Where to place PtX plants in the Nordic bidding zones
Example of analyses that can be done with PMS

Flemming Nissen

Strategirummet

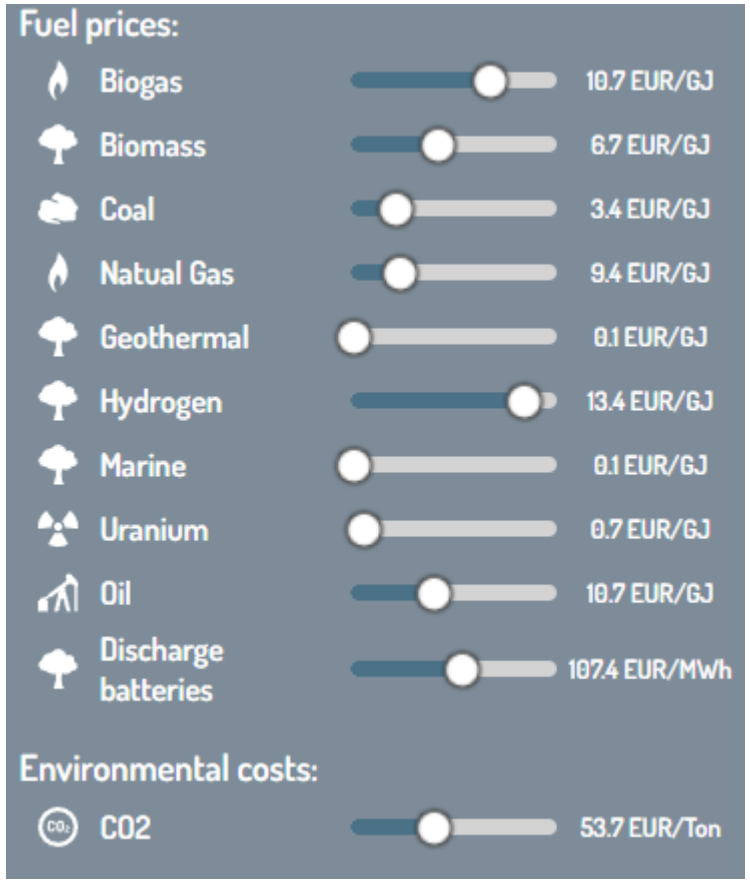
Purpose

- You will see how PMS can be used to create a preliminary project regarding the locations of PtX plants in the Nordic region
- The analysis will show the socio-economic and corporate economics of placing PtX plants in different bid zones
- This type of preliminary project will improve the ability to define the actual project, involving analysis companies that have advanced energy system models

The Preliminary Project

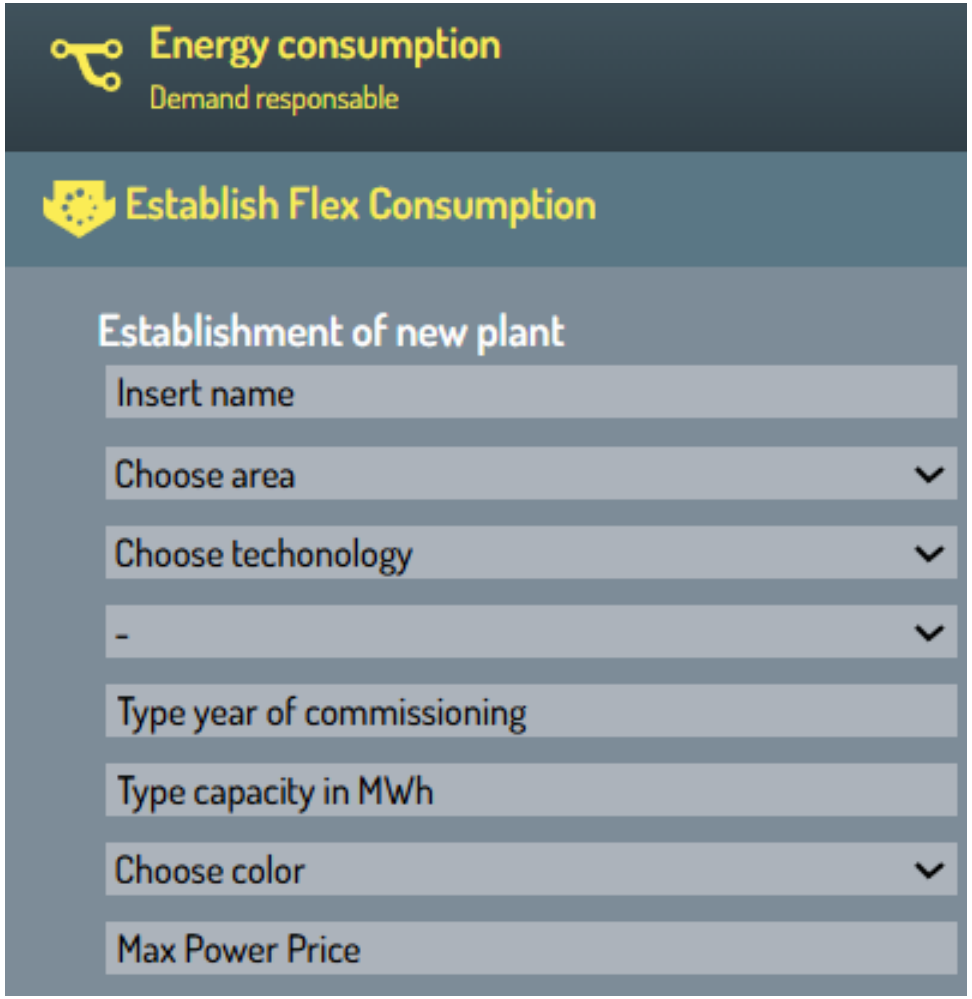
- Insert a PtX plant in different price zones in the Nordic market area and calculate revenues for the plant as well as societal benefits and costs
- PMS-scenario is used for the analysis
- Data input comes from the general database to the PMS

