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SURVEY ON THE COSTS OF ENTERING ELECTRICITY MARKET IN FINLAND – COST OF NEW ENTRY (CONE)

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CONTENTS

1. INTRODUCTION

Every EU member state shall have a reliability standard in place when applying electricity market capacity mechanisms. For the calculation of standard, the costs of the new power capacity need to be determined. Figure 1 illustrates the power demand between 2015 and 2017 in Finland. The peak electricity demand has been app. 14.000 MW and the capacity need has been less than 11.000 MW app. ten months in a year. The demand has been approximately equal also after the year 2017.

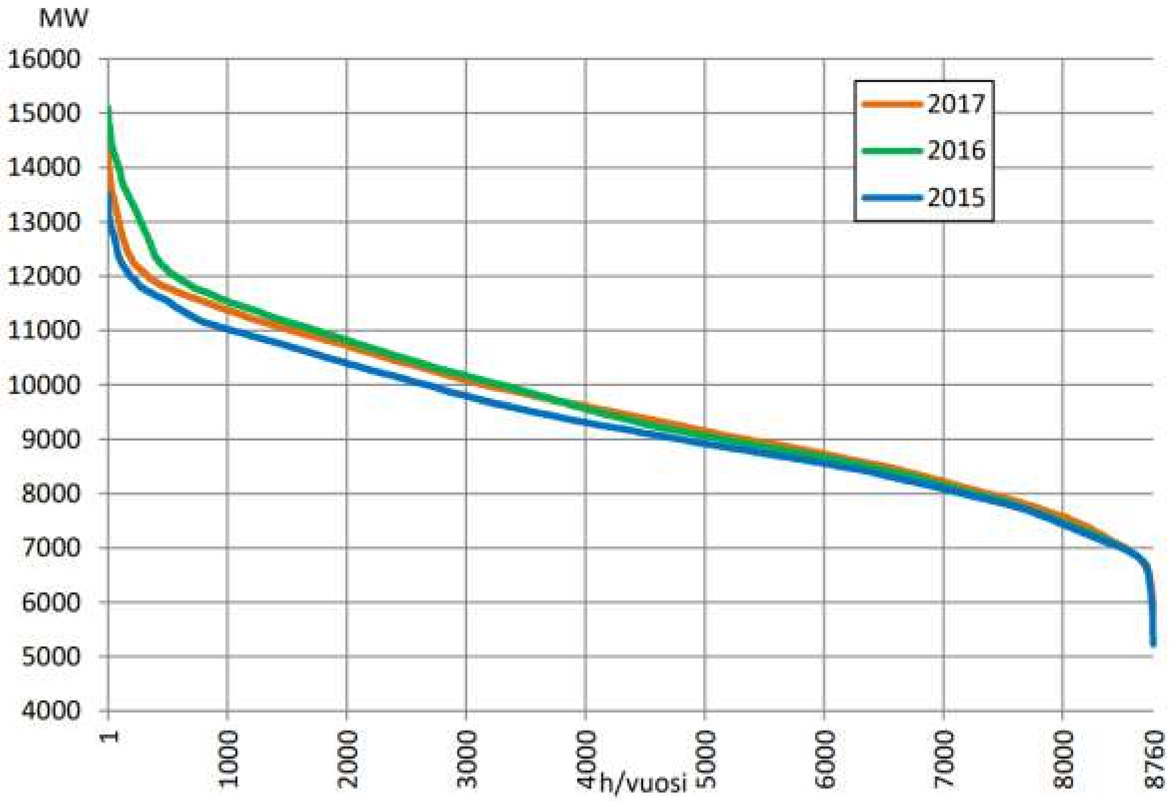

Figure 1. Duration curve of Finnish electricity use. [1]

In this report the cost of new entry (CONE) is determined for relevant technologies in maintaining the balance of electricity system in Finland. Chosen reference technologies can be related to electricity generation, storages or Demand Side Management (DSM). Report is ordered by Finnish Energy Authority and conducted by Ramboll Finland Oy (consultant).

