but remains positive.
- The import capacity utilisation in hours with high residual load in the Netherlands is moderately higher than in the Reference Case.

Impact on gas-fired power plants

- The regional CPF & coal ban improves the economic situation of gas-fired power plants compared to the Reference Case.
- Mothballed gas capacities are reactivated earlier than in the Reference Case.

[1] "Research on the effects of the minimum CO_2 price" for the Ministry of Economic Affairs and Climate Policy (2018).

Impact on power prices

- The regional CPF & coal ban increase power prices by 2.8 €/MWh in 2020 and 7.1 €/MWh in 2030.

Impact on state income

- The regional CPF in combination with the coal ban generates up to ca. 400 mn. EUR p.a. additional state income (in 2030).

Table 1 Key indicators for „Regional CPF & coal ban“ and “National CPF & coal ban” scenarios (compared to Reference Case)

	Regional CPF & coal ban	National CPF & coal ban
Domestic CO_2 emission reduction (NL)	▪ 2020: +1 mn. tCO_2 ▪ 2025: - 1 mn. tCO_2 ▪ 2030: - 19 mn. tCO_2	▪ 2020: - 10 mn. tCO_2 ▪ 2025: - 16 mn. tCO_2 ▪ 2030: - 26 mn. tCO_2
Net-reduction of CO_2 emissions (EU*)	▪ 2020: - 30 mn. tCO_2 ▪ 2025: - 43 mn. tCO_2 ▪ 2030: - 40 mn. tCO_2	▪ 2020: + 1 mn. tCO_2 ▪ 2025: - 0 mn. tCO_2 ▪ 2030: - 4 mn. tCO_2
Impact on import/exports of power	▪ + 18 TWh imports in 2030	▪ + 39 TWh imports in 2030
Impact on ARM** and import contribution***	▪ ARM remains positive ▪ Import contribution in peak hours increases from 29% to 40% in 2030	▪ ARM negative in 2025/30 ▪ Import contribution in peak hours grows from 29% to 62% in 2030
Impact on capacity margins and CCGTs****	▪ Contribution margin of CCGTs is higher than in the Reference Case ▪ Earlier reactivation than in the Reference Case	▪ Contribution margin of CCGTs is lower than in the Reference Case ▪ More mothballing and later reactivation than in the Ref. Case
Impact on power prices in 2023/2030	▪ 2023: + 2.8 €/MWh ▪ 2025: + 5.9 €/MWh ▪ 2030: + 7.1 €/MWh	▪ 2023: + 1.2 € ▪ 2025: + 2.1 € ▪ 2030: + 2.9 €

Source: *Frontier Economics*

Note: *All values shown are differences to the Reference Case.*
** Modelled: NL, DE, BE, FR, DK, CZ, PL, GB, IT; effects on EU ETS not taken into account.*
*** ARM = adequacy reserve margin (ARM = de-rated capacity + de-rated IC capacity - peak load).*
**** Contribution of imports to meet peak residual load (average over 10 highest residual load hours).*
***** CCGT = Combined-Cycle Gas Turbine.*

Comparison between regional and national CPF (both with the coal ban)

The difference between the scenarios of the regional and national CPF scenarios (both in combination with the coal ban) can be summarised as follows:

- The reduction in domestic **CO_2 emissions** is lower with the introduction of a regional CPF, while the CO_2 emission reduction in the **model-region** is higher with a regional CPF (without taking the impact of the measures on the EU ETS into account which reduces CO_2 emission abatement in both cases).
- The regional CPF leads to higher electricity **exports** than the national CPF.
- With the regional CPF the **ARM** remains positive, while it is temporarily negative (2025-2030) with the national CPF.
- The contribution margin of **CCGTs** in the Netherlands is higher under the regional CPF. There is less mothballing and earlier reactivations under the regional CPF.
- **Power prices** for consumers increase to a higher extent than under a regional CPF.
- The **state income** is higher under a regional CPF.

1 FRONTIER'S ASSIGNMENT

Background

On behalf of the Ministry of Economic Affairs and Climate Policy Frontier Economics analysed several scenarios on the introduction of a carbon price floor (CPF) and the ban of coal in the Netherlands (NL):

- Reference Case;
- National CPF;
- Coal ban until 2030;
- National CPF & coal ban until 2030.

Assignment by Energie-Nederland

Energie-Nederland asked Frontier to analyse additional scenarios around the CPF and coal ban in the same framework as the analysis on behalf of the Ministry. We analyse the following scenarios assuming that a regional CPF in the Pentalateral Forum (plus Austria and Switzerland) would be introduced:

- Regional CPF **without** coal ban until 2030 in NL;
- Regional CPF **with** coal ban until 2030 in NL.

In the following, we focus on the scenario of a regional CPF (Pentalateral Forum) in combination with a coal ban until 2030 in the Netherlands. Results for the national CPF and coal ban as well as for the scenario with a regional CPF without a coal ban can be found in the Annex.

The countries covered by the regional CPF, which is assumed to be introduced in 2020, are: Netherlands (NL), Germany (DE, incl. Luxembourg), Belgium (BE), France (FR), Austria (AT) and Switzerland (CH).

Furthermore, Energie-Nederland has asked Frontier to undertake additional output analyses for the scenarios analysed. In particular, we assess the state income for the Netherlands which is generated by a (regional) carbon price floor. In the scenario analyses described above

- We use exactly the same assumptions as in the scenarios for EZK (except those varied as stated above);
- We use exactly the same output analyses as for EZK in the current project and in addition consider the state income generated from the different policy measures.

2 INDICATOR BASED ASSESSMENT

In this section we

- briefly summarise the results of our analysis for the Reference Case[2] (**Section 2.1**); and
- discuss the results for the scenario "Regional Carbon Price Floor with coal ban" (**Section 2.2**).

The framework and assumptions used in this analysis are, apart from the variations in the policy measures, identical to those applied in our study for the Ministry of Economic Affairs and Climate Policy (2018).[3]

The results for the scenario "Regional CPF without coal ban" are summarised in **Annex A**.

2.1 Reference Case

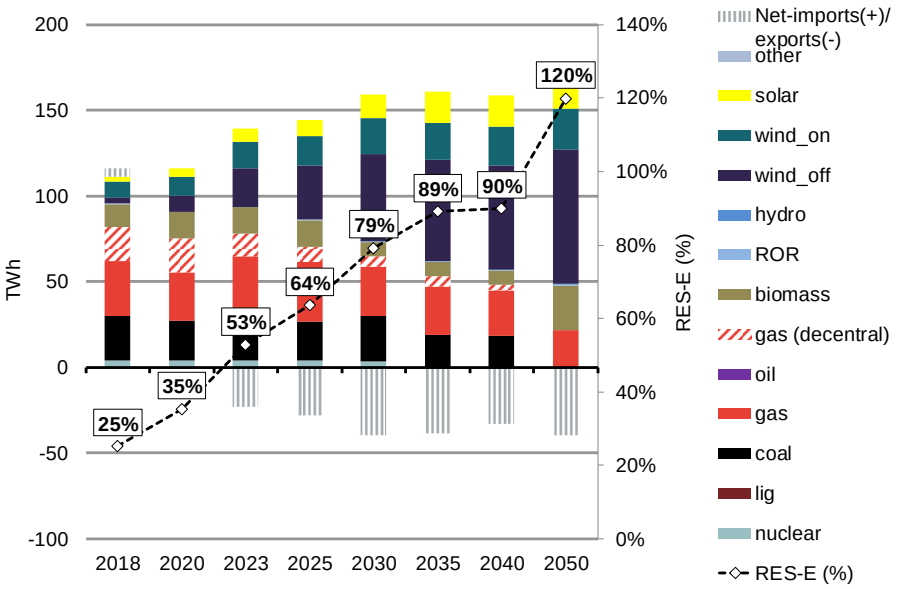
The developments in the Dutch power system in the Reference Case are driven by the transition from conventional generation capacities to largely renewable generation capacities. This transition has direct effects on the conventional generation capacities in the Netherlands and thereby on the Dutch capacity margin, on the electricity exchange with neighbouring countries and on the conversion of coal-fired plans to biomass-fired plants.

- **Electricity supply** – The expansion of renewable generation capacities increase overall electricity generation in the Netherlands from c. 110 TWh in 2018 to 158 TWh in 2030 (**Figure 1**). As a result, the Netherlands become a net-exporter from 2023 onwards.

