Analysis of the economics of establishing nuclear power in Denmark

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Abstract

All experience shows that a more flexible and robust energy supply is achieved when there is an ongoing constructive debate about the advantages and disadvantages of different expansion options that are analyzed with energy system models.

Another benefit is that when doing this type of analysis, new questions are often identified that it is important to get the answers to. In this analysis, we examined the economics of establishing nuclear power in Denmark; but as a spinoff, we found an important question for our next analysis: How do you establish an electricity system that can deliver baseload capacity to PtX plants at a price they can pay, and how do the PtX plants achieve a profit that can return on and repay their investment when they themselves are marginal price-setting entities on the electricity market for a significant part of their operating time?

The barrier to this type of debate and analysis is that there are only a few energy system models available, and that most of these models are so difficult to work with that only a handful of groups in Denmark have the necessary skills to do so. The Danish Energy Agency and Energinet have the competences, but they do not do “debate analyses”. EA Energianalyse, Energy Modelling Lab and other consulting companies only do the analyses they are paid for.

That leaves the universities. In practice, only AAU has, together with others, done “debate analyses”. AAU uses EnergyPlan, which is distinguished by being significantly more user-friendly than the other energy system models.

EnergyPlan, like other models, is not suitable for solving all types of problems. However, since it has so far been the only easily accessible model, it has sometimes been used for problems where it has some significant shortcomings. EnergyPro is also easily accessible, but it is only suitable for minor problems.

Strategirummet has developed the Power Market Simulator (PMS) model, which is also easily accessible and can solve some of the problems where EnergyPlan falls short.

Our hope is that more analysis environments will emerge that use the EnergyPlan, EnergyPro and Power Market Simulator models and that do analyses that contribute to a constructive debate about the development of the energy system.

In this document, we will show how PMS can advantageously replace EnergyPlan in a problem where one must calculate many market-related bidding zones at the same time.

As our first case, we have chosen to contribute to the debate between several Danish and Norwegian researchers about the economics of establishing nuclear power plants in Denmark. Thanks to the Danish researchers who have started to analyze the problem, and to the Norwegians who have followed up with their own analysis.

In this document, we provide a summary of the conclusions of the two studies. Then we comment on the two studies - and finally we show the results of our own analysis with the PMS model.

The two studies are each based on two different expansion scenarios:

• "IDA's Climate Response 2045", where Denmark is self-sufficient in energy, but where the electricity market is used as a free electricity storage. The scenario is calculated with EnergyPlan

• "Long-term implications of reduced gas imports on the decarbonization of the European energy system" where the purpose is to analyze how the EU + GB reduce gas imports. The scenario is analyzed with the PyPSA-Eur-Sec model

In our analysis with PMS, we base our approach on the Danish Energy Agency's Analysis Assumptions for Energinet 2025 (AF25).

In AF25, there is a significantly greater expectation for the expansion of PtX plants and data centers in Denmark than in the other two scenarios.

Since both PtX plants and data centers are expected to have a high utilization factor, this requires expansion with baseload plants or renewable energy plants with electricity storage. We focus on this issue in our analysis.

The great uncertainty surrounding the economics of establishing nuclear power plants in Denmark is about the price of a nuclear power plant. There is a very large spread in the historical prices for building nuclear power plants and in the expectations of future costs. Investment costs range from 4 – 10 million €/MW [Ref. 1]. The EU has launched an investigation into state aid for a nuclear power plant in Poland, where the Poles have defined the price to be 12 million €/MW [Ref. 2]. So, there is some indication that a Danish nuclear power plant will cost in the upper part of the range.

Our analysis shows that if you are very optimistic about the investment costs for a Danish nuclear power plant, it is economically a good idea to build the plant. If you are pessimistic, it is not a good idea.

The analysis shows that nuclear power plants and PtX plants play well together. Nuclear power is probably the only controllable technology where the plant can supply electricity at a short-term marginal price, which the PtX plants are able to buy electricity when they must supply a competitive hydrogen price. Both technologies can operate at base load and spread the fixed costs over many full load hours.

It could therefore be a good idea to locate combined nuclear power plants and PtX plants in sparsely populated and politically stable areas, where there is also access to deposit the radioactive waste. Hydrogen could then be transported in pipelines to the points of consumption.

If we want to establish large-scale hydrogen and ammonia production in Denmark, studies should be made that narrow the uncertainty interval around the establishment prices for nuclear power plants in

Denmark and for the deposit of radioactive waste, and then we also need to know more about the externalities in the form of fear and consequences of possible accidents.

” Fakta om Atomkraft i Danmark - Version 2” [Ref. 3]

Summary

As part of the study, the “Levelized cost of electricity” has been calculated for nuclear power plants, wind turbines and solar cells. The result is shown in the following figure.