Report introduces publicly available estimates for fixed and variable costs of new entry ($CONE_{fixed}$ and $CONE_{var}$). The determination of renewal/prolongation of existing capacity ($CORP_{fixed}$ and $CORP_{var}$) is also presented. These values are needed in the calculation of reliability standard. The calculation methods are based on the ACER Decision on the Methodology for calculating the value of lost load, the cost of new entry, and the reliability standard (October 2nd, 2020) in accordance with Article 23(6) of Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity.

2. IDENTIFICATION AND SELECTION OF REFERENCE TECHNOLOGIES

In this chapter the identification and selection of reference technologies is executed. As a starting point consultant has composed a longlist of all available technologies for power generation, power storing and demand side management.

The selected reference technologies need to be considered as standard technology and they need to have potential for new capacity (potential new entry) in Finland. The selection process is described in detail in the following subchapters.

2.1 Longlist of technologies

The following power generation, power storage and demand side management technologies were identified as candidates of reference technologies in Finland by the consultant.

Candidate technologies of power generation are presented in Table 1, Table 2 and Table 3.

Table 1. Condensing power alternatives.

Candidate Technology
POWER GENERATION
Condensing power
1. Nuclear power plants
2. Coal-fired power plants
3. Gas turbines
4. Gas engines
5. Diesel engines
6. Biomass-fired power plants
7. Waste-to-Energy plants

Table 2. Combined heat and power alternatives.

Candidate Technology
POWER GENERATION
Combined Heat and Power (CHP)
8. Nuclear power plants
9. Coal-fired power plants
10. Gas turbines
11. Gas engines
12. Diesel engines
13. Biomass-fired power plants
14. Waste-to-Energy plants
15. Utilization of current CHP capacity in power adjustment
16. Installation of low-pressure turbines in old CHP capacity
17. Capacity raise with auxiliary cooling and/or heat storages

Table 3. Power only alternatives.

Candidate Technology
POWER GENERATION
Power Only
18. Hydropower
19. Photovoltaics (PV)
20. Windpower

Candidate technologies of power storages are presented in Table 4.

Table 4. Power storage alternatives.

Candidate Technology
POWER STORAGES
21. Pumped hydro storages
22. Battery storages
23. Power-to-Gas

Candidate technologies of demand side management are presented in Table 5 and Table 6.

Table 5. Demand side management of real estates.

Candidate Technology
DEMAND SIDE MANAGEMENT (DSM)
DSM 1: Households
24. Electric heating and other loads
DSM 2: Real estates and Service Sector
25. HVAC, lighting and other loads

Table 6. Demand side management of other systems.

Candidate Technology
DEMAND SIDE MANAGEMENT (DSM)
Other
26. Utilization of heat pumps in DH production
27. Industrial power consumption

2.2 Potential New Entry

In this subchapter new entry (capacity) potential of every longlisted technology is evaluated. Technology is considered potential new entry if

- its capacity has been developed in the recent years, is in process of development, or is planned for development for the considered timeframe; and
- future development of this technology is allowed and is not significantly hampered by the (national and European) regulatory framework.

In this survey the timeframe for new capacity development in the future is considered **five to ten years**.

2.2.1 Condensing power

1. **Nuclear power plants**
   In Finland condensing nuclear power is an important part of the energy system. New capacity is being built and planned. **Potential new entry: YES**

2. **Coal-fired power plants**
   Currently one coal-fired condensing power plant is in operation in Finland. New capacity is not built or planned due to drift to decrease the CO_2-emissions of energy production. Coal-fired power and heating generation will be banned as of 1 May 2029 in Finland. [2]
   Potential new entry: NO

3. **Gas turbines**
   New capacity of gas turbines is not being developed in Finland. **Potential new entry: NO**

4. **Gas engines**
   New capacity of gas engines without heat recovery is not being developed in Finland.
   Potential new entry: NO

5. **Diesel engines**
   Current capacity of diesel engines is mainly used as reserve electrical capacity in the industry. New capacity of diesel engines without heat recovery is not being developed in Finland. **Potential new entry: NO**

6. **Biomass-fired power plants**
   Electricity produced by combusting biomass is mainly CHP production in Finland. Capacity of biomass-fired condensing power is not being developed. **Potential new entry: NO**

7. **Waste-to-Energy plants**
   Waste combustion capacity developed in recent years and capacity currently being developed in Finland is only for CHP production. **Potential new entry: NO**

Potential new entry assessment of condensing power technologies is presented in table 7.