[2] The Reference Case described here is identical to the Reference Case used in the report "Research on the effects of the minimum CO_2 price" for the Ministry of Economic Affairs and Climate Policy (2018).

[3] "Research on the effects of the minimum CO_2 price" for the Ministry of Economic Affairs and Climate Policy (2018)

Figure 1 Reference Case: Electricity generation in the Netherlands

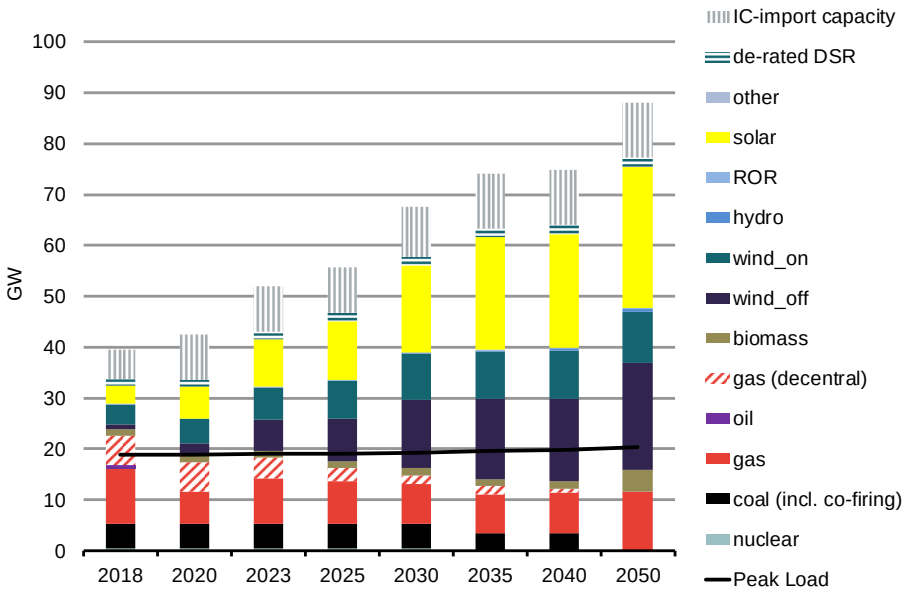


Source: Frontier Economics

- **Operational capacities** – In the short-run, additional gas-fired power plant capacities are mothballed (1.6 GW by 2020) and closed (2.5 GW by 2020). From 2023 onwards gas-fired power capacities are stepwise reactivated: power plants comprising 3 GW are reactivated between 2023 and 2025 and an additional capacities of c. 2 GW are reactivated by 2035 and by 2040. In the long-run (2050) new investments into CCGT plants are undertaken (5.9 GW).

  Conversion of coal-fired plants into biomass plants only becomes economically viable in the very long-run (2050), when a total of c. 3 GW is converted.

Figure 2 Reference Case: Operational capacities



Source: Frontier Economics

Note: "Coal (incl. co-firing)" includes co-firing of biomass that is undertaken under the SDE+ regime. Plants that are converted from coal to biomass after the end of SDE+ are captured as "biomass".

- **Capacity margin and mothballing** – The capacity margin of the Dutch electricity system declines with increasing renewable capacities and decreasing conventional capacities. The adequacy reserve margin (ARM)[4] falls as a result, however, it remains positive (taking de-rated import capacity into account).

[4] The adequacy reserve margin informs about the level of reliable capacity compared to peak load. It is calculated as the difference of the de-rated available capacity (incl. a share of reliable import capacity) and peak load. We de-rate import capacity with 60%, which corresponds to the lowest availability of import capacity observed in the modelled years. Deriving an exact value for de-rating IC capacity would need extensive probabilistic analyses of availability of foreign generation capacities and the interconnectors which is not subject of this study.

2.2 Regional Carbon Price Floor with coal ban

In this section, we summarise the modelling results of the regional CPF scenario in combination with the coal ban. We compare the results of the regional CPF with the coal ban scenario with the Reference Case presented in **Section 2.1**. In addition, we discuss the differences to the national CPF with the coal ban.

The section is structured along the following indicators:

- Electricity supply and imports/exports (**Section 2.2.1**);
- Power-related CO_2 emissions (**Section 2.2.2**);
- Adequacy Reserve Margin (ARM) and electricity imports in critical hours (**Section 2.2.3**);
- Mothballing/De-mothballing and economics of CCGTs (**Section 2.2.4**);
- Wholesale power prices (**Section 2.2.5**); and
- State income from the CPF (**Section 2.2.6**).

2.2.1 Electricity supply and imports/exports

The impact of the introduction of the regional CPF in combination with a coal ban on the Dutch electricity supply leads in the short-term (2020) to a reactivation of 0.9 GW of gas capacity (+2.5 GW compared to the Reference Case in which additional gas capacity is mothballed, **Figure 3**). Moreover, the Netherlands export more electricity to its neighbouring countries in 2020 than in the Reference Case (+8.1 TWh, **Figure 4**). From 2025 onwards, the regional CPF in combination with the coal ban leads, in comparison with the Reference Case, to

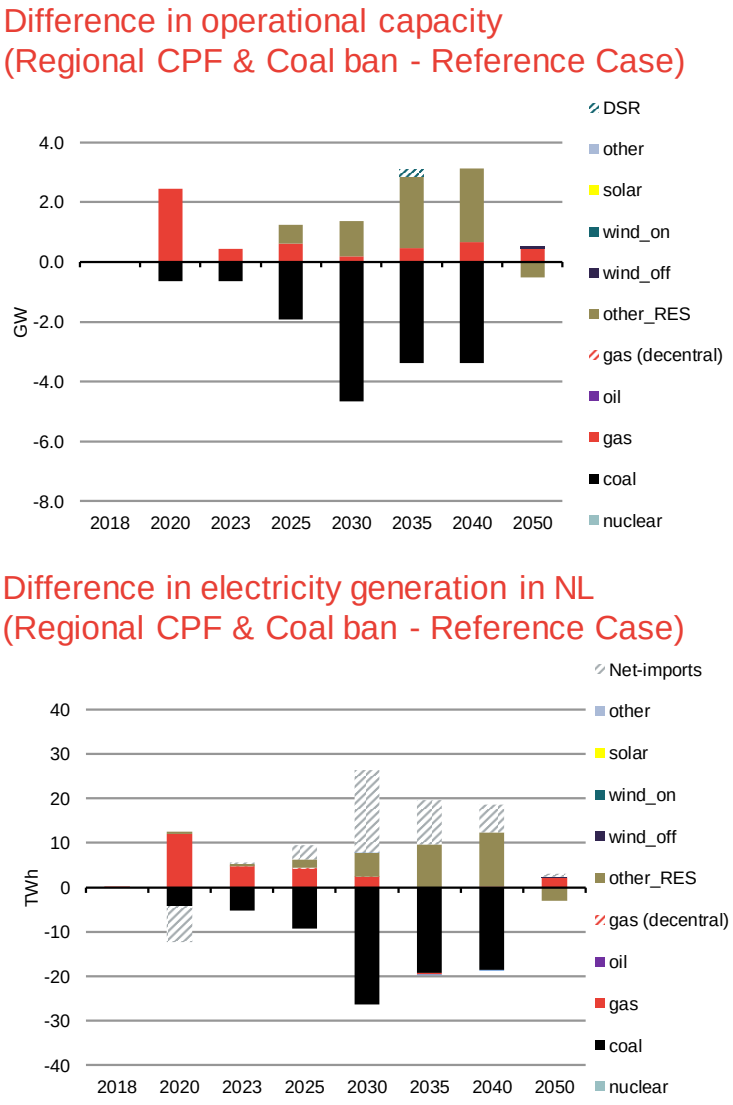
- lower net-exports;
- an earlier conversion of coal plants to biomass; and
- slightly higher gas-fired generation capacities, due to an earlier reactivation of mothballed capacities.

In 2050, there are only small differences in the power plant park compared to the Reference Case as the effect of the CPF fades out: it is assumed that the carbon price from the EU ETS is higher than the regional CPF after 2040.

Comparison with the national CPF and coal ban

The impact of the regional CPF differs from the impact of the national CPF: in a scenario with a national CPF (in combination with the coal ban), more domestic gas-fired generation capacities are closed or mothballed than in the case of a regional CPF (**Figure 22**). Closed or mothballed gas plants are largely replaced by electricity imports.