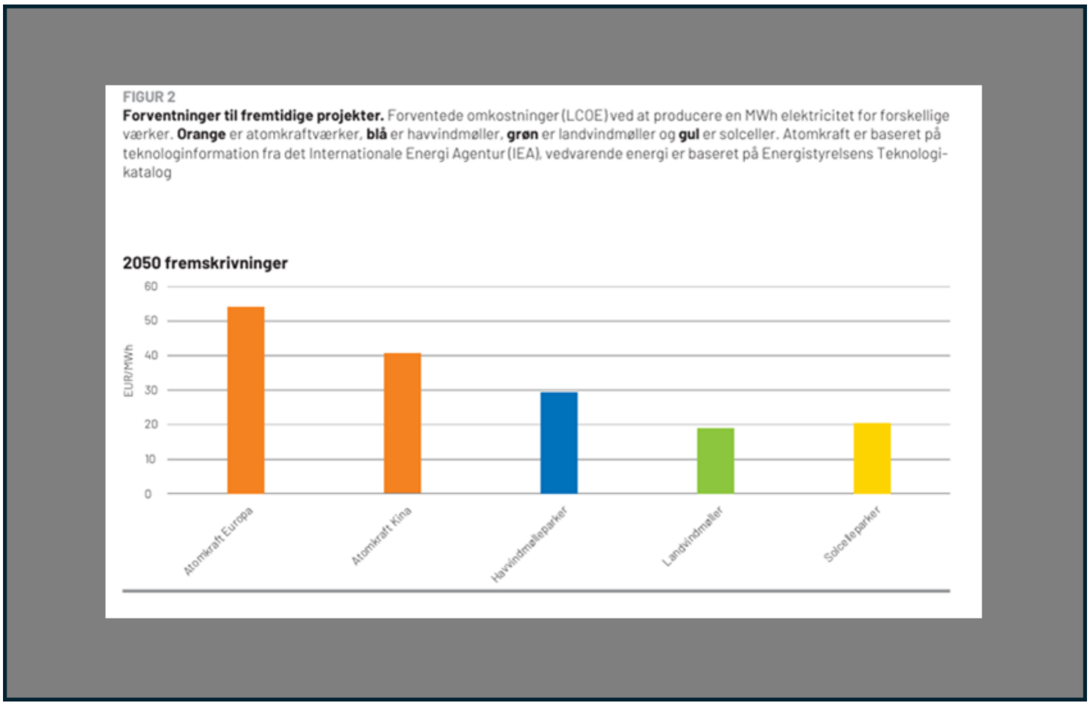

Figure 1. “Levelized cost of electricity” for nuclear power plants, wind turbines and solar cells

The figure shows that nuclear power plants are more than twice as expensive as solar and onshore wind turbines.

The Danish researchers have used EnergyPlan to calculate the difference between a development with and without a 1,000 MW nuclear power plant in Denmark.

The analysis is based on “IDA’s Climate Response 2045” [Ref. 4], which is a somewhat different scenario than the Danish Energy Agency’s Analysis Assumptions for Energinet [Ref.5].

The result shows that nuclear power plants increase the annual costs of the Danish energy supply by 1.5-2.2 billion DKK (200 – 300 million €), depending on whether it replaces part of the Danish offshore wind farms or part of the Danish onshore wind farms, and whether district heating from the plant is utilized.

This analysis only considers Denmark, but with the possibility of exchanging electricity with neighboring areas corresponding to the total capacity of the international connections.

The researchers have also made a calculation for the entire European electricity market. Here they have used the PyPSA-Eur model. The calculation assumes a situation in 2050 where there are no existing electricity generation plants left. The model thus expands the electricity generation system from scratch.

The result of the analysis shows that it is not economically favorable to choose nuclear power as the primary energy source in Europe until the investment costs fall by at least 25% compared to the base costs. If the investment price for nuclear power can be reduced by 50% to 3400 €/kW, it will be economically favorable to invest roughly equally in renewable energy (wind and solar) and nuclear power in Europe. If the price for nuclear power is reduced to 1700 €/kW, nuclear power will become the dominant energy source in Europe. But even in this case, there is no investment in nuclear power in Denmark, because we have good wind resources.

”The total costs of energy transitions with and without nuclear energy” [Ref. 1]

Summary

The Norwegian researchers reach a different conclusion. They believe that the Danish researchers have chosen an unrepresentative climate year in their analysis, that they are too optimistic about the costs of establishing offshore wind turbines and too pessimistic about the operating costs of nuclear power plants.

The tables below show the differences in relation to prices.

Table 13
Comparison of capital expenditure (CAPEX) levels for nuclear energy in 2035 and renewables in 2040 in $€_{2023}$.[1]

		Technology				References
		Nuclear	Onshore wind	Offshore wind	Photovoltaic	
	Reference study	€6180/kW	€1030/kW	€1900/kW	€600/kW	[13,53]
Cost level	Advanced	€4250/kW	€1010/kW	€2180/kW	€550/kW	[20,27]
	Moderate	€6180/kW	€1130/kW	€2500/kW	€710/kW	[20,27]
	Conservative	€10,150/kW	€1260/kW	€3200/kW	€940/kW	[20,27]

[1] Offshore wind is based on the Danish Energy Agency's 2025 report [27], excluding nearshore wind, while the advanced and conservative cost levels differentiate between offshore and farshore bottom-fixed wind. NREL ATB2024 [20] covers the remainder.

Table 14
Comparison of nuclear energy's operating expenditure (OPEX) levels on a 90 % capacity factor basis in $€_{2023}$.