Data for fuel prices and CO_2-quota prices

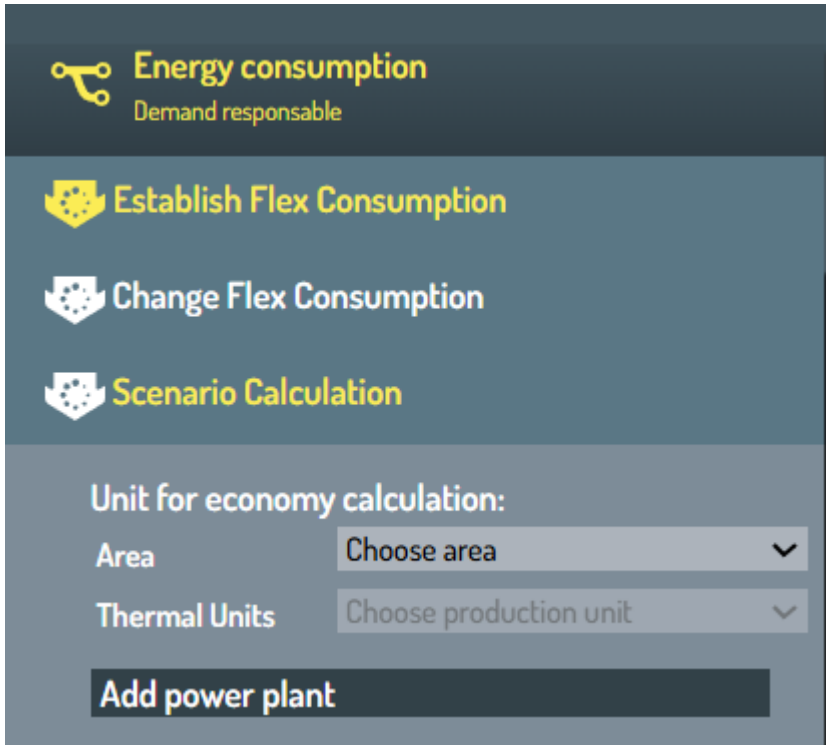


Can be easily changed by the user

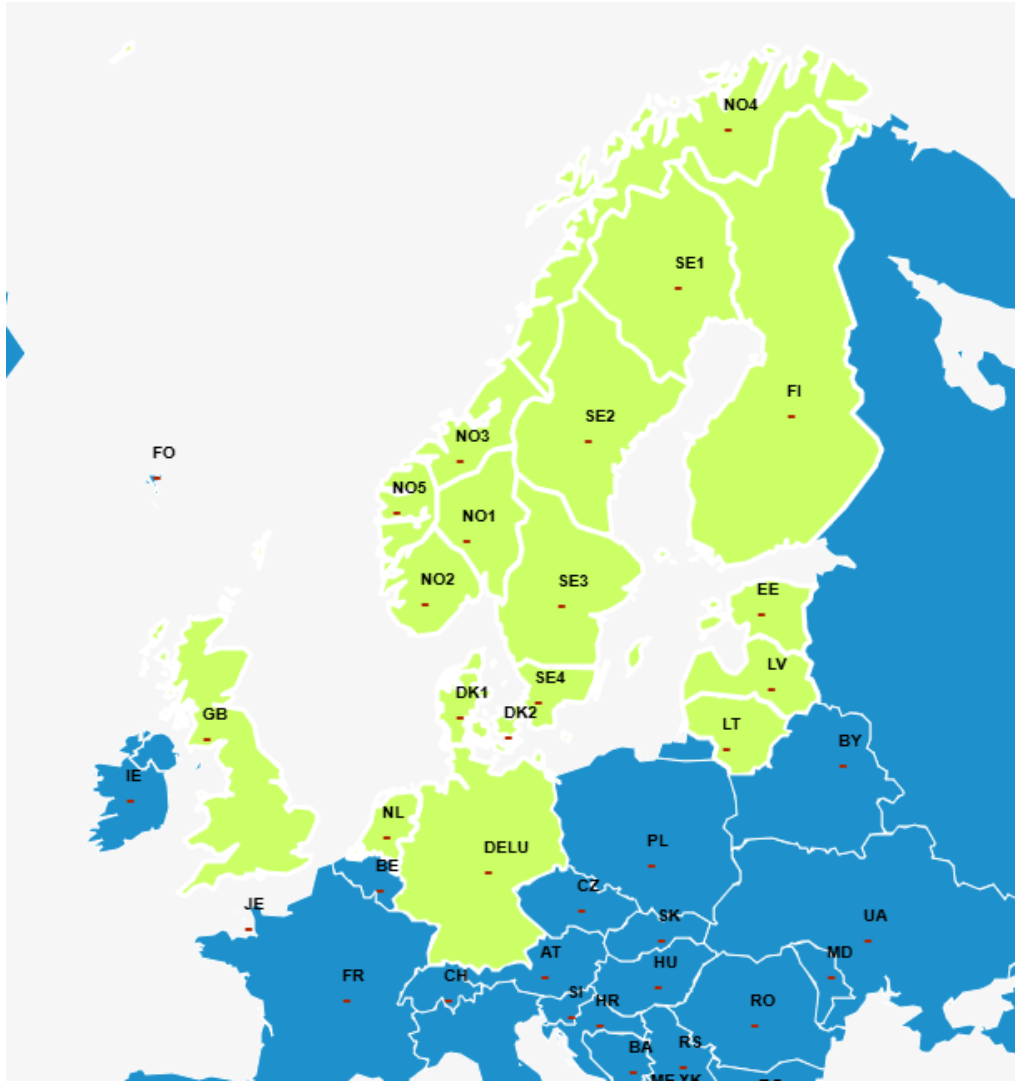
The PtX plants are build here



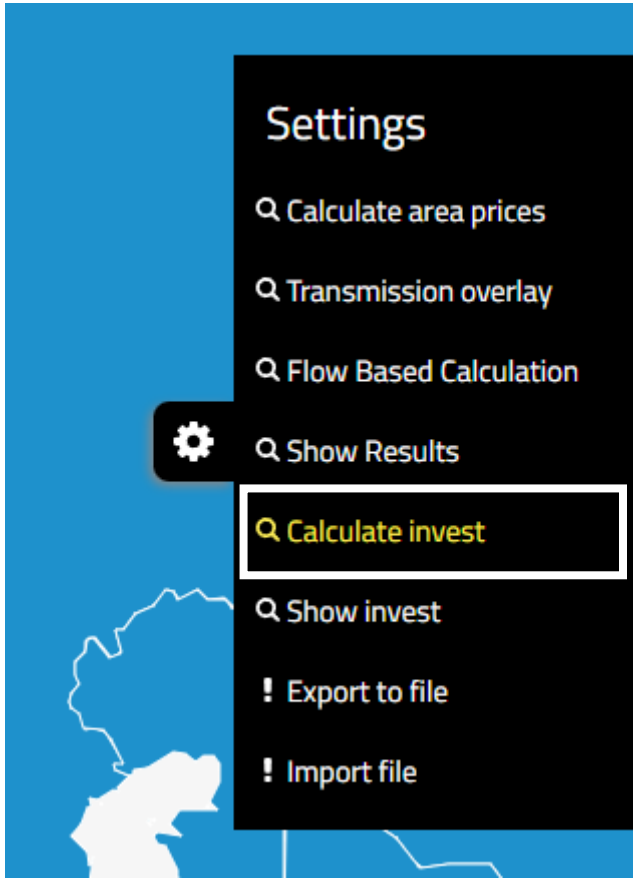
The flexible electricity consumption plants for which we will calculate contribution margins are inserted here



The areas included in the calculation are shown here



The scenario calculation starts here



Calculation assumptions

- We analyze the period 2025 – 3035
- There will in turns be installed 4,000 MW electrolysis plants in a price area in each of the Nordic countries
- The plants are commissioned year 2030
- The maximum price for buying electricity for the electrolysis plant is 40 euro per MWh
- The model only builds power generation plants
- Existing and planned flexible consumption plants are included in the calculation
- The earnings of the PTX plant are calculated as the difference between the KIP price and the electricity market price. The plant is only in operation when the electricity price is below the KIP price

Data used to calculate annual interest costs, repayments and fixed operating costs

AEC-unit		
Capacity (Power)	100	MW
Specific investment	550	euro/kW(Power)
Fixed O&M	4	% of investment per year
Lifetime	25	years
Interest	7	% per year
Interest and repayments	4.719.578	euro
Fixed O&M	2.200.000	euro
Total yealy costs	6.919.578	euro

Total yearly fixed cost for a 4.000 MW unit: 276 mill. euros

Apart from the interest rate, all data comes from the Danish Energy Agency's technology catalogue

We need more debate

- There will certainly be some who believe that other input data should be used for the model, and that this will change the conclusion of the analysis
- That is correct, the analysis could be improved by many others participating with their ideas for the future
- This fits well with the purpose of Power Market Simulator, which is to create a commonly available modeling tool that can be used to increase the debate about how we develop the energy system of the future.

Results for PtX plant in DK1 for the total calculation area

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Without PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total C02 discharge	1,114

With PtX

Total production costs	151,003
Total production surplus	399,978
Total consumption surplus	37,504,555
Total transmission surplus	47,015
Total societal surplus	37,951,548
Interest and payback of investments in new plants	45,232
Social profit minus investments in new plants	37,906,316
Total C02 discharge	1,114
Total profit for :PtX (DK1)	914,087,718

Results for PtX plant in DK1 for the Denmark

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Without PtX

Total production costs	2,734
Total production surplus	17,423
Total consumption surplus	1,299,769
Total transmission surplus	10,692
Total societal surplus	1,327,884
Interest and payback of investments in new plants	1,999
Social profit minus investments in new plants	1,325,884
Total CO2 discharge	0