Figure 3 Impact on operational capacity and electricity supply in the Netherlands (compared to Reference Case)



Source: Frontier Economics

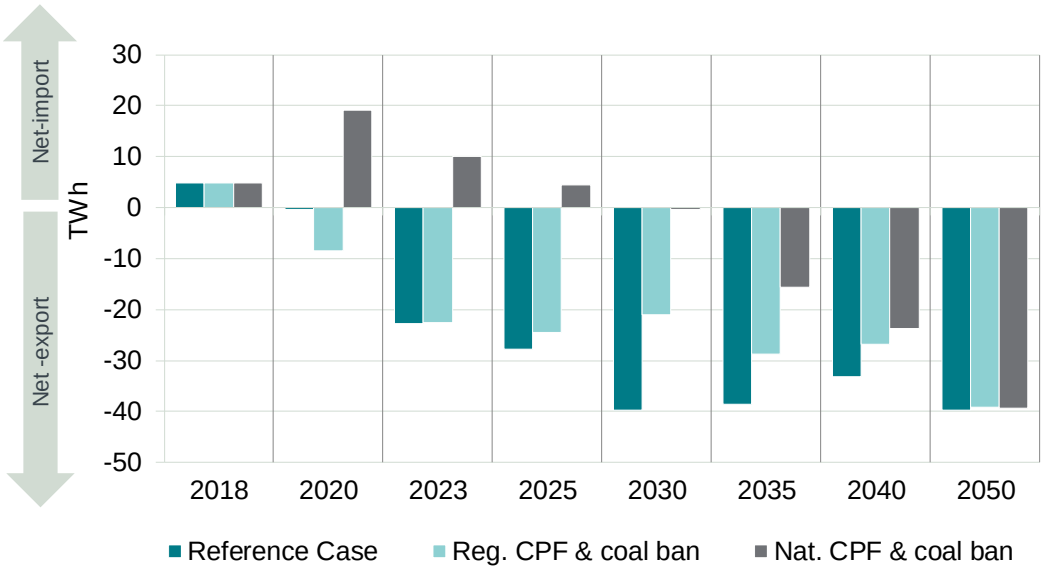
Impact on imports and exports from/to the Netherlands

In the scenario with a regional CPF and coal ban, The Netherlands export more electricity in 2020 than in the Reference Case and becomes a net-exporter (**Figure 4**). In the years from 2025 to 2040, Dutch exports are lower than in the Reference Case (-19 mn. tCO_2 in 2030).

Comparison with the national CPF and coal ban

The impact of a national CPF in combination with the coal ban differs: with a national CPF, the Netherlands are a net-importer in the modelling periods 2020 and 2025 and becomes a net-exporter from 2035 onwards.

Figure 4 Net-imports and exports to/from the Netherlands



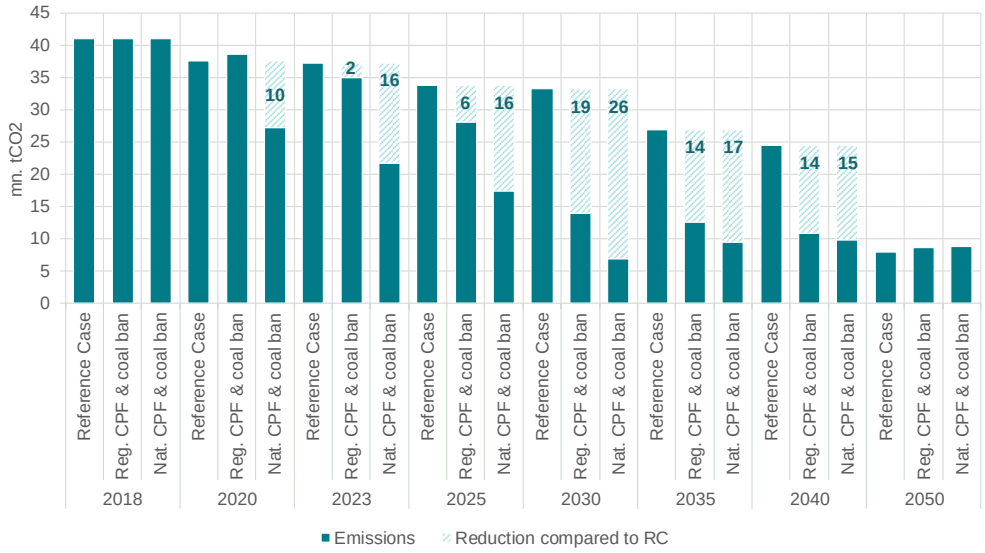
Source: Frontier Economics

Note: Positive values represent imports into the Netherlands and vice versa.

2.2.2 Power-related CO_2 emissions

The regional CPF in combination with the coal ban increases power-related CO_2 emissions in NL in the short-run (2020) slightly as the Netherlands generate and exports more electricity (**Figure 5**). There is a stronger reduction in emissions in the Netherlands between 2025 and 2040 than in the Reference Case as the coal ban takes effect. Emissions decrease by up to 19 mn. tCO_2 in 2030. CO_2 emissions accumulated between 2018 and 2030 are 11% lower than in the Reference Case.

Figure 5 Comparison of domestic power-related CO_2 emissions



Source: Frontier Economics

Note: Dashed area represents the difference to the Reference Case.

Emission reductions realised in the other countries which are subject to the regional CPF are higher than in the Netherlands, in particular between 2020 and 2025 (**Figure 6**). Emissions in the model-region[5] are reduced by up to 43 mn. tCO_2 in 2025.[6]

Comparison with the national CPF and coal ban

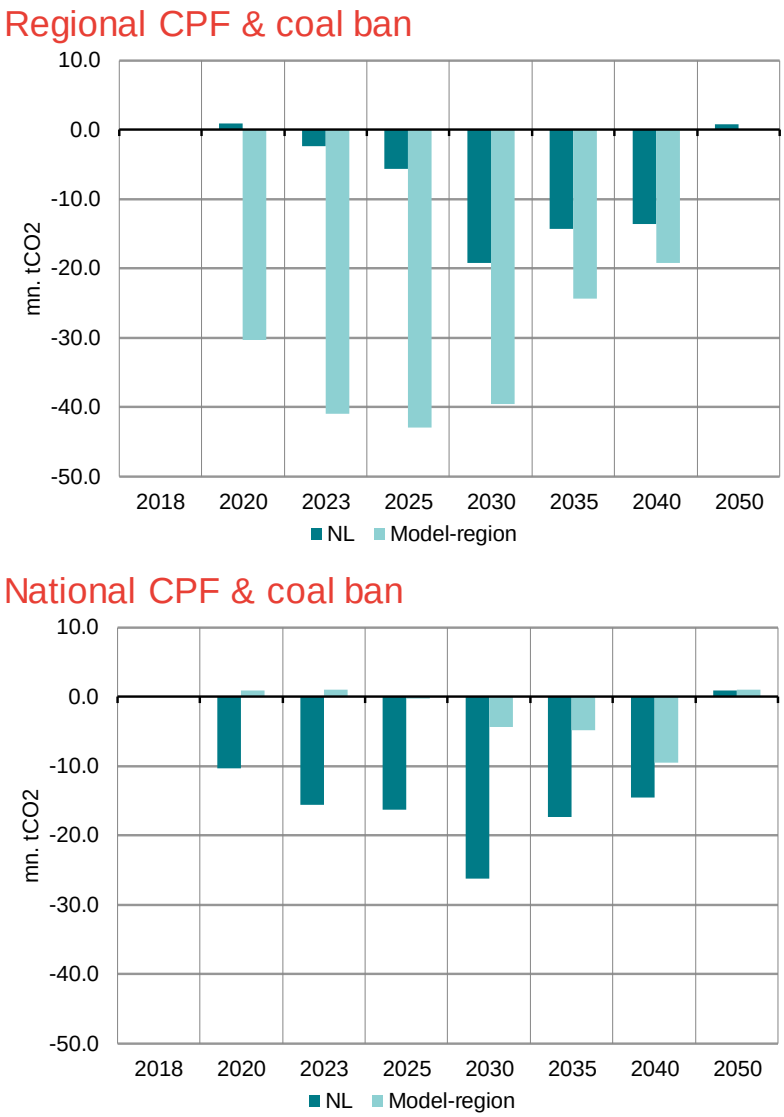
The national CPF in combination with the coal ban reduces domestic emissions to a higher extent than in the case of a regional CPF. Domestic CO_2 emissions are reduced by 10 mn. tCO_2 in 2020 and by up to 26 mn. tCO_2 in 2030.

