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Ensuring Generation Adequacy in Finland with Smart Energy Policy – How to save Finnish CHP production?

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Abstract—The Finnish electricity market is experiencing a period of prolonged low electricity wholesale prices. Concurrently, there is a growing concern regarding generation adequacy particularly during peak demand periods. Combined heat and power (CHP) accounts for a large share of Finnish energy production and it is expected to continue doing so under the new energy and climate strategy. However, the current and predicted future electricity wholesale prices encourage replacing retiring CHP capacity with heat only boilers (HOBs), which practically excludes the possibility of electricity production at the site for decades to come. This article analyses the economics of biomass-based heat and CHP production, and the required electricity price level to ensure the economic competitiveness of CHP production in Finland. Moreover, this paper analyses the legal framework within which energy policy measures such as subsidisation can be implemented in order to ensure a functional energy system in the future.

Index Terms—generation adequacy, energy policy, CHP, feasibility analysis, legal framework

I. INTRODUCTION

The Finnish electricity market is experiencing a period of prolonged low electricity wholesale prices, which is partly caused by lower-than-expected demand for electricity and partly by the exceptionally warm weather during the past decade. Concurrently, there is a growing concern regarding generation adequacy particularly during peak demand periods.

Combined heat and power (CHP) accounts for a large share of Finnish electricity production and it is expected to continue doing so under the new energy and climate strategy [1]. Moreover, CHP production is a source of flexibility and inertia in the electricity grid. The need for flexibility grows more important by the year with the current trends of increasing wind power capacity and market-based shutdown of the Finnish condensing power capacity [2]. The prolonged and continuing [3] low electricity wholesale prices encourage replacing retiring cogeneration capacity with heat only production, a process which some major utilities in Finland are already planning. Concurrently, there is a consensus among industry experts that a significant reduction in Finnish CHP capacity would have negative impacts on energy security.

This article uses an interdisciplinary approach to analyse the tools that are required to keep CHP production in the Finnish energy system over the period of low electricity wholesale prices. First, section II introduces the Finnish energy market with an emphasis on the role of cogeneration. Secondly, section III analyses the economics of biomass-based thermal generation. Thirdly, section IV analyses the legal instruments and State-driven financing options available to address the apparent lack of investment in CHP. Finally, Section V draws conclusions.

II. CHP IN THE FINNISH ENERGY MARKET

Finland has high demand for energy due to its cold climate and energy-intensive industry [4]. Compared to many European countries, the demand for heat is especially high in Finland. Consequently, larger cities in Finland have wide district heating networks and, as a result, cogeneration has supplied a significant share of municipal energy demand during the last few decades. One of CHP production's benefits is that it can reach thermal efficiencies of up to 90% as the excess heat from electricity production is utilised as heat in the district heating network.

However, several simultaneous trends set the future of Finnish CHP production on an ambiguous path. First, demand for district heat is stagnating due to improving energy efficiency of buildings and the development of competing heating methods, such as heat pumps [5]. Secondly, a large share of district heat in Finland has traditionally been produced with either coal or natural gas. However, Finland aims to phase out coal in energy use by 2030 [1] and natural gas has lost its economic competitiveness during the past decade [6]. Thirdly, the current and predicted future electricity wholesale prices encourage replacing retiring CHP capacity with heat only boilers (HOB) [7], which practically excludes the possibility of electricity production at the site for decades to come.

Investment in a steam generator (SG) instead of a HOB would leave an option for a turbine investment at the site in case electricity prices reached an adequate level to spur investment in the future. However, such an investment is dubious both technically and economically under the current

market uncertainty, and hence it is highly unlikely that an energy company would commit to such an investment without any additional incentives.

III. INVESTMENT PROFITABILITY ANALYSIS

This section analyses the economics of heat and combined heat and power production in Finland. Finland aims to decarbonise its energy sector in the long run and increase self-sufficiency in energy supply [1]. Biomass is the most abundant domestically available fuel in Finland for thermal production [8] and it is currently considered carbon neutral. Therefore, this section analyses the economics of biomass-based thermal production.