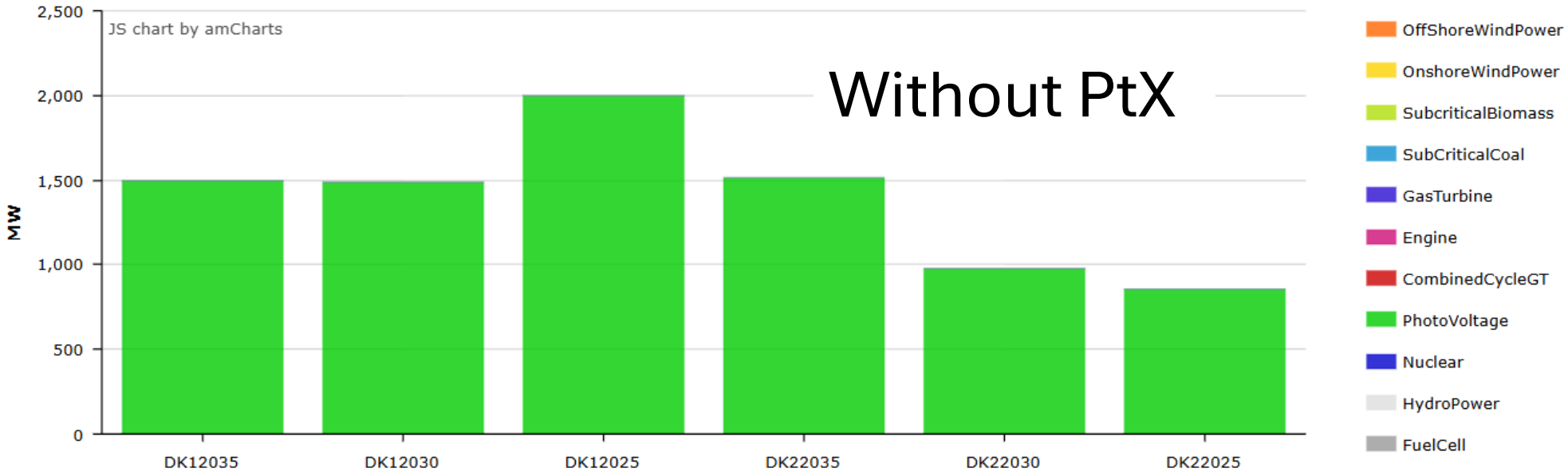
With PtX

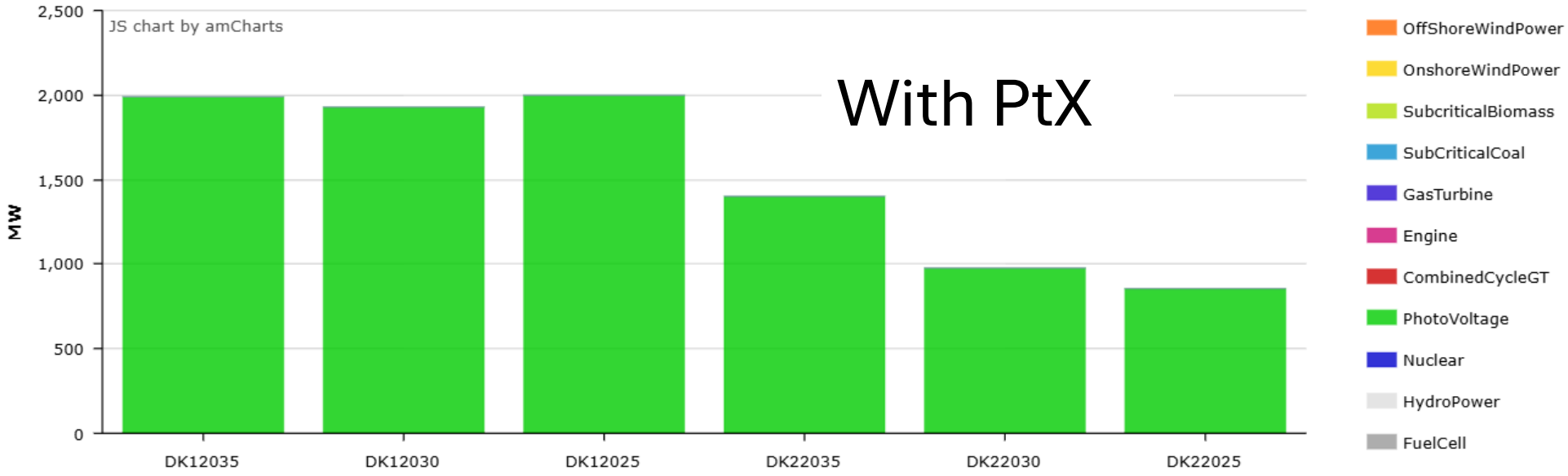
Total production costs	2,732
Total production surplus	17,530
Total consumption surplus	1,299,806
Total transmission surplus	10,689
Total societal surplus	1,328,025
Interest and payback of investments in new plants	2,108
Social profit minus investments in new plants	1,325,917
Total CO2 discharge	0
Total profit for :PtX (	914,087,718

Minus investment in PtX: 1.325.641

Fixed cost for PtX for the period: 1.400.000.000 euro

Expansion with new power units according to the model





What can be deduced from the partial analysis?

- There is room in terms of power to establish 4,000 MW PtX plants in DK1 without having to expand with more power production plants
- There will only be a little more investment in solar cells in DK1 after 2030, when PtX plants are established
- The profit from production at the PtX plant cannot finance the fixed annual costs of the plant
- The PtX plant reduces societal surpluses by 243 mill. euros in the period

Sensitivity analysis regarding the maximum electricity price the electrolysis plants will buy electricity at

- To investigate the importance of the maximum purchase price for the electrolysis plants, we repeat the analysis with a KIP-price of 30 and 50 euros
- Higher KIP prices mean that consumers are willing to pay more for green hydrogen

Result of sensitivity calculation

KIP price for hydrogen production: 30 euro/MWh

Total production costs	2,732
Total production surplus	17,530
Total consumption surplus	1,299,806
Total transmission surplus	10,689
Total societal surplus	1,328,025
Interest and payback of investments in new plants	2,108
Social profit minus investments in new plants	1,325,917
Total CO2 discharge	0
Total profit for :PtX (DK1)	666,227,718

KIP price for hydrogen production: 40 euro/MWh

Total production costs	2,732
Total production surplus	17,530
Total consumption surplus	1,299,806
Total transmission surplus	10,689
Total societal surplus	1,328,025
Interest and payback of investments in new plants	2,108
Social profit minus investments in new plants	1,325,917
Total CO2 discharge	0
Total profit for :PtX (DK1)	914,087,718

KIP price for hydrogen production: 50 euro/MWh

Total production costs	2,732
Total production surplus	17,530
Total consumption surplus	1,299,806
Total transmission surplus	10,689
Total societal surplus	1,328,025
Interest and payback of investments in new plants	2,108
Social profit minus investments in new plants	1,325,917
Total CO2 discharge	0
Total profit for :PtX (DK1)	2,037,261,141

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

What can be deduced from the sensitivity analysis?