However, the overall emission reduction in the model-region is significantly lower with a national CPF than with a regional CPF. As a result of the national CPF, Dutch gas generation is substituted by foreign generation from coal and gas. Therefore, emissions in the neighbouring countries are higher and the net-reduction in the modelled countries is smaller (-4 mn. tCO_2 in 2030). The regional CPF leads to an emission reduction in the model-region of almost 40 mn. tCO_2 in 2030.

[5] The Netherlands, Germany, France, Belgium, Great Britain, Italy, Austria, Switzerland, Denmark, Czech Republic, Poland.

[6] It has to be noted, that effects of the CPF on the EU ETS are not taken into account in the model: A regional/national CPF would free up allowances for CO_2 emissions in the EU ETS, and therefore CO_2 prices would be lower than without the CPF. Therefore, emissions in other countries and/or sectors increase respectively. This effect is not taken into account.

Figure 6 Impact on power-related CO_2 emissions in NL and model-region



Source: *Frontier Economics*
Note: *Effects on EU ETS not taken into account.*

2.2.3 Adequacy Reserve Margin (ARM) and imports in critical hours

In order to assess the impact of the policy measures on the capacity balance and the contribution of imports in scarce hours, we analyse:

- Adequacy Reserve Margins (ARM) (reliable capacity minus peak load), and
- The utilisation of import capacity and the contribution of imports to residual load in critical (highest residual load) hours.

Capacity margins and generation adequacy (ARM)

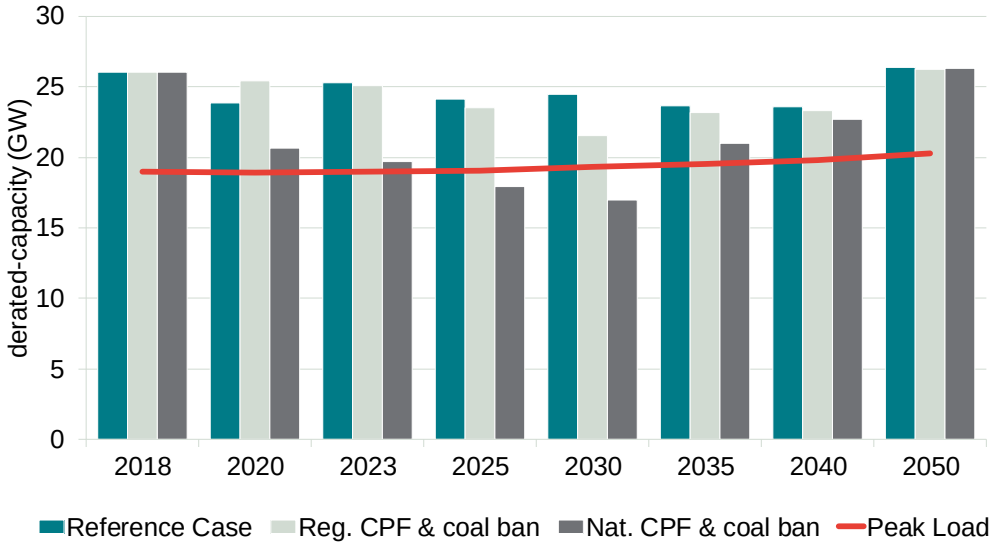
The adequacy reserve margin informs about the level of reliable capacity compared to peak load. It is calculated as the difference of the de-rated available capacity (incl. a share of reliable import capacity) and peak load. A negative ARM indicates that more import capacity is used than assumed to be available in the critical periods (we assume availability of 60% of IC capacity in the calculations[7]).

With the introduction of a regional CPF in combination with the coal ban, the ARM falls in the medium term, but remains positive for all model years (**Figure 7**). The ARM shows a decline in the years 2025 and 2030 as the coal ban takes effect, however still remains positive.

Comparison with the national CPF and coal ban

A national CPF in combination with the coal ban leads to lower ARM figures than the regional CPF, and reaches negative ARM values in 2025 and 2030. The national CPF leads to lower domestic generation capacities as a higher share of demand is served by imports.

Figure 7 Comparison of de-rated capacity and peak load per annum



Source: Frontier Economics

Note: De-rated capacity includes DSR and IC-capacity de-rated at 60%.

Interconnector utilisation and import contribution to residual load

We analyse the impact of the policy measures on the import of electricity to the Netherlands based on:

- the utilisation of import capacity over the year and in critical hours; and
- the share of residual load in critical peak hours that is served by imports.

[7] We de-rate import capacity with 60%. For more information see report "Research on the effects of the minimum CO_2 price" for the Ministry of Economic Affairs and Climate Policy (2018).

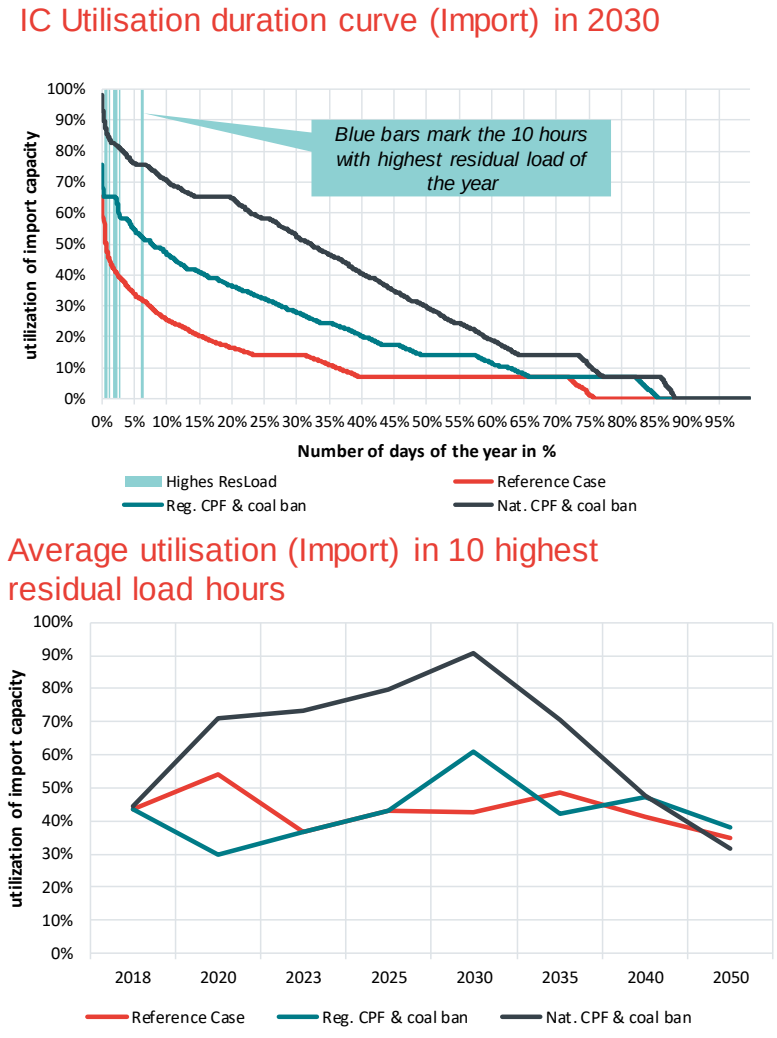
It is important to note that the hourly interconnector flows are an outcome of the economically optimised dispatch of power plants in the Netherlands and the neighbouring countries. Increasing imports indicate that electricity in other countries is less costly than in the Netherlands.

The regional CPF in combination with the coal ban increases the utilization compared to the Reference Case. While there is a lower average utilisation of import capacity in critical hours in 2020, the utilisation is higher in 2030 and 2040 (**Figure 8**).

Comparison with the national CPF and coal ban

The introduction of a national CPF in combination with a coal ban leads to higher utilisation figures, which reach up to 90% in 2030. The national CPF leads to a lower provision of domestic generation capacities as a higher share of demand is served by imports, so that the IC utilisation is higher.

Figure 8 Utilisation of import capacity



Source: *Frontier Economics*

Note: *Residual load = load – wind infeed – solar infeed – CHP must run;*
The figure shows the utilization of the import capacity relative to the physically existing capacity.