		Cost category				References
		Fixed O&M	Fuel	Variable O&M	Total OPEX	
	Reference study	€14.26/MWh	€9.33/MWh	€15.00/MWh	€38.59/MWh	[13,53]
Cost level	Advanced	€13.71/MWh	€7.83/MWh	€1.63/MWh	€23.17/MWh	[20,21]
	Moderate	€19.04/MWh	€8.73/MWh	€2.40/MWh	€30.17/MWh	[20,21]
	Conservative	€22.19/MWh	€9.72/MWh	€2.92/MWh	€34.83/MWh	[20,21]

Figure 2. Prices for nuclear power, wind turbines, and solar cells in the two studies

Figure 3 shows the result of their analysis.

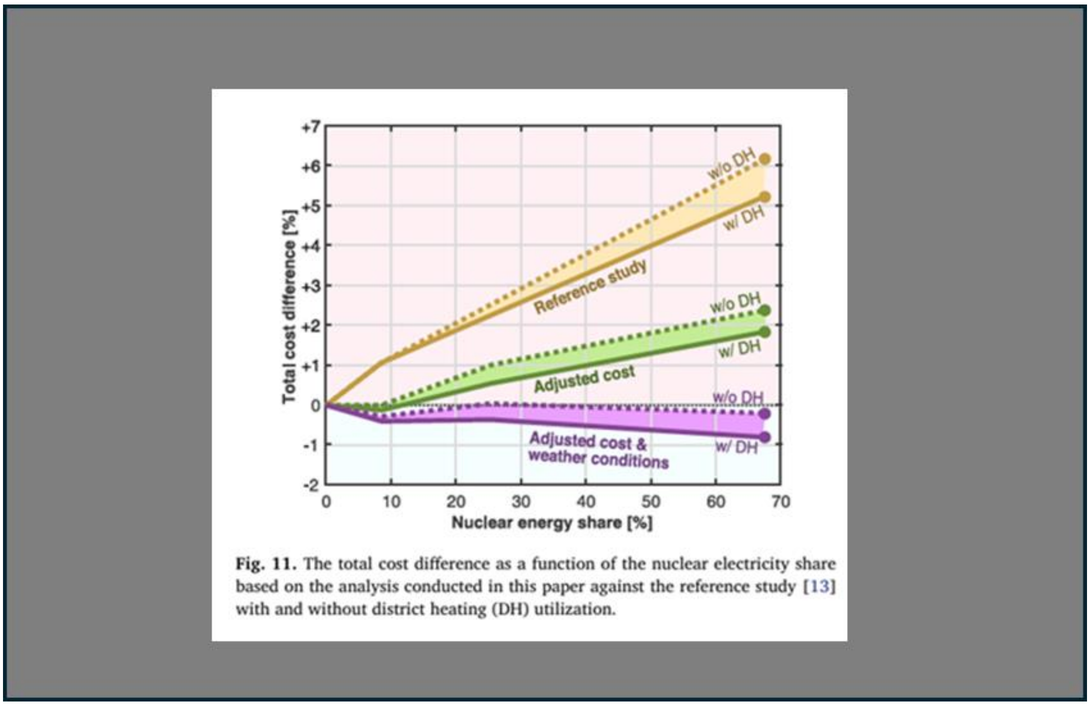

Figure 3. The result of the Norwegian study

The Norwegians also believe that the Danish researchers underestimate the costs of storing electricity and hydrogen.

The position of the Danes' PyPSA-Eur calculations is that the model expands with transmission capacity, which makes it possible to exchange large amounts of controllable power with neighboring countries.

Comments on the two studies

A weakness of both analyses is that it is not immediately clear how they relate to official projections of the energy system.

The Danish study does not take official expectations for the future development of the energy system as its starting point. The starting point for the analysis with EnergyPlan is a previous analysis made for IDA [Ref. 4].

The PyPSA-Eur-Sec analysis is not immediately sufficiently documented in terms of input data to determine how this scenario relates to official projections of the energy system. The nuclear power analysis appears to be a “one day’s work”, where various calculations have been made on an existing model that was developed for a different purpose, and where the only thing that has been changed is the price of a nuclear power plant.

The Norwegian study uses the same scenario and model as the Danish one. The purpose has apparently been to point out several errors in the Danish study and how this affects the result.

The Norwegians have subsequently accused the Danish researchers of violating scientific integrity [Ref. 6].

Both analyses use EnergyPlan, which is not suitable for answering the question about the economics of establishing nuclear power plants in Denmark, because it is not a market model.

We have therefore chosen to do our own analysis with the Power Market Simulator model, which is suitable for solving this type of problem. It is also much more easily accessible than PyPSA-Eur.

Regarding the calculation of the "Levelized cost of electricity" for nuclear power, wind and solar in the Danish study, our comment is that an analysis of the value of electricity production on the technologies is missing. Paul-Frederik Bach has analyzed the relationships between market prices and production on solar, wind and controllable units [Ref.7]. He concludes:

The current situation is, roughly speaking, that the commercial value of wind energy is around ⅔ of the commercial value of dispatchable production, while the value of solar energy is even lower.

If the value of electricity from the different technologies is considered, the differences between the technologies are narrowed.

When the Danish study was conducted, the expectations for the price of establishing offshore wind turbines were significantly lower than in the current version of the Technology Catalogue [Ref. 14]. In our analysis, we use the latest projections.

There is a significant difference between the variable costs of nuclear power in the Danish and Norwegian studies. In the Danish study, the price is set at 15 €/MWh. The Norwegians expect 1.5 – 3 €/MWh. In the reference used by the Norwegians, it is stated that the operating costs do not include all operating costs. In the Danish study, there is a reference to an MIT study where the operating costs are around 8 €/MWh [Ref. 8].