- The earnings of the PTX plant increase when the KIP price increases. This is logical because the earnings are calculated as the difference between the KIP price and the electricity market price
- With a KIP price of 50 euros per MWh of electricity, it becomes economical to invest in the PtX plant

Results for PtX plant in NO1 for the total calculation area

Without PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total C02 discharge	1,114

With PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total C02 discharge	1,114
Total profit for :PtX (NO1)	6,582,023,944

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Results for PtX plant in NO1 for NO1

Without PtX

Total production costs	172
Total production surplus	7,560
Total consumption surplus	1,351,431
Total transmission surplus	827
Total societal surplus	1,359,819
Interest and payback of investments in new plants	0
Social profit minus investments in new plants	1,359,819
Total CO2 discharge	0

With PtX

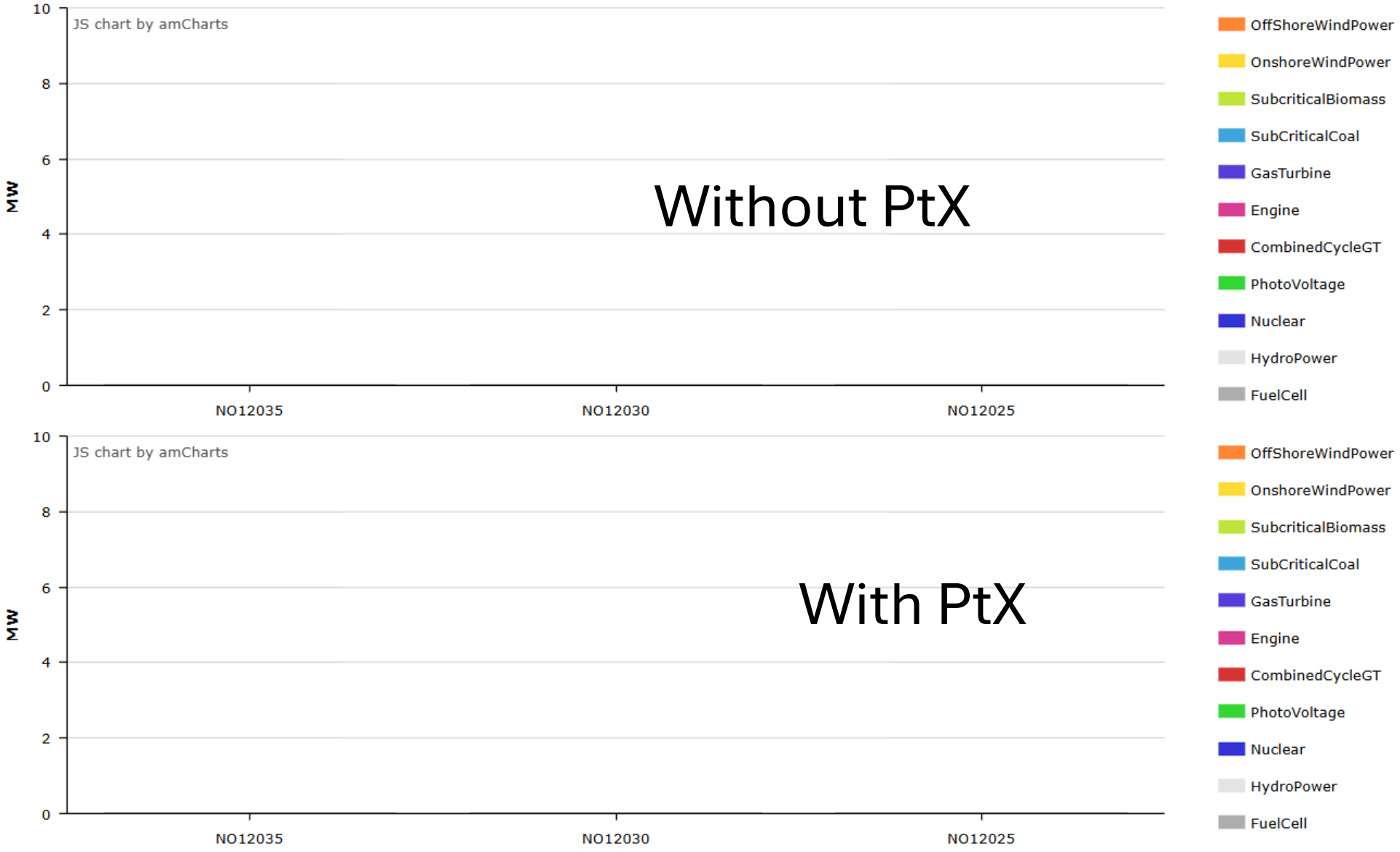
Total production costs	172
Total production surplus	7,560
Total consumption surplus	1,351,431
Total transmission surplus	827
Total societal surplus	1,359,819
Interest and payback of investments in new plants	0
Social profit minus investments in new plants	1,359,819
Total CO2 discharge	0
Total profit for :PtX (NO1)	6,582,023,944

Minus investment in PtX: 1.359.543

Fixed cost for PtX for the period: 1.400.000.000 euro

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Expansion with new power units according to the model



What can be deduced from the partial analysis?

- There is room in terms of power to establish 4,000 MW PtX plants in NO1 without having to expand with more power production plants
- The profit from production at the PtX plant can finance the total fixed annual costs of the plant
- The PtX plant reduces societal surpluses by 276 mill. euros in the periode

Results for PtX plant in SE2 for the total calculation area

Without PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total CO2 discharge	1,114

With PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total CO2 discharge	1,114
Total profit for :PtX (SE2)	7,334,802,065

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Results for PtX plant in SE2 for SE2

Without PtX

Total production costs
534
Total production surplus
7,944
Total consumption surplus
594,164
Total transmission surplus
984
Total societal surplus
603,091
Interest and payback of investments in new plants
0
Social profit minus investments in new plants
603,091
Total CO2 discharge
0