As CHP plants produce both heat and power, allocating the production costs for electricity is less straight-forward. In this paper, we derive the production cost of electricity as the incremental cost of investing in a CHP plant instead of a HOB or a steam generator with equal heating capacity. Lifecycle costs of the studied production facilities are based on the levelised cost of energy (LCOE) method, which depicts the average price of energy required throughout the plant's lifespan to result in a net present value (NPV) of zero. NPV is calculated by discounting the free cash flow (FCF) of a project using the weighted average cost of capital (WACC) [9]:

$$NPV = \sum_{T=0}^n \frac{FCF_T}{(1+WACC)^T} \quad (1)$$

where T is the time in years and n is the time span of the investment. LCOE is now defined as follows:

$$LCOE = \frac{\sum_{T=0}^n \frac{C_T}{(1+WACC)^T}}{\sum_{T=0}^n \frac{E_T}{(1+WACC)^T}} \quad (2)$$

where C_T includes all costs associated with the project in year T and E_T is the electricity production in year T. The LCOE provides a clear indication of the required average price of energy to ensure the project's economic feasibility. The authors present the theory behind the calculations in more detail in Ref [7].

It should be noted that the average spot price for a year in Nord Pool is calculated without taking into account the amount of electricity consumed per hour [10]. Therefore, an average MWh bought from the spot market in 2016 was actually 2.7% more expensive than the annual average price of electricity (calculated by taking into account the hourly electricity demand in 2016 [11]). Moreover, district heating CHP production emphasises on hours with lower temperatures and higher consumption and, consequently, higher spot price. Therefore, an average MWh produced with district heating CHP in fact yielded 5.3% more revenues than what the average spot price would indicate. This should be taken into account when comparing the results of the LCOE calculations with annual average electricity spot prices.

A. Input data and assumptions

Capital and operational expenditures (CAPEX and OPEX) and technical plant data are based on recent realised

investments and industry averages in Finland. Technical and commercial assumptions for plants with heating capacities of 100 MW and 200 MW are presented in Table I and Table II, respectively. Comparing to a CHP investment, the additional CAPEX for making the turbine investment with an existing steam generator separately afterwards is 3 MEUR in the 100 MW case and 5 MEUR in the 200 MW case. We assume the plants to use wood chips as fuel.

Table I. Input data for calculations – 100 MW heating capacity.

100 MW heating capacity	HOB	SG	CHP
Technical assumptions			
Capacity (MWe)	-	-	35
Operation hours (h/a)	6,000	6,000	6,000
Efficiency	88.5%	87.0%	85.0%
Construction time (a)	2	2	2
Technical lifetime (a)	25	25	25
Annual degradation	0.5%	0.5%	0.5%
Commercial assumptions			
CAPEX (EUR/MWh _{th})	0.842	1.177	1.314
OPEX (EUR/MWh _{fuel})	4.32	5.11	5.26
Fuel cost (EUR/MWh _{fuel})*	22.5	22.5	22.5

*until 2025, 1%/a increase after that

Table II. Input data for calculations – 200 MW heating capacity.

200 MW heating capacity	HOB	SG	CHP
Technical assumptions			
Capacity (MWe)	-	-	90
Operation hours (h/a)	6,000	6,000	6,000
Efficiency	88.5%	87.0%	86.0%
Construction time (a)	2	2	2
Technical lifetime (a)	25	25	25
Annual degradation	0.5%	0.5%	0.5%
Commercial assumptions			
CAPEX (EUR/MWh _{th})	0.686	1.019	1.142
OPEX (EUR/MWh _{fuel})	3.71	4.60	4.53
Fuel cost (EUR/MWh _{fuel})*	22.5	22.5	22.5

*until 2025, 1%/a increase after that

A WACC of 5.7% is applied in the calculations [3].

B. Calculation results

Results of the LCOE calculations are presented in the following table and they omit the feed-in tariff for biomass-based electricity production.

Table III. Results of the LCOE calculations.

Plant type	LCOE (EUR/MWh)
100 MW heating capacity	
Heat only boiler (HOB)	46.19*
Steam generator (SG)	52.87*
Incremental HOB → CHP, 35 MWe	63.72
Incremental SG → CHP, 35 MWe	44.37
200 MW heating capacity	
Heat only boiler (HOB)	43.06*
Steam generator (SG)	49.82*
Incremental HOB → CHP, 90 MWe	54.35
Incremental SG → CHP, 90 MWe	40.97

*LCOE for heat only production

As Table III indicates, there are benefits from economies of scale, i.e. costs of electricity production are notably lower with the larger plant size. Moreover, the difference of the production costs between a HOB and a SG is significant: LCOE (heat production) of the SG is approximately 15% higher in both plant sizes. However, also the difference in the incremental electricity production costs is substantial.