In our study, we use 8 €/MWh.

EnergyPlan would be well suited to solving the problem of nuclear power in a Danish electricity system where we do not want to be dependent on others. When you include export/import without pricing the difference between market prices for export and import, you create a wrong picture. When there is a surplus of solar and wind, we export, and then the electricity price is typically low. When there is a deficit, we import, and in those cases the electricity price is typically high. It therefore costs something to use the outside world as a storage. This cost is not included in the Danish study.

We have calculated the correlations between electricity prices in Denmark and exports/imports for Denmark in 2024. The result is shown in Figure 4.

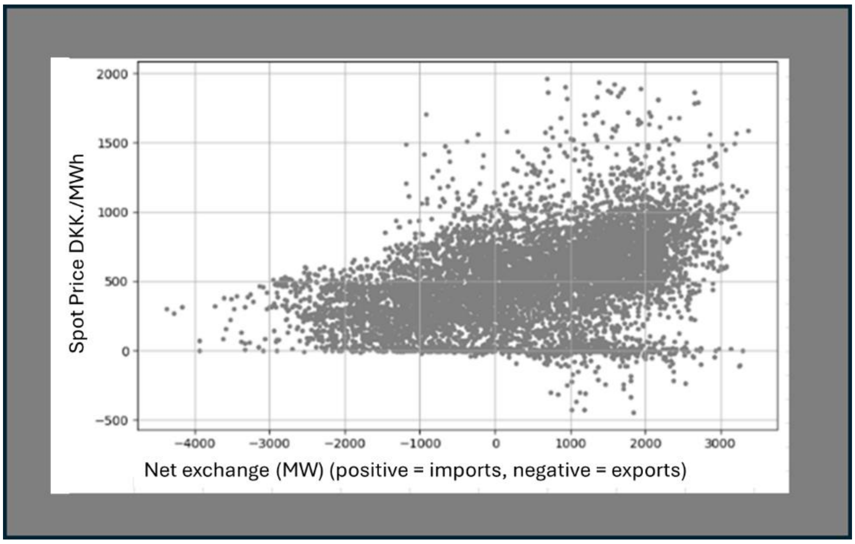

Figure 4. Relationships between exports/imports and market prices

The figures show that market prices are significantly higher for imports than for exports. The average price for imports is 328 DKK/MWh (44 €/MWh). The average price for exports is 680 DKK/MWh (90 €/MWh).

It therefore costs something to use the international connections as storage. This cost is missing in the Danish study, and it favors solar and wind.

Analysis with the Power Market Simulator model

Introduction

The Power Market Simulator model [Ref. 9] was developed by Strategirummet over a period of 10 years, where Insero and the University of Southern Denmark have participated in various sub-developments.

In this analysis, we use PMS-Scenario to calculate the expected profit for a Danish nuclear power plant in the period 2040 – 50.

We then compare this profit with how large an investment in a nuclear power plant the profit can yield and repay.

In contrast to the other two studies, we take as our starting point the projection that appears in the Analysis Assumptions 2025 (AF25).

Calculation examples with nuclear power in Denmark

We analyze two situations:

• A situation where Denmark expands the electricity system so that we can manage alone without exchanging electricity with neighboring systems. What will the economics of nuclear power be like in this case?

• A situation where we interact with neighboring systems in terms of the market. What will the economics of nuclear power be like in this case?

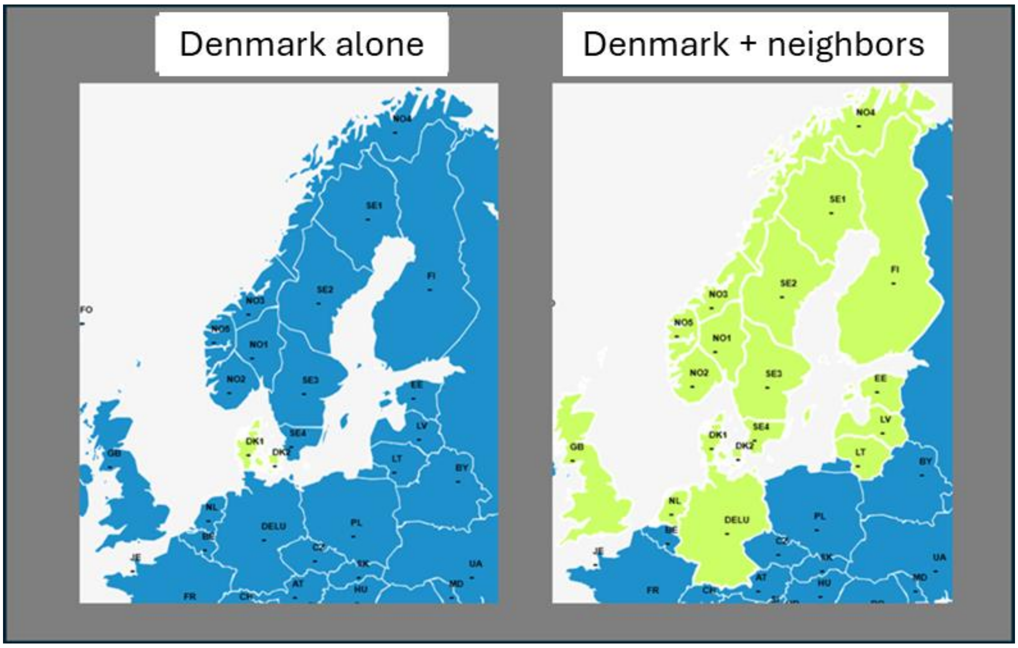

Figure 5. The two areas considered in this analysis.