2.2.4 Mothballing and economics of CCGTs

The economics of gas-fired power plants depend on the costs of the plant and the power prices achievable on the market. In the following we analyse:

- Possible running hours of an exemplary CCGT and contribution margins from day-ahead operation; and
- The mothballing and reactivation of gas-fired generation in the policy scenarios.

The model optimises mothballing and reactivation subject to the assumed cost savings and additional investment necessary to reactivate a plant after mothballing from a system cost perspective.

Impact on profitability of CCGTs

The graph below shows the contribution margin[8] of an exemplary CCGT and the number of hours, in which this plant realises a positive spread (price minus variable costs) when operating.[9]

The regional CPF in combination with the coal ban increases the profitability of gas-fired power plants in comparison with the Reference Case (**Figure 9**). While the CPF increases the variable generation costs of gas-fired plants, the scarcity induced by the regional CPF compensates for this: higher power prices in the region and more exports from the Netherlands in the short-run lead to a higher profitability.

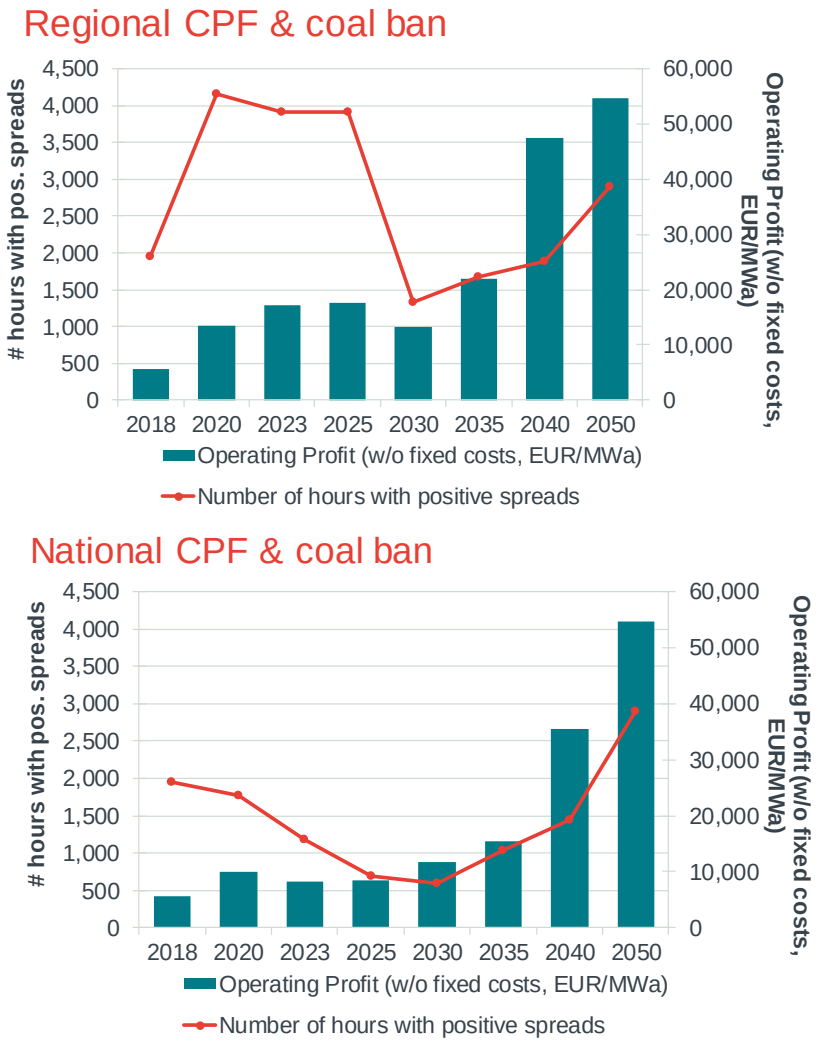
Comparison with the national CPF and coal ban

The regional CPF leads to consistently higher contribution margins of gas-fired power plants than the national CPF (both in combination with the coal ban). The national CPF leads to a lower contribution margin since foreign thermal power plants are not subject to the CPF and thus do not face higher generation costs.

[8] (Price - variable costs) * running hours

[9] Technical constraints like minimum load condition or ramping are not taken into account.

Figure 9 Running hours and operating profit



Source: Frontier Economics

Mothballing and reactivation

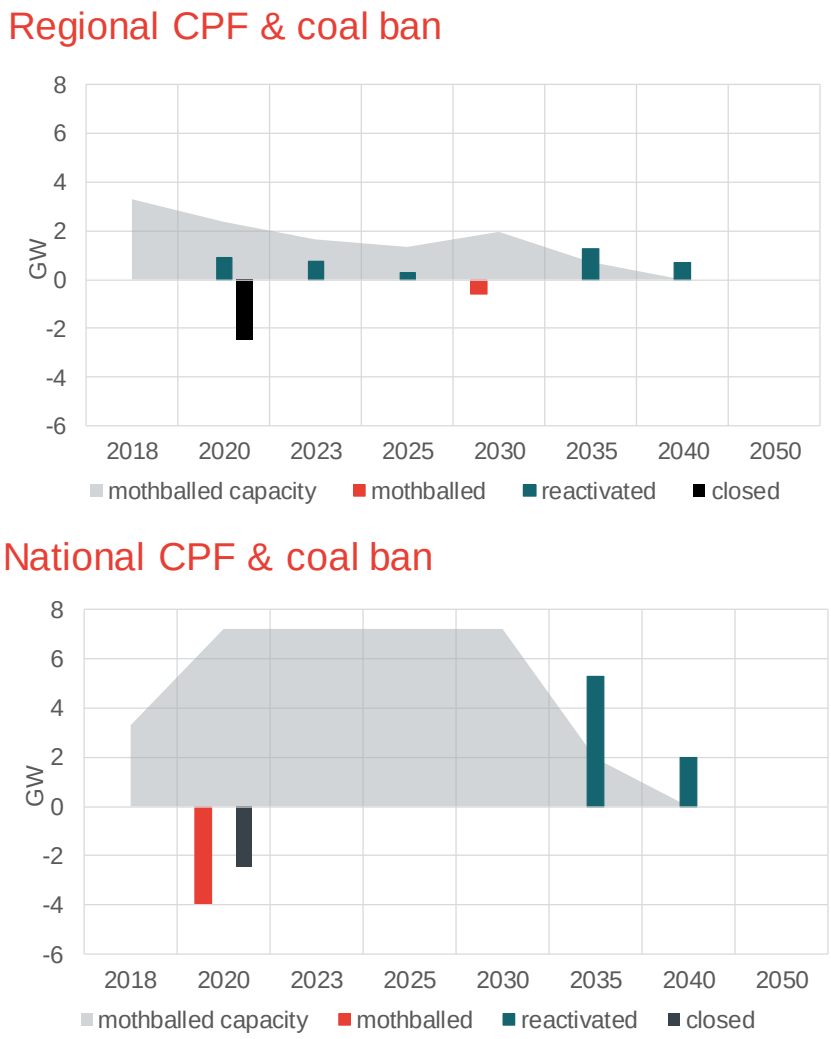
In the following, we summarise the impact of the policy measures on the economics of CCGTs by analysing the mothballing and reactivation of plants in the policy scenarios.

The positive impact on the profitability of gas-fired power-plants in the short-run is reflected in the development of reactivated capacity. While the same amount of capacity is closed in 2020 as in the Reference Case, more capacity is reactivated in the years between 2020 and 2025 compared with the Reference Case (**Figure 10**). The level of mothballed capacity from 2030 onwards is similar to the level in the Reference Case.

Comparison with the national CPF and coal ban

The contribution margins of CCGTs in the Netherlands are higher under the regional CPF than under the national CPF (both with a coal ban). The regional CPF also leads to less mothballing and earlier reactivations.