C. Least-cost investment strategy

To gain a deeper understanding of the results, we study the least-cost strategy for an investor in a market with demand for 200 MW heating capacity. The method is based on finding the highest NPV in each scenario. Subventions for biomass-based CHP electricity production are assumed to continue according to the current law on RES subvention in Finland (30.12.2010/1396) 25 §. We analyse the following three scenarios with different electricity and CO₂ emissions allowances prices:

- 1) Low price scenario: electricity and CO₂ emissions allowances prices remain at 30 EUR/MWh and 10 EUR/t until 2045, respectively
- 2) Intermediate price scenario: electricity and CO₂ emissions allowances prices are the averages of those in scenarios 1 and 3
- 3) High price scenario: price of electricity and CO₂ emissions allowances develop according to the national energy and climate strategy of Finland (42.5 EUR/MWh and 15 EUR/t in 2020, 57.5 EUR/MWh and 22.5 EUR/t in 2025 and 62.5 EUR/MWh and 30 EUR/t from 2030 onwards [12])

The best investment strategy in scenario 1 is to invest in a 200 MW HOB. Despite the feed-in tariff of 18 EUR/MWh for electricity production for the first 12 years of operation, the investment is not economically justifiable. In scenario 3, the highest NPV is achieved via a direct investment in a CHP plant. Taking into account the feed-in tariff and the higher value of CHP production comparing to the average spot price, the electricity sales price surpasses the calculated LCOE already in the first year of operation.

Scenario 2, on the other hand, deserves a more thorough scrutiny. Investment in a CHP plant results in a slightly negative NPV (-5.2 MEUR, comparing to -52.6 MEUR in scenario 1), and an increase of 1 EUR/MWh in the average spot price throughout the plant's technical lifetime would already make the investment feasible. We then analysed whether an initial investment in a SG with a turbine investment later on would be feasible in scenario 2 with negative results. The current feed-in tariff for bio-CHP decreases as the emissions allowances price increases, and the rising emission allowances price is one of the main components that could cause an increase in the average price of electricity in the Nordics.¹ The revenues for a bio-CHP

¹ Recent and future power plant investments in Finland are mainly in wind and nuclear power plants. Both are carbon neutral and have low short-term marginal costs, and therefore are most probably not about to increase the average electricity market price. Generation units with higher marginal costs, such as condensing coal plants, have left the market as uncompetitive during

plant are hence very even in our scenario and, consequently, there is no clear justification for postponing the turbine investment. In fact, the sooner the turbine investment is made, the higher the NPV of the investment is. It should be noted, however, that the SG in question has notable over-capacity in heat only production, as it is designed to still have 200 MW of heating capacity after the turbine investment.

IV. THE POTENTIAL OF STATE AID

In the European Union (EU), the granting of State aid is governed by Article 107(1) of the Treaty of the Functioning of the European Union (TFEU). The provision prohibits all aid in any form whatsoever if it fulfils four cumulative criteria. First, the aid must be granted by a Member State or through State. Secondly, it must distort or threaten to distort competition. Thirdly, the aid measure must be selective in the sense that it favours certain undertakings or the production of certain goods. Finally, the aid is only prohibited if it affects trade between Member States.² There is an abundant body of case law, which demonstrates the broad interpretation given to Article 107(1) TFEU.³

In practice, the *prima facie* broad prohibition of State aid is significantly narrowed by an extensive body of exemptions, which can be successfully invoked if certain criteria are met. Two main legal bases relevant in the context of Finnish CHP are identified here. First, the Block Exemption Regulation declares certain aid schemes compatible with the internal market.⁴ Second, Article 107(3)(c) TFEU allows aid to facilitate the development of certain economic activities or of certain economic areas on the condition that such aid does not adversely affect trading conditions to an extent contrary to the common interest. These options are next analysed with regard to Finnish CHP.

A. The Block Exemption Regulation

The Block Exemption Regulation includes several provisions, which could be invoked to justify State aid for CHP. First, aid to support CHP could be defended by Article 38 regarding investment aid for energy efficiency measures or by Article 40 regarding investment aid for high-efficiency cogeneration as defined by Article 2(34) of the Energy Efficiency Directive.⁵ Secondly, State aid for CHP could be

the 2020s. Thus, the rising price of emission allowances is the most plausible reason for the increasing price of electricity in the Nordics.

² Article 107 of the Consolidated version of the Treaty on the Functioning of the European Union, OJ C 326, 26.10.2012, p. 47–390.