Table 7. Conclusion of new entry potential for condensing power technologies.

Candidate Technology	Capacity developed in recent years?	Capacity in develop-ment?	Planned capacity for the considered timeframe?	Future development allowed/not hampered by national framework?	Future development allowed/not hampered by EU framework?	Potential new entry?
POWER GENERATION						
Condensing power						
1. Nuclear power plants	Yes	Yes	Yes	No	No	**Yes**
2. Coal-fired power plants	No	No	No	Yes	No	**No**
3. Gas turbines	No	No	No	No	No	**No**
4. Gas engines	No	No	No	No	No	**No**
5. Diesel engines	No	No	No	No	No	**No**
6. Biomass-fired power plants	No	No	No	No	No	**No**
7. Waste-to-Energy plants	No	No	No	No	No	**No**

2.2.2 Combined Heat and Power (CHP)

8. **Nuclear power plants**
   Nuclear power capacity being currently developed is only condensing power. **Potential new entry: NO**

9. **Coal-fired power plants**
   There is coal-fired CHP capacity in production in Finland. However, new capacity is not built or planned due to drift to decrease the CO_2 emissions of energy production. Coal-fired power and heating generation will be banned as of 1 May 2029 in Finland (Ministry of Economic Affairs, 2019). **Potential new entry: NO**

10. **Gas turbines**
    New capacity of gas turbines is not being developed in Finland. **Potential new entry: NO**

11. **Gas engines**

    a. **Natural gas**
       New capacity of natural gas fired gas engines with heat recovery is not being developed in Finland. **Potential new entry: NO**

    b. **Biogas**
       New capacity of biogas/landfill gas fired gas engines with heat recovery has been developed in recent years in Finland. **Potential new entry: YES**

12. **Diesel engines**
    New capacity of diesel engines with heat recovery is not being developed in Finland. **Potential new entry: NO**

13. **Biomass-fired power plants**
    Large-scale biomass-fired CHP power plants have an important role in Finnish electricity production. New capacity has been developed in recent years and is currently being developed. **Potential new entry: YES**

14. **Waste-to-energy plants**
    Major capacity increase has occurred in recent years. New capacity is being built in Salo and the capacity of existing waste-to-Energy plants is planned to be increased. **Potential new entry: YES**

15. **Utilization of current CHP capacity in power adjustment**
    Existing turbine capacity already supports electrical resource adequacy by reacting to changes on electricity market price. **Potential new entry: NO**

16. **Installation of low-pressure turbines in old CHP capacity**
    Low-pressure turbines are not being installed in old CHP capacity. In recent years the development has headed to the opposite direction when existing low-pressure turbine capacity has been disassembled. **Potential new entry: NO**

17. **Capacity raise with auxiliary cooling and/or heat storages**
    New electrical resource adequacy supporting capacity has been developed in recent years and is currently being developed. **Potential new entry: YES**

Potential new entry assessment of CHP technologies is presented in table 8.

Table 8. Conclusion of new entry potential for CHP technologies.