Figure 10 Mothballing and reactivation

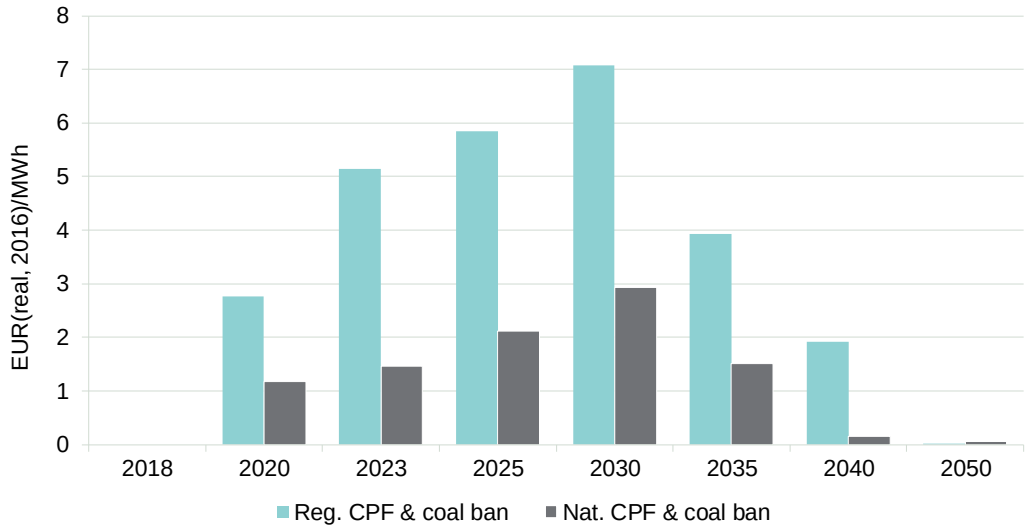


Source: Frontier Economics

2.2.5 Power prices

The regional CPF in combination with the coal ban increases power prices by up to 7 €/MWh in 2030 compared to the Reference Case (**Figure 11**). The increase in power prices is stronger than with the national CPF (+2.9 €/MWh in 2030) as the increase in generation costs also affects the neighbouring countries: with a regional CPF there is less scope to substitute domestic generation by cheaper foreign generation.

Figure 11 Impact on power prices



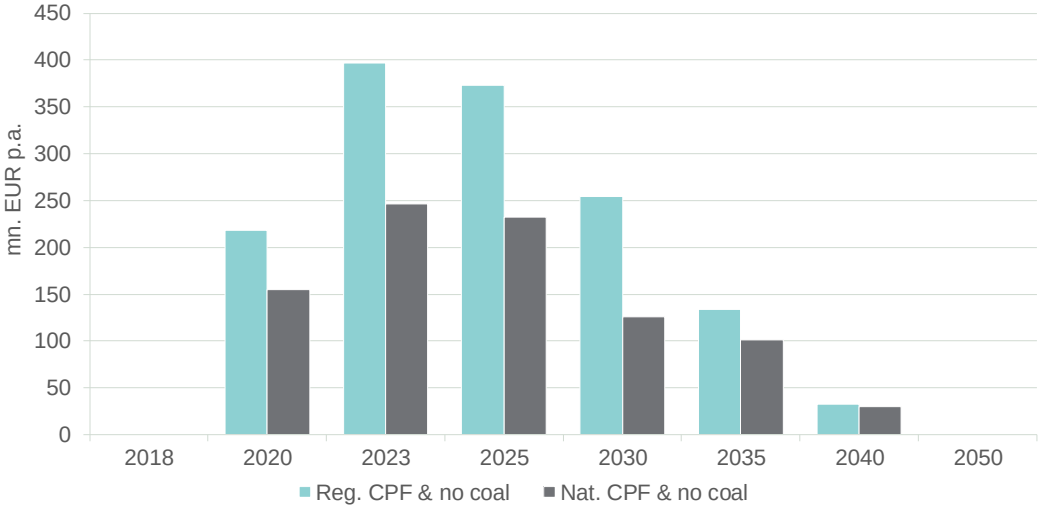
Source: *Frontier Economics*
Note: *All values expressed in real terms (base year 2016).*

2.2.6 State income

The introduction of a CPF generates additional income for the Dutch state. The state income is defined by the annual domestic emissions multiplied with the difference between the CPF and the EU ETS price.[10]

The regional CPF in combination with the coal ban generates up to 397 mn. EUR p.a. additional state income (in 2030, **Figure 12**). The Dutch state income is higher with a regional CPF than with a national CPF (both in combination with the coal ban), because less domestic generation is replaced by imports.

Figure 12 Dutch state income from CPF



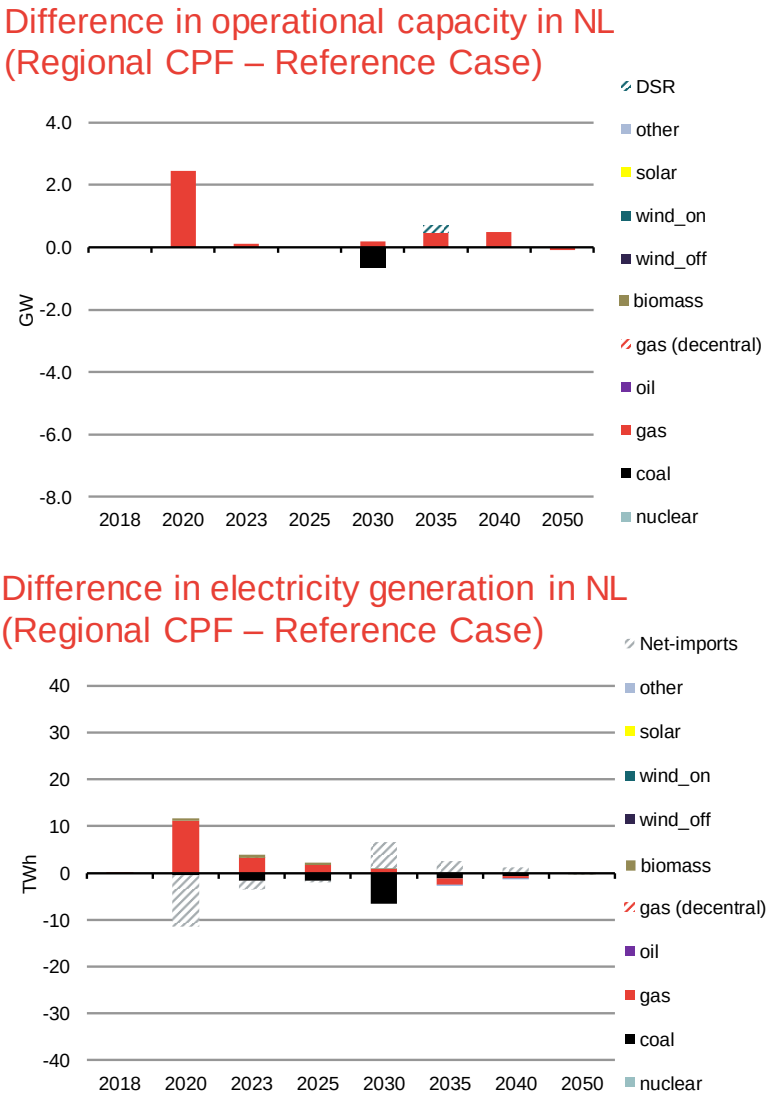
Source: *Frontier Economics*
Note: *All values expressed in real terms (base year 2016).*

[10] The calculation does not take taxes or macroeconomic effects into account.

ANNEX A REGIONAL CPF AS AN ISOLATED MEASURE

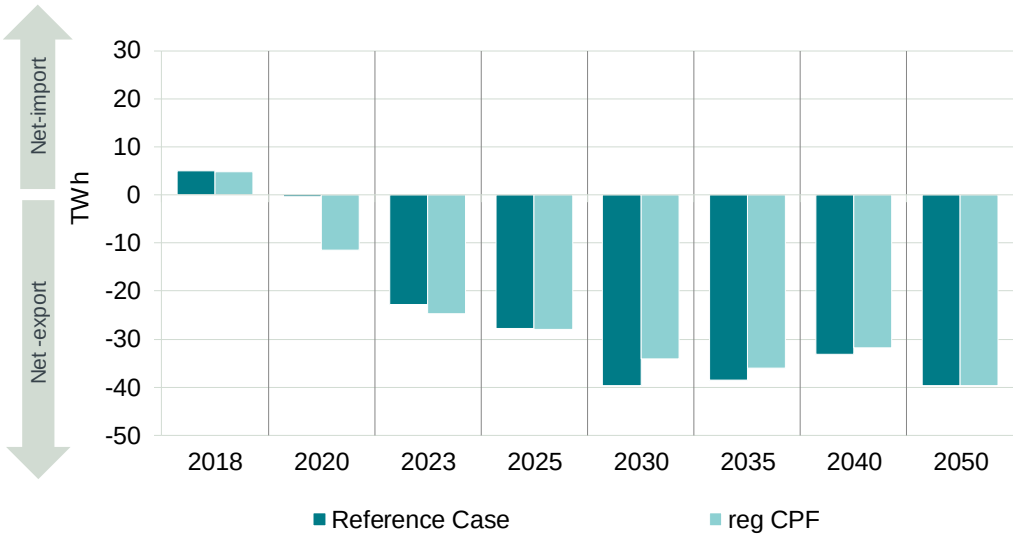
In the following we present the results for the scenario of a regional CPF as an isolated measure.