With PtX

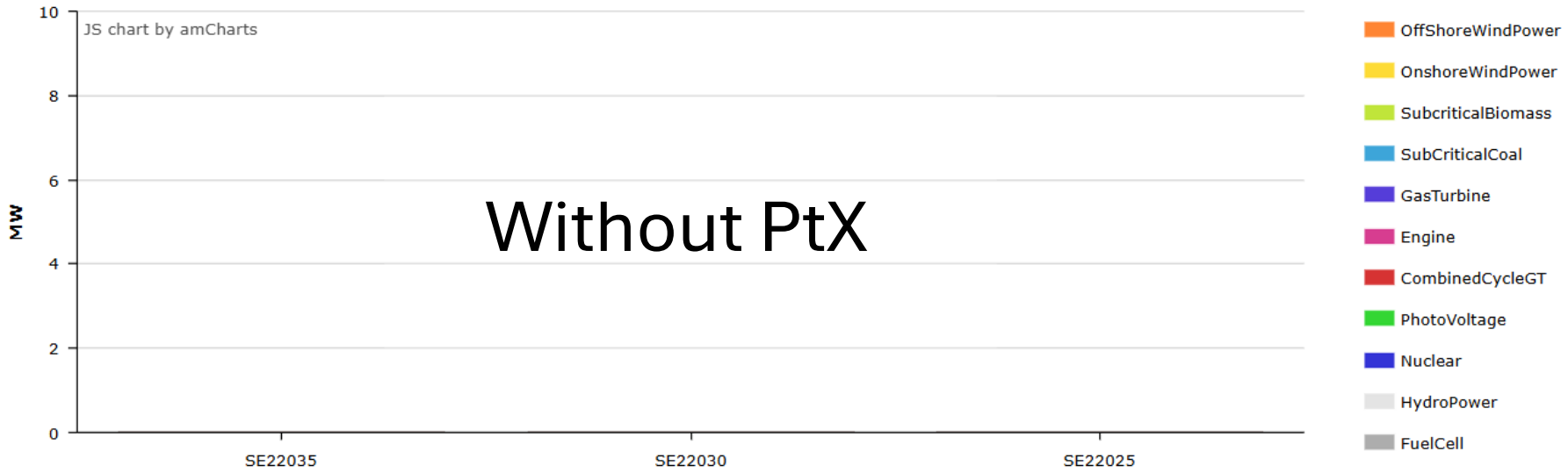
Total production costs
534
Total production surplus
7,944
Total consumption surplus
594,164
Total transmission surplus
984
Total societal surplus
603,091
Interest and payback of investments in new plants
0
Social profit minus investments in new plants
603,091
Total CO2 discharge
0
Total profit for :PtX (S
7,334,802,065

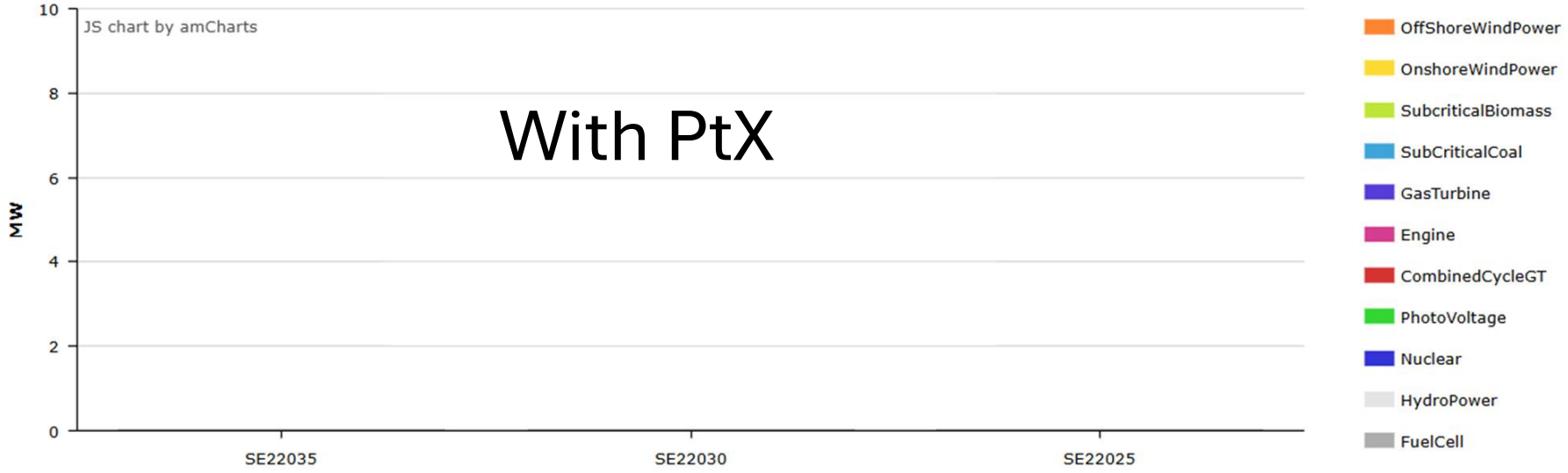
Minus investment in PtX: 602.815 mill. euros

Fixed cost for PtX for the period: 1.400.000.000 euro

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Expansion with new power units according to the model





What can be deduced from the partial analysis?

- There is room in terms of power to establish 4,000 MW PtX plants in SE2 without having to expand with more power production plants
- The profit from production at the PtX plant can finance the total fixed annual costs of the plant
- The PtX plant reduces societal surpluses by 276 mill. euros in the period

Sensitivity analysis regarding the deployment of additional PtX capacity in SE2

- To investigate whether there is room for additional PtX capacity in SE2, a new calculation is made, where the electrolysis capacity is increased to 10,000 MW

Results for 10,000 MW PtX plant in SE2 for the total calculation area

Without PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total C02 discharge	1,114

With PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total C02 discharge	1,114
Total profit for :PtX (SE2)	18,337,005,163

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Results for 7,000 MW PtX plant in SE2 for SE2