The first situation is like the Danish study with EnergyPlan except that we have removed the international connections. The second study is like the PyPSA-Eur analysis except that we calculate for the period 2025 – 50, and not just a single year, and that we use the official projection of the Danish electricity system from AF25 [Ref. 5]

The Power Market Simulator model for solving the task

We use the Scenario version of PMS for the analysis. PMS-Scenario can analyze the development of the electricity system in the future. The model continuously scraps existing plants that exceed their service life and builds new electricity production plants that are economical to establish [Ref. 9]. The user can also manually establish both production and flexible consumption plants.

Users can choose from existing and new plants for which plants they want to calculate contribution margins and full load hours. Owners of production and flexible consumption plants can therefore use PMS-Scenario to (based on data in AF25) obtain a qualified estimate for use in their budgets, and investors in new plants can use the model to calculate expected future earnings. If you want help with this, just contact Strategirummet.

Based on our knowledge of energy system models, PMS is the only model where users can calculate future contribution margins for individual plants.

If you want to repeat our analysis with changed assumptions, or if you want to do your own analysis where you calculate economics for another unit it is quite easy.

When you have access to PMS-Scenario, you must:

- During manual building of plants “Establishment”, load the nuclear power plant or another plant that you want to analyze
- During automatic loading “Auto build”, set the end period to 2050 and select the plant for which you want to calculate the profit “Chose unit for economy calculation”
- Change the rate of increase in consumption to 3% in DK1 and 2% in DK2
- Click on the areas that should be included in the calculation
- Start the calculation by clicking on “Calculate scenario”

You can then see the result by clicking on “Show invest”.

PMS-Scenario’s strengths in relation to the task are:

- The model is well documented and easily accessible
- The model contains Danish data corresponding to the Danish Energy Agency’s Analysis Assumptions for Energinet
- The model covers the entire world in terms of production, and uses updated consumption and transmission data for Europe
- The model itself establishes new plants during the calculation period, based on the technologies’ earnings on the electricity market compared to the investment and operating costs

PMS-Scenario’s weaknesses in relation to the task:

- The model uses duration curves and therefore does not calculate chronologically. The model therefore has difficulty optimizing electricity storage.
- The model includes district heating via hourly profiles for cogeneration production, and therefore cannot account for heat storage

Data base

Data is obtained from the following sources

- Development of electricity consumption in Denmark is based on the Analysis Assumptions 2025 [Ref. 5]. The AF25 expansion with PtX plants, heat pumps and electric boilers is loaded as part of the data base for PMS.
- Development of electricity consumption in other bidding zones is based on historical maximum consumption from ENTSOe [Ref. 10] + an increase rate of 1% per year. Hourly profiles for electricity consumption in the different bidding zones are obtained from ENTSOe [Ref. 10]. Development with foreign PtX plants is included in the calculation based on the data that Strategirummet has purchased from Enerdata [Ref. 11]. Strategirummet plans to enter electricity consumption, PtX plants, etc. based on ENTSOe scenarios [Ref. 12] in connection with future analyses.
- Data for existing electricity production plants in Denmark is obtained from the Danish Energy Agency's “producenttælling” [Ref. 13]. Data for electricity production plants outside Denmark is purchased from Enerdata [Ref. 11]. The efficiency and operating costs of the plants are calculated based on data in the technology catalogue [Ref. 14] and the development in this

data over time. Older plants therefore have lower efficiency and higher operating costs than newer plants

- Hourly profiles for production from solar cells, offshore turbines, onshore turbines and run-of-river hydropower in the different bidding zones are taken from ENTSOe [Ref. 10]. The climate year is 2021
- Data for transmission connections are taken from ENTSOe [Ref. 10]
- Fuel prices and prices for CO2 quotas are taken from AF25 [Ref. 5]
- Data for nuclear power plants are taken from the MIT report [Ref. 8] (French plants)
- The discount rate is 4%

We assume that the PtX plants purchase electricity at a maximum of 40 €/MWh. The heat demand follows an hourly profile, and the heat pumps purchase electricity at a maximum of DKK 240 €/MWh. The electric boilers switch on when the price is below 20 €/MWh. The batteries charge when the price is below 33 €/MWh and discharge when the price is above 52 €/MWh. The model ensures that there is a balance between charging and discharging on an annual basis.

We have limited the expansion of onshore wind turbines to 7,100 MW in DK1 and 1,000 MW in DK2.

The above data is included as default in PMS. So, when using the model, you do not have to enter the relevant data yourself; but you can change them yourself. The only thing you need to change in the model yourself is the percentage increase in non-controllable electricity consumption. This is set to 1% by default and in AF25 it is 3% in DK1 and 2% in DK2.

Results

In the calculations, we have manually entered the capacities for the flexible electricity consumption plants (PtX, heat pumps, electric boilers and batteries) as they appear from AF25. The model itself optimizes the expansion with electricity production plants.