Candidate Technology	Capacity developed in recent years?	Capacity in develop-ment?	Planned capacity for the considered timeframe?	Future development allowed/not hampered by national framework?	Future development allowed/not hampered by EU framework?	Potential new entry?
POWER GENERATION						
Combined Heat and Power (CHP)						
8. Nuclear power plants	No	No	No	No	No	**No**
9. Coal-fired power plants	No	No	No	Yes	No	**No**
10. Gas turbines	No	No	No	No	No	**No**
11. Gas engines						
a. Natural gas	No	No	No	No	No	**No**
b. Biogas	Yes	Yes	Yes	No	No	**Yes**
12. Diesel engines	No	No	No	No	No	**No**
13. Biomass-fired power plants	Yes	Yes	Yes	No	No	**Yes**
14. Waste-to-Energy plants	Yes	Yes	Yes	No	No	**Yes**
15. Utilization of current CHP capacity in power adjustment	Yes	Yes	Yes	No	No	**No**
16. Installation of low-pressure turbines in old CHP capacity	No	No	No	No	No	**No**
17. Capacity raise with auxiliary cooling and/or heat storages	Yes	Yes	Yes	No	No	**Yes**

2.2.3 Power Only

18. **Hydropower**
    New hydropower capacity is not in development in Finland. **Potential new entry: NO**

19. **Photovoltaics (PV)**

    a. **Residential rooftop PV**
       There has been a remarkable increase in the capacity of residential rooftop PV in recent years. New capacity is being and will be developed. **Potential new entry: YES**

b. **Commercial PV**
There is a major increase also in commercial PV capacity in recent years. New capacity is being and will be developed. **Potential new entry: YES**

20. Wind power

a. **Onshore**
There has been a major increase in onshore wind power capacity in recent years. New capacity is being and will be developed. **Potential new entry: YES**

b. **Offshore** New offshore wind power capacity has been developed in recent years in Meri-Pori and new capacity is being developed e.g. in Kemi Ajos. **Potential new entry: YES**

Potential new entry assessment of power only technologies is presented in table 9.

Table 9. Conclusion of new entry potential for power only technologies.

Candidate Technology	Capacity developed in recent years?	Capacity in develop-ment?	Planned capacity for the considered timeframe?	Future development allowed/not hampered by national framework?	Future development allowed/not hampered by EU framework?	Potential new entry?
POWER GENERATION						
Power Only						
18. Hydropower	No	No	No	No	No	No
19. Photovoltaics (PV)						
a. Residential rooftop PV	Yes	Yes	Yes	No	No	Yes
b. Commercial PV	Yes	Yes	Yes	No	No	Yes
20. Wind power						
a. Onshore wind	Yes	Yes	Yes	No	No	Yes
b. Offshore wind	Yes	Yes	Yes	No	No	Yes

2.2.4 Power Storages

21. Pumped hydro storages
Pumped hydro storage capacity has not been developed or is not currently being developed in Finland. **Potential new entry: NO**

22. Battery storages

a. **Buildings-grid connected storages**
Development of the modular electricity battery storage technology, prices and installed capacity has occurred in recent years and further development is expected in near future. Most potential stationary application is Li-ion battery technology and readiness level is mature technology. **Potential new entry: YES**

b. **Utility-grid connected storages**
Development in the large-scale electricity battery storage technology, prices and installed capacity has occurred in recent years and further development is expected in near future. Most potential stationary application is Li-ion battery technology and readiness level is mature technology. **Potential new entry: YES**

23. Power-to-Gas

Power-to-Gas (and gas-to-power) technology is not yet in the commercial phase. Potential/planned capacity increase is not within the considered timeframe (5–10 years). **Potential new entry: NO**

Potential new entry assessment of power storage technologies is presented in table 10.

Table 10. Conclusion of new entry potential for power storages.