Without PtX

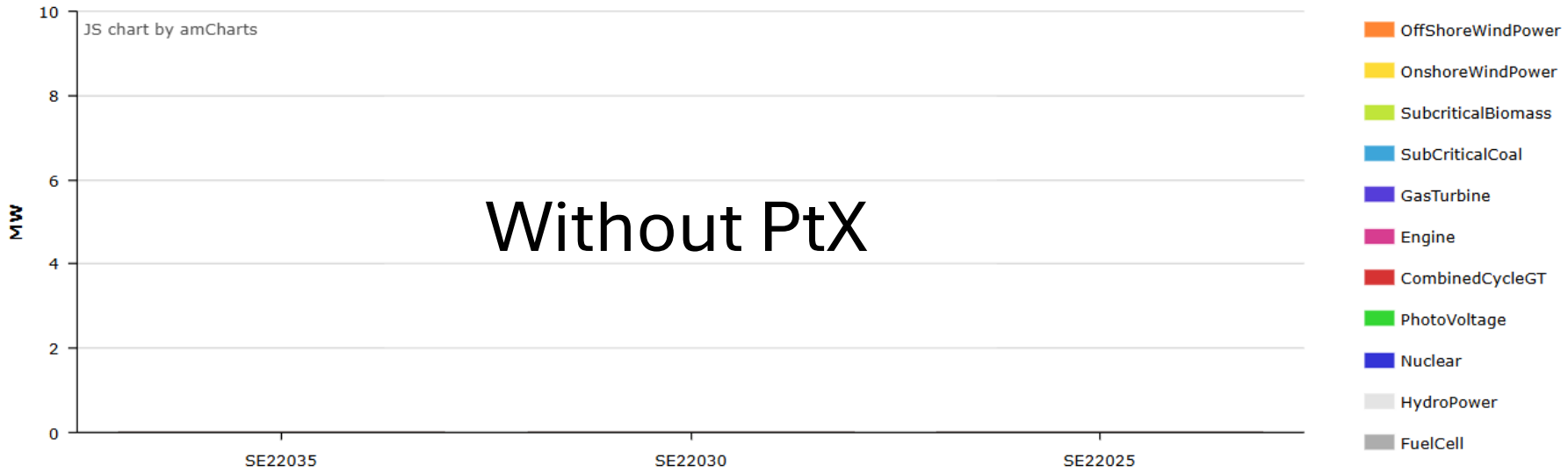
Total production costs	593
Total production surplus	9,747
Total consumption surplus	587,452
Total transmission surplus	1,650
Total societal surplus	598,849
Interest and payback of investments in new plants	0
Social profit minus investments in new plants	598,849
Total C02 discharge	0

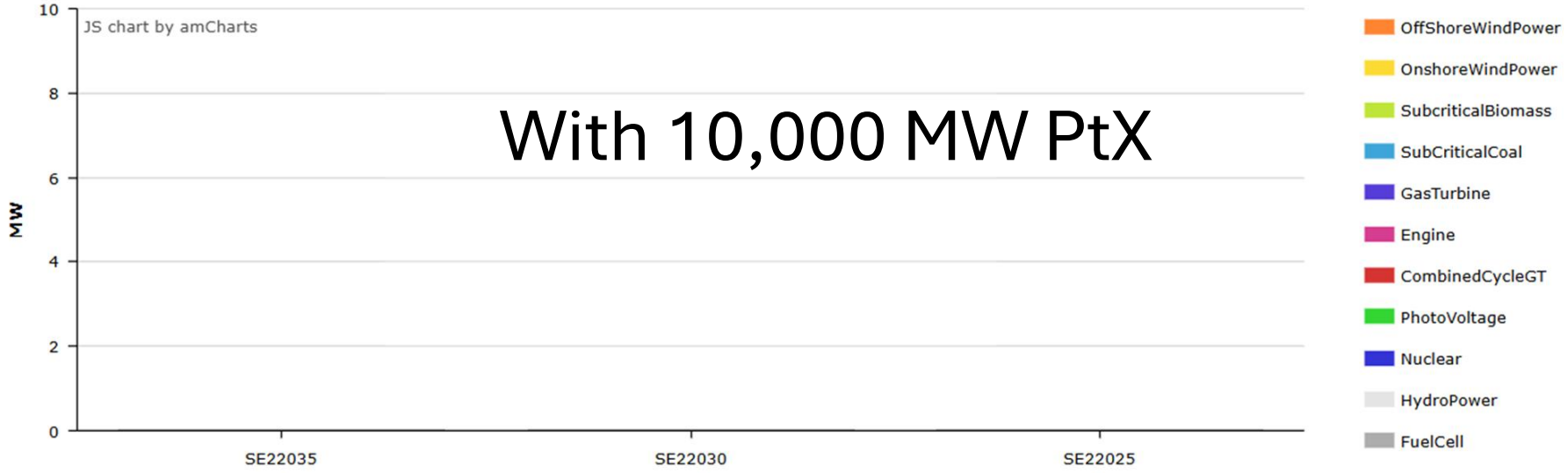
With PtX

Total production costs	534
Total production surplus	7,944
Total consumption surplus	594,164
Total transmission surplus	984
Total societal surplus	603,091
Interest and payback of investments in new plants	0
Social profit minus investments in new plants	603,091
Total C02 discharge	0
Total profit for :PtX (SE2)	18,337,005,163

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Expansion with new power units according to the model





What can be deduced from the sensitivity analysis?

- There is room for 10,000 MW PtX plants in SE2 without affecting the market
- When comparing the profit for the 4,000 PtX plants with the 10,000 MW plants, you can see that both plants have the same specific profit
- This means that the last PtX plants do not change the earnings from the first ones

Results for PtX plant in FI for the total calculation area

Without PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total C02 discharge	1,114

With PtX

Total production costs	151,085
Total production surplus	399,938
Total consumption surplus	37,504,483
Total transmission surplus	47,027
Total societal surplus	37,951,448
Interest and payback of investments in new plants	45,123
Social profit minus investments in new plants	37,906,324
Total C02 discharge	1,114
Total profit for :PtX (FI)	7,334,802,065

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Results for PtX plant in FI for Finland

Without PtX

Total production costs
4,224
Total production surplus
13,968
Total consumption surplus
3,087,505
Total transmission surplus
12
Total societal surplus
3,101,485
Interest and payback of investments in new plants
0
Social profit minus investments in new plants
3,101,485
Total CO2 discharge
2