³ C-399/08 P *Commission v Deutsche Post* [2010] ECR I-7831; C- 237/04 *Enirisorse* [2006] ECR I- 2843; C-206/06 *Essent Netwerk Noord and Others* [2008] ECR I-5497; C-522/13 *Ministerio de Defensa and Navantia* [2014] Judgment of the Court, 9 October 2014; Philipp Werner and Vincent Verouden (eds.), *EU state aid control: law and economics* (Wolters Kluwer, 2017); Conor Quigley, *European State aid law and policy* (Hart publishing, 2015); Kelyn Bacon, *European Union law of state aid*. 3rd Edition (Oxford University Press, 2017).

⁴ Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, OJ L 187, 26.6.2014, p. 1–78.

⁵ Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, OJ L 315, 14.11.2012, p. 1–56.

defended by Article 36, which lays down rules on the types of investment aid allowed in the interest of enabling undertakings to go beyond Union standards for environmental protection or to increase the level of environmental protection in the absence of Union standards. The application of these provisions is limited by additional requirements, which vary depending on the provision in question. For example, Article 38(3) of the Block Exemption Regulation only allows the State to cover costs that are directly linked to the achievement of a higher level of energy efficiency. Therefore, an aid scheme supporting the mere option for an improvement in energy efficiency would be unlikely to be compatible with the Regulation. This interpretation is particularly relevant in terms of potential support for a SG, which does not improve efficiency as such, but only leaves the option open for future CHP investment, which would ultimately improve energy efficiency if completed. As another example, the investment aid covered by Article 40 is only allowed in respect of newly installed or refurbished capacities. The application of these legal bases is also limited by maximum thresholds for annual aid allowed for each aid type.⁶

B. Certain economic activities in Article 107(3)(c) TFEU

It is well-established that granting State aid in the energy sector may be compatible with the internal market on the basis of Article 107(3)(c) TFEU. The interpretation of this broadly formulated provision is further elaborated in the European Commission's Guidelines on State aid for environmental protection and energy 2014–2020.⁷ Although the Guidelines are not legally binding on Member States, they bind the Commission itself when it assesses Member States' aid schemes and therefore, provide valuable legal predictability for Member States planning aid schemes.

The Guidelines include relevant guidance on aid schemes for not only energy efficiency measures, including cogeneration, but also financial measures to safeguard generation adequacy. Support for CHP in the Finnish context can be assessed under both rules. In accordance with the general conditions laid down by the Guidelines, compatible aid must contribute to a well-defined objective of common interest. The aid measure must be necessary, appropriate, transparent and proportional and it must have a demonstrable incentivising effect. Finally, the aid must avoid undue negative effects on competition and trade.⁸ In addition, the Guidelines establish specific conditions for aid schemes depending on whether they are introduced in the interest of energy efficiency or in the interest of generation adequacy.

Adopting an aid scheme in the interest of energy efficiency can only be considered compatible with the internal market if it is granted for investment, including upgrades, to high-efficient CHP as defined by Article 2(34) of the Energy

Efficiency Directive.⁹ Furthermore, there is a case for arguing that investment aid in generation capacity cannot be justified on grounds of energy efficiency if there is no market demand for the capacity. Moreover, the requirement of an incentivising effect may prove impossible to demonstrate if the aid scheme only delivers an option for a future CHP investment but not an actual commitment to an improvement in energy efficiency. Overall, invoking an energy efficiency interest under both the Block Exemption Regulation and the Guidelines in terms of CHP requires that the measure is justified on grounds of energy efficiency, whereas the Finnish rationale for pursuing CHP is based on concerns over security of supply and generation adequacy in particular.

Defending an aid scheme on grounds of generation adequacy is potentially even more challenging than doing so in the interest of energy efficiency. This is particularly because the Guidelines require that there is a need for State intervention, which can bring about a material improvement that the market alone cannot deliver. In contrast, recent research indicates that generation adequacy in the Finnish electricity market is not threatened to an extent that would currently justify the adoption of a support scheme for generation capacity, e.g. [7]. In addition, support for generation capacity should be allocated on a non-discriminatory and competitive basis, which is likely to exclude the allocation of aid to CHP alone.¹⁰

C. Comparing the legal options for State aid

Granting State aid on grounds of Article 107(3)(c) TFEU and the Guidelines on the one hand and adopting a State aid scheme on the basis of the Block Exemption Regulation has significant differences. Three essential differences are identified here with regard to CHP.