Calculation for Denmark alone

Comparison between PMS expansion of capacity in DK1 and DK2 and the expansion in AF25 [Ref. 5] is shown in Table 1.

Capacities in MW	DK1		DK2	
Year 2050	AF25	PMS	AF25	PMS
Offshore Wind	9.616	3.289	4.764	1.754
Onshore Wind	6.514	7.100	609	1.000
Photovoltage	24.133	25.952	11.232	15.819
Thermal units	775	3.899	1.557	456

Table 1. Comparison between expansion of production units in AF25 and in PMS in "Denmark-alone"

The table shows that significantly less offshore wind capacity is being established in the PMS calculation than in AF25. The offshore wind development in AF25 is included exogenously based on a target fulfillment scenario for Denmark. In PMS, the development is a result of the optimization, and we use the high establishment costs that appear from the latest edition of the technology catalog [Ref. 14].

The table also shows that more thermal capacity is being developed in PMS, and that it is primarily located in DK1.

In AF25, the international connections are used to create balance between production and consumption. In "Denmark alone" there are no international connections, and therefore thermal capacity must be established to cover electricity supply in those situations when the wind turbines and solar cells are not producing.

If you are not satisfied with the development of new units that PMS reaches, you can enter the development plan that you believe in.

The results show:

The established nuclear power plant will earn in the period 2040 – 2050:	*€4.972.299.280.*
The earnings per MW and per year are:	*€497.230.*
When the fixed operating costs are deducted, the profit is:	*€347.229*
With an interest rate of 4%, the profit can finance a maximum investment of:	*7,0 million €/MW*

The earnings are calculated for each period by multiplying the area prices in each time group by the plants' full load hours in the same time groups. Figure 6 shows the prices in the different time groups and which plant types are price-setting (in the case of 1.000 MW nuclear power in DK1). The figure shows that the PtX plants are price-setting for a large part of the time.

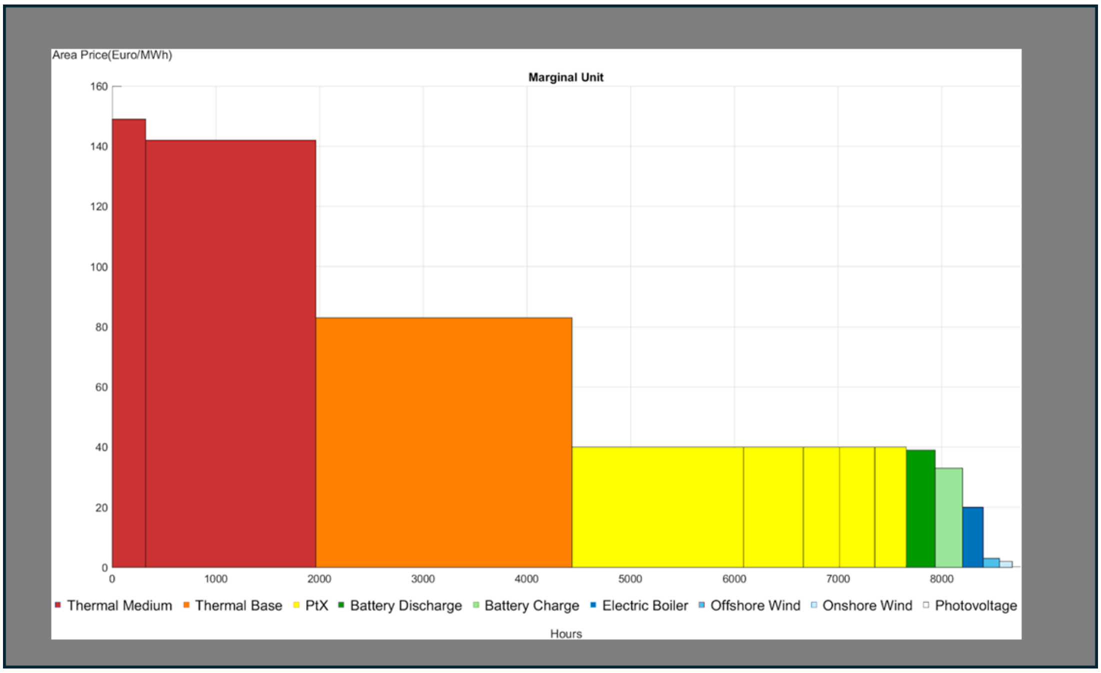

Figure 6. Area prices in DK1 in 15 time-groups in 2050 and the price-setting plants

Table 2 shows an example where the contribution margin is calculated for a photovoltage plant. The prices in the time groups are multiplied by the full-load hours for the photovoltage plant in the time groups in question.

The total profit for the photovoltage in this example is equal to €36,531/MW/year. Since it costs €28,699/MW/year in interest, repayments and fixed operating costs, it is economical in this case to invest in photovoltage. The model then does this iteratively until the price has fallen so much that it is no longer economical.