With PtX

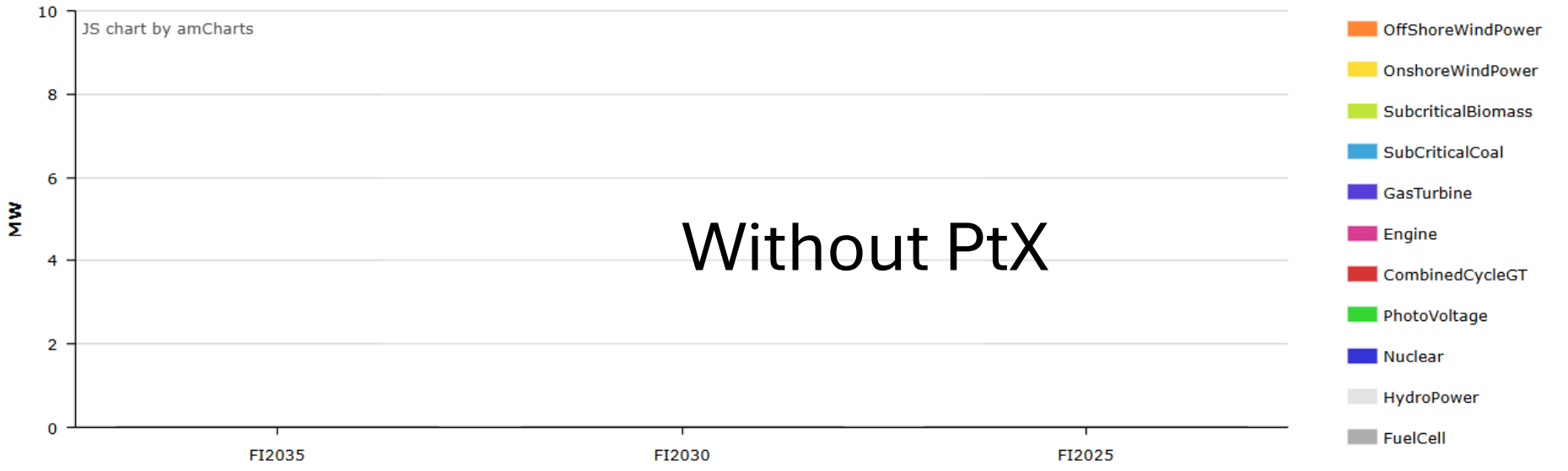
Overview over investment for for FI
Total production costs
4,224
Total production surplus
13,968
Total consumption surplus
3,087,505
Total transmission surplus
12
Total societal surplus
3,101,485
Interest and payback of investments in new plants
0
Social profit minus investments in new plants
3,101,485
Total CO2 discharge
2
Total profit for :PtX (FI)
7,334,802,065

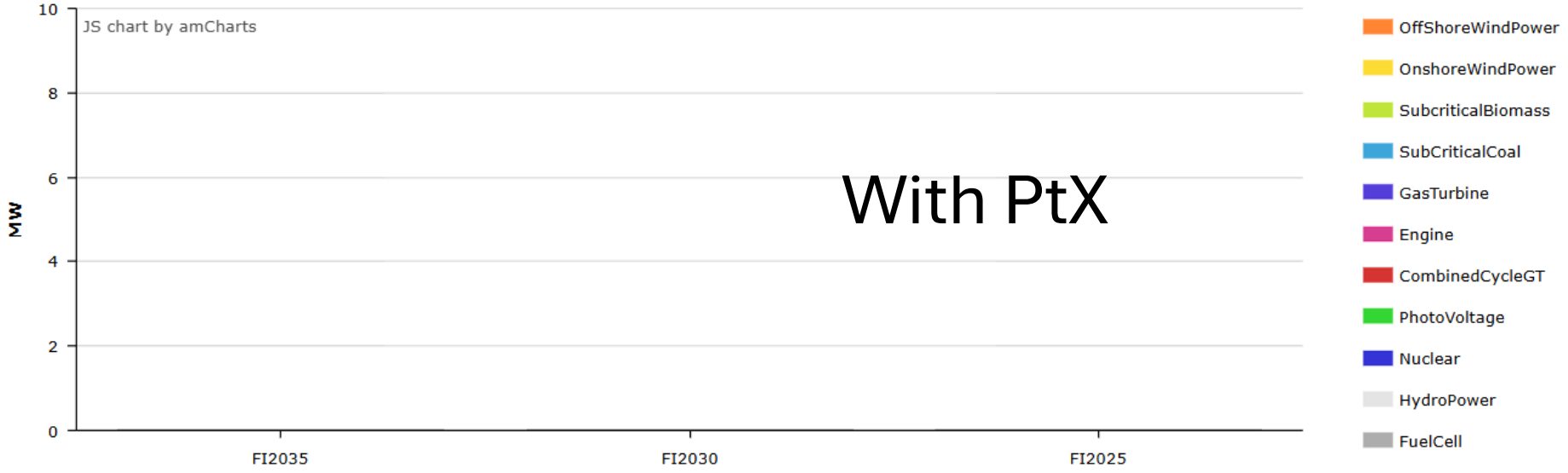
Minus investment in PtX: 3.102.209 mill. euro

Fixed cost for PtX for the period: 1.400.000.000 euro

Except for the profit value which is in euros, all other economic values are in million euros. CO_2-dischart is in mill. tons

Expansion with new power units according to the model





What can be deduced from the partial analysis?

- There is room in terms of power to establish 4,000 MW PtX plants in FI without having to expand with more power production plants
- The profit from production at the PtX plant can finance the total fixed annual costs of the plant
- The PtX plant reduces societal surpluses by 276 mill. euros in the period

What can be deduced from the total analysis?

- There is room to expand significant amounts of PtX capacity in the Nordic countries without having to expand additional production capacity
- In connection with the price Zones examined, the profit for the PtX plant is greatest when placed in SE2 and FI
- A placement in DK1 results in a deficit