The first difference between these two legal grounds is procedural. If the conditions laid down in the Block Exemption Regulation are fulfilled, the aid does not have to be notified to the Commission in accordance with Article 108 TFEU but can be processed on a national level. In comparison, an exemption by Article 107(3)(c) TFEU and the Guidelines still requires a Commission review under most circumstances.¹¹ Secondly, the Block Exemption Regulation only allows investment aid with regard to CHP, whereas both investment and operating aid is possible within the framework of the Guidelines.

Finally, there is a significant difference in terms of the common interest that is pursued through the aid scheme. The importance set for energy efficiency in the EU energy policy ensures that options for granting aid in the interest of energy efficiency are more extensive than for aid schemes pursuing other interests. The reserved approach to generation adequacy measures, and especially to capacity mechanisms, is particularly clear in comparison to energy efficiency. This

⁶ Chapter 1 of the Block Exemption Regulation.

⁷ Communication from the Commission — Guidelines on State aid for environmental protection and energy 2014–2020, OJ C 200, 28.6.2014, p. 1–55.

⁸ Guidelines on State aid for environmental protection and energy 2014–2020, OJ C 200, 28.6.2014, p. 1–55, para. 27.

⁹ Guidelines on State aid for environmental protection and energy 2014–2020, OJ C 200, 28.6.2014, p. 1–55, para. 139.

¹⁰ Report from the Commission, Final Report of the Sector Inquiry on Capacity Mechanisms, COM(2016) 752 final.

¹¹ Guidelines on State aid for environmental protection and energy 2014–2020, OJ C 200, 28.6.2014, p. 1–55, para. 20.

difference demonstrates the concern that aid for generation adequacy may contradict the objective of phasing out environmentally harmful subsidies.

V. DISCUSSION AND CONCLUSIONS

We have analysed trends and the role of cogeneration in the Finnish energy market. Moreover, we have examined the economics of biomass-based thermal production (heat only and CHP) in Finland with the LCOE method. In addition, we have studied the optimal investment strategies in three different electricity price scenarios based on the NPV method. Finally, we have identified the legal framework within which subsidisation for the provision of generation adequacy and energy efficiency is possible.

First, we analysed the economics of bio-CHP production in comparison with heat only production. Our calculations resulted in LCOEs of 63.70 EUR/MWh and 54.40 EUR/MWh for bio-CHP plants with district heating capacities of 100 MW and 200 MW, respectively, when comparing with HOBs with corresponding heating capacities. However, a HOB and a CHP plant are practically mutually exclusive, as a HOB is ill-suited for a turbine investment later on. Therefore, replacing the retiring CHP capacity with HOBs in the 2020s could result in plausible generation inadequacy in the future. A steam generator, on the other hand, would leave the option for a turbine investment in the future. Our calculations resulted in incremental LCOEs of 44.40 EUR/MWh and 41.00 EUR/MWh for the turbine investment with existing steam generators with 100 MW and 200 MW district heating capacities, respectively. However, investing in a steam generator is both technically and economically more demanding than in a HOB, and hence makes no sense in the investor's perspective without additional incentives or certainty that the market price will eventually rise higher.

We analysed the least-cost strategy for an investor in three different electricity and emission allowances price scenarios. If the average electricity price remains around 30 EUR/MWh, HOBs are clearly the more reasonable option. If the average electricity price rises as predicted in the national energy and climate strategy, a direct investment in a CHP plant is the most profitable option. In the intermediate price scenario, on the other hand, minor additional policy instruments could make a difference. An increase of 1 EUR/MWh in the average electricity spot price or a corresponding increment in the current subsidy mechanism would already make the 90/200 MW CHP plant economically feasible. The current feed-in tariff for bio-CHP decreases as the price of emissions allowances increases, thus resulting in very even revenues for a bio-CHP plant in the scenario. Consequently, there is no clear economic justification for investing in a steam generator instead of a HOB and postponing the turbine investment in the intermediate price scenario either.

The future of Finnish CHP production is therefore contradictory. On the one hand, the energy and climate strategy expects significant security of supply contributions

from CHP in the future. On the other hand, the analysis conducted above demonstrates an apparent lack of economic justifications to keep CHP operational or to invest in a steam generator to leave an option for a future CHP investment. Therefore, fulfilling the expectations of the strategy would require a significant increase in market prices or, in the absence of such an increase, State-driven financing. However, the legal analysis above indicates that such State financing to CHP or steam generators in the interest of generation adequacy is unlikely to comply with EU law.

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