Hours in Timegroup	Area Price (€/MWh)	Photovoltage (Full Load Hours)	Profit for Photovoltage (€/MW)
15	0	13	0
65	0	53	0
124	2	93	205
156	3	100	310
200	20	123	2.460
264	33	143	4.767
279	39	130	5.027
303	40	117	4.680
340	40	111	4.440
349	40	86	3.440
576	40	86	3.440
1.655	40	61	2.440
2.471	83	40	3.334
1.641	142	13	1.840
322	149	1	149
8.760		1.170	36.531

Table 2 Calculation of annual contribution margin for photovoltage plants in 2050

Table 3 shows the number of hours in the time groups and the area price for 2050 in the case of nuclear power. The PtX plant produces hydrogen if the price is equal to or below 40 €/MWh. In this case, this corresponds to 4,326 hours without deduction for availability. With an availability of 90%, the number of full load hours for the PtX plant is 3,893 hours. (Corrected for availability: 4,326 * 0.9 = 3,893).

Hours in Timegroup	Area Price (€/MWh)	Marginal unit
15	0	Photovoltage
65	0	Photovoltage
124	2	Onshore Wind
156	3	Offshore Wind
200	20	Electric boiler
264	33	Battery Charge
279	39	Battery Discharge
303	40	PtX-Unit
340	40	PtX-Unit
349	40	PtX-Unit
576	40	PtX-Unit
1.655	40	PtX-Unit
SUM = 4.326		
2.471	83	Thermal Base
1.641	142	Thermal Medium

322	149	Thermal Medium

Table 3 The number of hours in the time groups, electricity prices in DK1 and price-setting units

Table 4 shows the availability of the PtX facility in the years when the nuclear power plant is in operation, with and without the nuclear power plant.

		Full Load Hours	
		Without Nuclear	With Nuclear
2040	PtX	4.943	6.562
2045	PtX	4.250	4.521
2050	PtX	3.305	3.893

Table 4 Availability of PtX plants in different market situations

The table shows that the nuclear power plant increased the utilization of the PtX plants. This is because the nuclear power plant produces electricity at a price that is below the KIP price for the PtX plant.

Calculation for Denmark + neighboring areas

Comparison between PMS capacity expansion in DK1 and DK2 and the expansion in AF25 [Ref. 5] is shown in Table 5.

Capacities in MW	DK1		DK2	
Year 2050	AF25	PMS	AF25	PMS
Offshore Wind	9.616	1.800	4.764	1.754
Onshore Wind	6.514	7.100	609	1.000
Photovoltage	24.133	44.426	11.232	28.685
Thermal units	775	3.858	1.557	239

Table 5. Comparison between expansion of production plants in AF25 and in PMS in "Denmark + neighbors"

The table shows that, in the same way as in the "Denmark-alone" analysis, expansion is carried out with less offshore wind power and more thermal power in PMS than in AF25. Expansion with solar cells increases sharply in the situation where we are interconnected with neighboring systems. If the increase in solar cell capacity is unrealistic, a limit for expansion can be inserted in the model.

We have repeated the calculation, limiting the expansion of solar cells to the values stated in AF25. This only increases the earnings at the nuclear power plant by 4.400 €/MW/year.

The results show:

The established nuclear power plant earns in the period 2040 – 2050: *€3.124.119.941.*

The earnings per MW and per year are: *€312.411.*

When the fixed operating costs are deducted, the profit per MW per year is: *€162.411.*

With an interest rate of 4%, the profit can finance a maximum investment of: *3,2 million €/MW*

Figure 7 shows the prices in the different time groups for DK1 and which plant types are price-setting in the case of nuclear power. The figure shows that the PtX plants are still price-setting for a large part of the time.

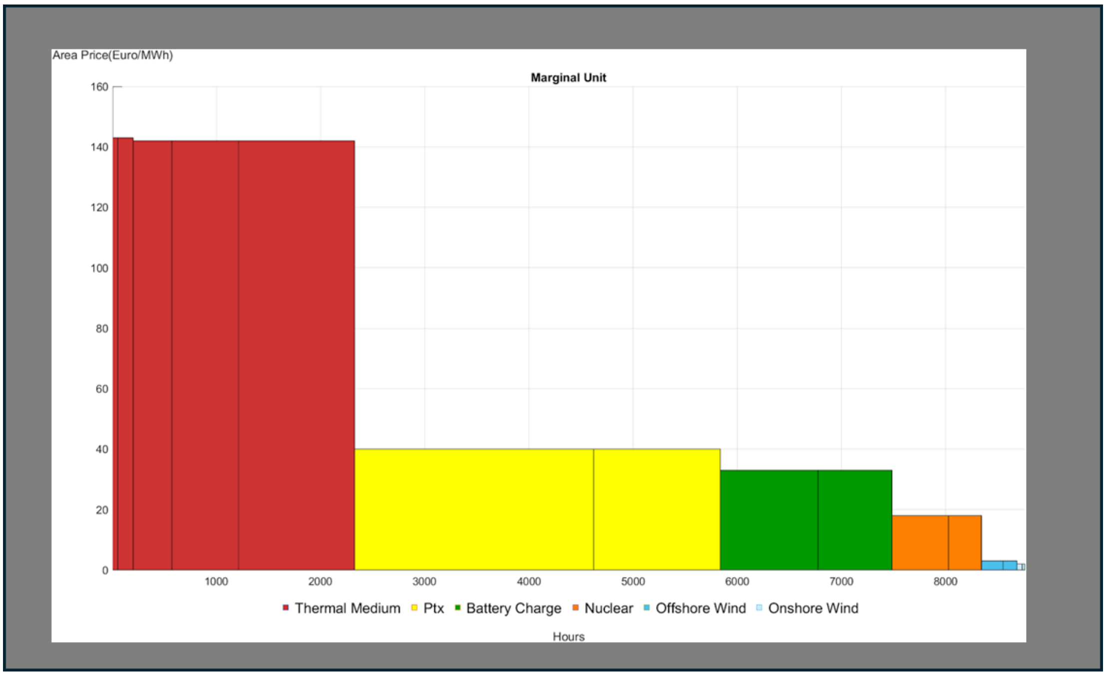

Figure 7. Area prices for DK1 in the 15 time-groups and pricing plants

Table 6 shows the full load hours at the PtX plants in different market simulations.