Figure 13 Regional CPF – Impact on operational capacity and electricity supply in the Netherlands



Source: Frontier Economics

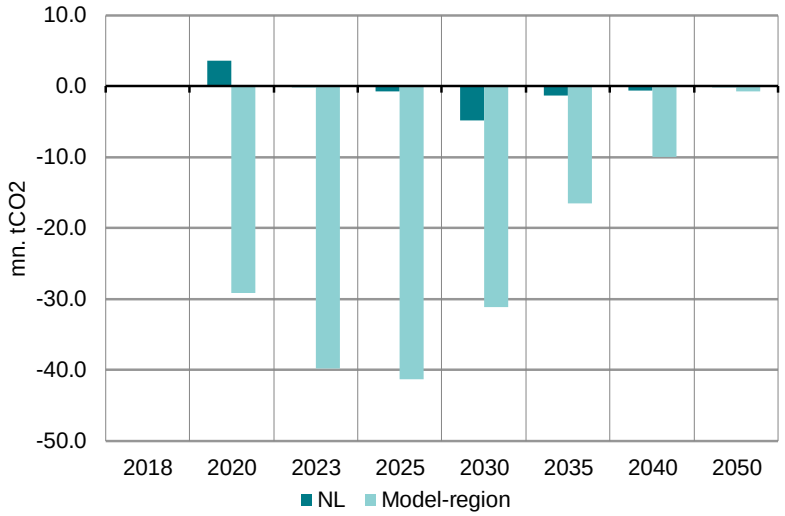
Figure 14 Regional CPF – Net-imports and exports to/from the Netherlands



Source: Frontier Economics

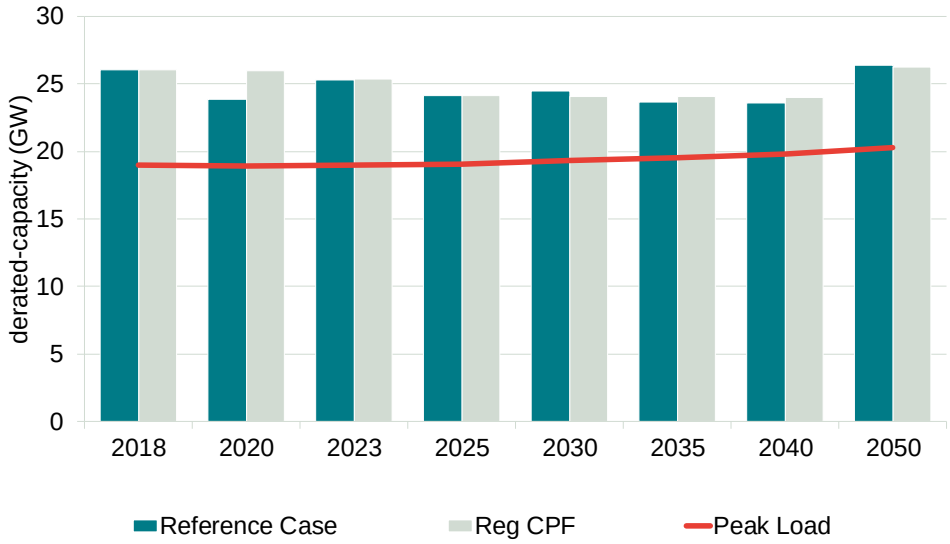
Note: Positive values represent imports into the Netherlands and vice versa.

Figure 15 Regional CPF – Impact on emissions in NL and in model-region



Source: Frontier Economics

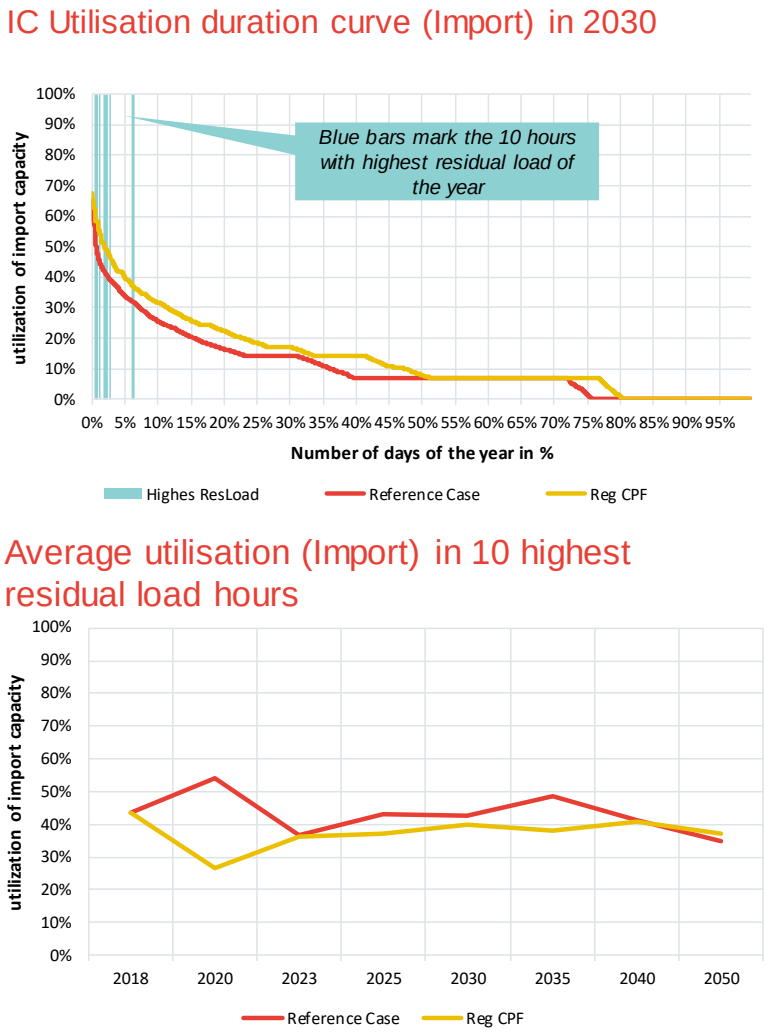
Figure 16 Regional CPF – Comparison of de-rated capacity and peak load per annum



Source: *Frontier Economics*

Note: *De-rated capacity includes DSR and IC-capacity de-rated at 60%.*

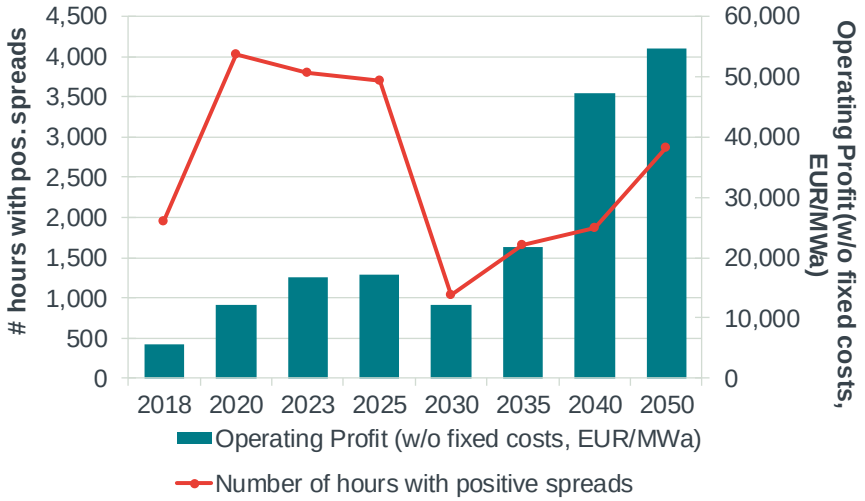
Figure 17 Regional CPF – Utilisation of import capacity