		Full Load Hours			
		Without Nuclear in Denmark		With Nuclear in Denmark	
Year	Unit Name	Denmark + neighbors	Denmark alone	Denmark + neighbors	Denmark alone
2040	PtX	5.320	4.943	5.320	6.562
2045	PtX	4.287	4.250	5.942	4.521
2050	PtX	3.618	3.305	5.792	3.893

Table 6. Full load hours for the PtX plants in DK1

The table shows that the PtX plants in most cases achieve a reasonable utilization factor; but the question is how much they earn when they in many hours are price-setting on the market.

When the Danish study succeeds in achieving a utilization rate of 50 – 60% on the electrolysis plant without thermal baseload plants, it is because they use the transmission connections to other countries as a free electricity storage.

With PMS-Scenario, we have repeated the analysis that the Danish researchers made with the PyPSA-Eur model [Ref. 15], where they halved the establishment costs for nuclear power plants, to investigate how this affects the expansion of nuclear power plants in Denmark. In the PyPSA-Eur analysis, nuclear power was not expanded in Denmark even though the investment costs were halved.

In our analysis, approximately 3,000 MW of nuclear power is expanded in DK1 in 2045, when the investment costs are halved.

We therefore do not reach the same conclusion as in the Danish study with the PyPSA-Eur model, that it is not a good idea to establish nuclear power in Denmark under any circumstances.

Discussion

The major economic uncertainty surrounding the establishment of nuclear power in Denmark is primarily about the establishment price for a nuclear power plant. According to the Norwegian study, the uncertainty interval is: 4 – 10 million €/MW. The Danish study estimates an investment cost of: 6,4 million €/MW.

We do not consider where we think the investment cost lies in the interval. We calculate backwards and find, based on the operating profit the plant can achieve, how much investors can invest in a nuclear power plant per MW.

Our analysis shows that a maximum of 3,2 million €/MW can be invested in a nuclear power plant when we calculate on Denmark + neighboring systems. The maximum investment can be increased to 7,0 million €/MW if we only calculate on a closed Danish electricity system.

If we assume that the investment costs for the nuclear power plant are 6,4 million €/MW (as in the Danish study), and the annual operating profit is 162.411 €/MW (as we do in our analysis with connections to foreign countries), the nuclear power plant's deficit will be approximately €160 million. This is significantly lower than the result of the Danish study, where the loss is calculated at between €270 and €335 million.

Some of the difference is due to different assumptions regarding variable operating costs for a nuclear power plant. In the Danish study, the costs are 15 €/MWh. We assume that the cost is 8 €/MWh. With approximately 7,000 hours of full load the difference will be approximately €49 million/year.

In our analysis, we have not included any income from the sale of ancillary services. The income from such a sale will reduce the deficit which as a starting point is €162 million/year.

Regarding the disposal of radioactive waste, the problem is more political than economic. Various external analyses show that it does not cost much per MWh of electricity production to dispose of waste, if one can get permission to do so.

When the Danish study succeeds in achieving a utilization rate of 50 – 60% at the electrolysis plant without thermal baseload plants, it is because they use the international connections as a free electricity storage.

Conclusion

With the very extensive expansion with PtX plants, which is assumed in AF25, there is room for a significant baseload capacity of electricity production plants. To create economy in producing hydrogen at electrolysis plants, they must have a high utilization factor (relate the investment costs in the Technology Catalogue [Ref. 16]). They will not achieve this if the electrolysis plants only produce when the wind is blowing and the sun is shining. The PtX plants therefore play well with nuclear power plants or renewable energy systems with batteries.

Our analysis shows that if Denmark wants to become independent of other countries, baseload plants must be established together with the expansion with solar and wind power. In this case, nuclear power is economically a good solution.

If Denmark wants to continue to exchange electricity with our neighbors on market terms, nuclear power is only an attractive solution if the installation price is reduced compared to current expected costs.

If you want to learn more about whether it is economically a good idea to establish nuclear power in Denmark, you should focus on narrowing the uncertainty interval around the investment costs.

Another issue that you should be interested in is how to establish an electricity system that fits well with PtX plants and data centers. The PtX plants and datacenters must have a high utilization factor, and the PtX-plants must avoid being price-setting for a large part of the time. This issue will be the subject of our next analysis in Strategirummet's analysis group. In this analysis we will use EnergyPro because it is most suitable for this type of problem. We would like to hear from others who have done a similar analysis.

We have not - as in the Norwegian study - considered different climate years in our analyzes. At present, PMS can only retrieve data from one database. We are working on enabling users to create their own databases, and when starting PMS, you can choose which database you want to use. This addition to the model is expected to be available in spring 2026. When that is the case, we will repeat the calculations with different climate years.

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