Source: *Frontier Economics*

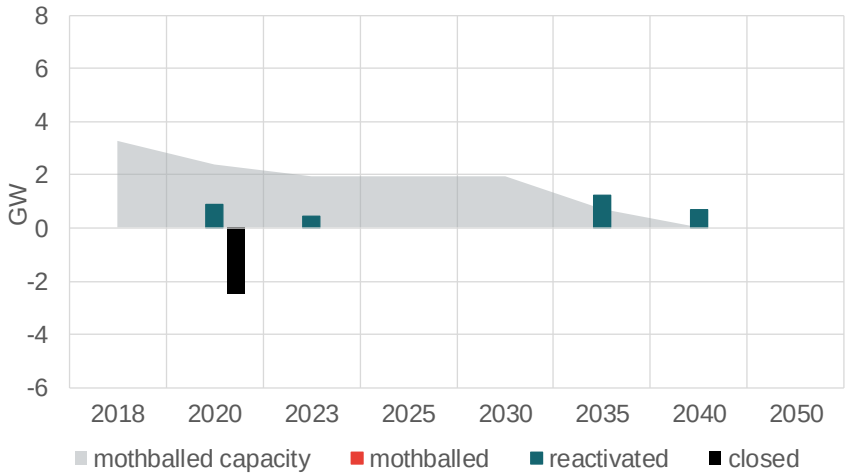
Note: *Residual load = load – wind infeed – solar infeed – CHP must run;*
The figure shows the utilization of the import capacity relative to the physically existing capacity.

Figure 18 Regional CPF – Running hours and operating profit



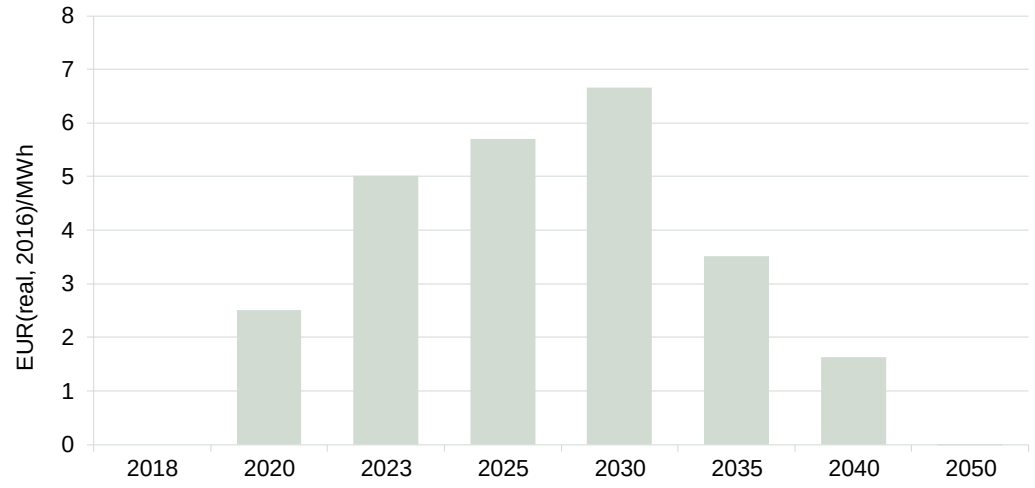
Source: Frontier Economics

Figure 19 Regional CPF – Mothballing and reactivation



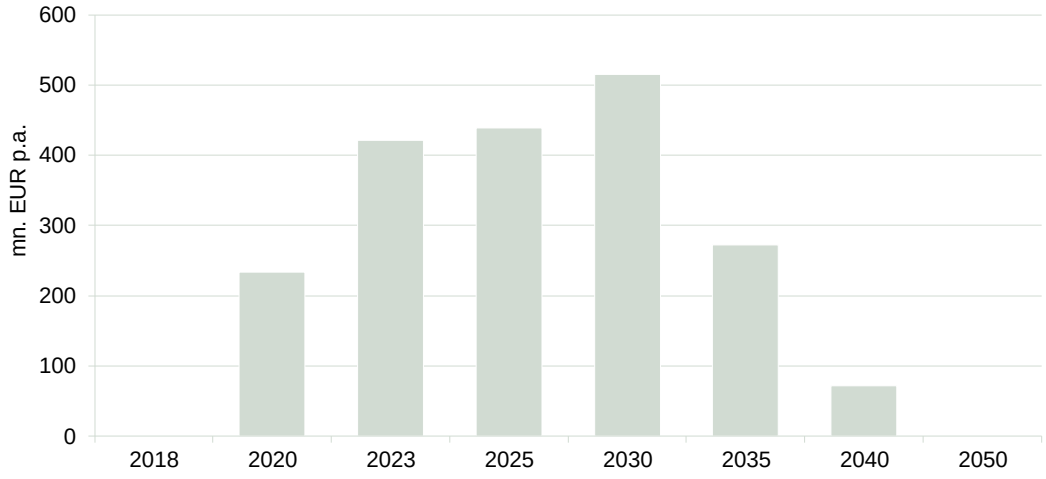
Source: Frontier Economics

Figure 20 Regional CPF – Impact on power prices



Source: Frontier Economics
Note: All values expressed in real terms (base year 2016).

Figure 21 Regional CPF – Dutch state income from CPF

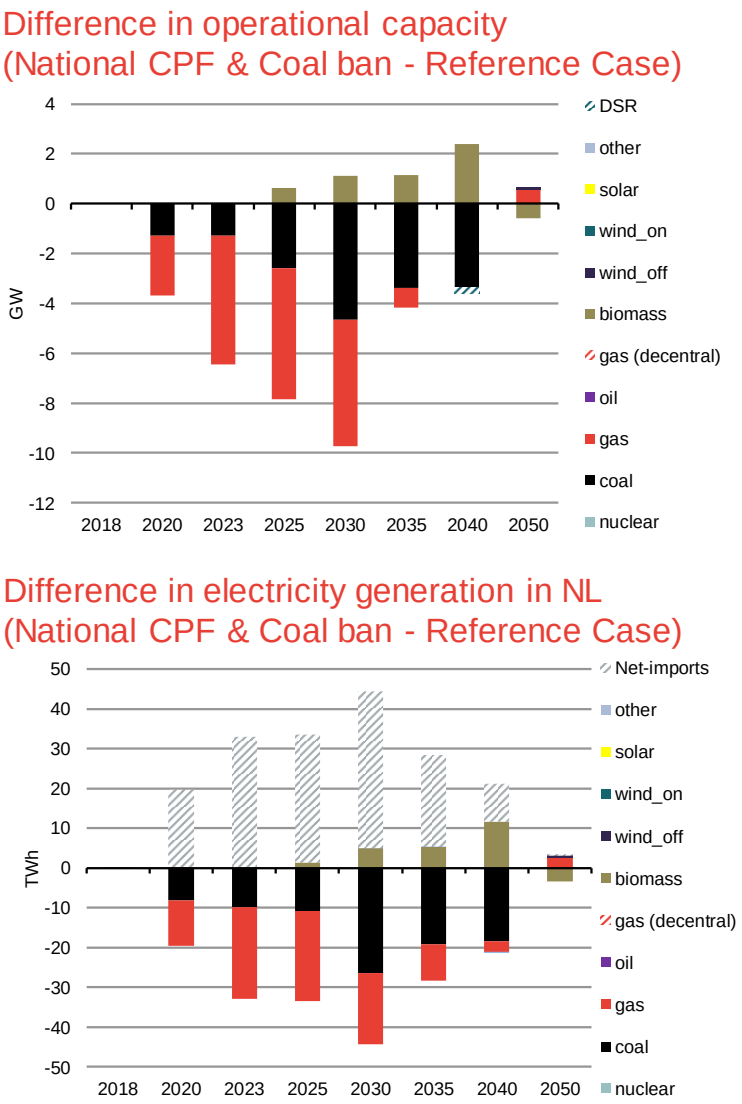


Source: Frontier Economics

ANNEX B NATIONAL CPF IN COMBINATION WITH THE COAL BAN

Figure 22 shows the impact of a regional CPF as an isolated measure on operational capacity and electricity supply. The results for all other indicators are provided in **Section 2.2** of this report.

Figure 22 National CPF & Coal ban – Impact on operational capacity and electricity supply in the Netherlands



Source: Frontier Economics

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