Candidate Technology	Capacity developed in recent years?	Capacity in develop-ment?	Planned capacity for the considered timeframe?	Future development allowed/not hampered by national framework?	Future development allowed/not hampered by EU framework?	Potential new entry?
POWER STORAGES						
21. Pumped hydro storages	No	No	No	No	No	**No**
22. Battery storages						
a. Buildings-grid connected storages	Yes	Yes	Yes	No	No	**Yes**
b. Utility-grid connected storages	Yes	Yes	Yes	No	No	**Yes**
23. Power-to-Gas	No	No	No	No	No	**No**

2.2.5 Demand Side Management (DSM)

24. DSM 1: Households

a. Electric heating and other loads

Electric heating (direct heating, water heat storages) is popular in the small real estates (houses, rowhouse apartments etc.) and has a massive potential not yet fully utilized as DSM. Remote-controlled capacity has been developed. **Potential new entry: YES**

25. DSM 2: Real estates and Service Sector

a. HVAC, lighting and other loads

HVAC (Heating, Ventilation, Air and Cooling) and lighting systems in buildings (commercial and real estates, service sector and small industry) has load cutting and balancing potential, not yet fully utilized Finland. Pilot projects and reference solutions has been developed in recent 5 years. Also Demand Response controlled commercial refrigeration and cooling capacity has been developed in recent years and is currently being developed. The number of EV (electric vehicles) has increased in Finland lately, and expected growth in popularity in load control will offer a huge DSM potential in the future. **Potential new entry: YES**

Potential new entry assessment of DSM technologies in real estates is presented in table 11.

Table 11. Conclusion of new entry potential for demand side management in real estates.

Candidate Technology	Capacity developed in recent years?	Capacity in develop-ment?	Planned capacity for the considered timeframe?	Future development allowed/not hampered by national framework?	Future development allowed/not hampered by EU framework?	Potential new entry?
DEMAND SIDE MANAGEMENT (DSM)						
DSM 1: Households						
24. Electric heating and other loads	Yes	Yes	Yes	No	No	**Yes**
DSM 2: Real estates and Service Sector						
25. HVAC, lighting and other loads	Yes	Yes	Yes	No	No	**Yes**

26. Utilization of heat pumps in DH production

Exiting district heat producing heat pump capacity is considered to already react on electricity price. Future heat pump capacity will also increase electricity consumption and is therefore considered not to support resource adequacy. **Potential new entry: NO**

27. Industrial power consumption

The estimates for technical potential of DR in industrial load are mainly formed from pulp and paper, metal and chemical industry currently. Some of industry areas already been contracted as TSO disturbance reserve. There is challenge for Demand Response as industrial processes need to be run a continuous basis. **Potential new entry: YES**

Potential new entry assessment of DSM technologies in other than real estates is presented in table 12.

Table 12. Conclusion of new entry potential for demand side management in other than the real estates.

Candidate Technology	Capacity developed in recent years?	Capacity in develop-ment?	Planned capacity for the considered timeframe?	Future development allowed/not hampered by national framework?	Future development allowed/not hampered by EU framework?	Potential new entry?
DEMAND SIDE MANAGEMENT (DSM)						
Other						
26. Utilization of heat pumps in DH production	Yes	Yes	Yes	No	No	**No**
27. Industrial power consumption	Yes	Yes	Yes	No	No	**Yes**

2.3 Standard Technology

Besides having potential for new capacity (potential new entry) each reference technology shall be standard. For standard technology

- reliable and generic cost information is available
- the costs of building and operating units of the technology shall be of the same order of magnitude from one project to another; and
- development of the technology is not significantly bound by technical constraints. Technologies with limited individual capacity which can be aggregated in homogeneous clusters shall be considered as standard if reliable data is available to characterize these clusters.

Some industry areas have already been contracted to reserves, but currently reliable and generic cost information is not available for future potential capacity increase. **Industrial power consumption is not acceptable as standard technology.**

All the other technologies with new entry potential were considered standard technology.

2.4 Reference technologies and their potential for additional capacity

Reference technologies are the technologies having potential in maintaining the electricity system balance (reference technologies) in Finland. Reference technologies and their potential for additional capacity are listed in the Table 13 – Table 17.

1. Nuclear power

In this survey the Olkiluoto 3 power plant currently being constructed is considered existing capacity and is therefore not included in the potential for additional capacity. According to the project schedule the Fennovoima nuclear plant Hanhikivi 1 is in operation within the considered timeframe. **Additional capacity potential for nuclear condensing power is therefore considered 1.200 MW.**

Table 13. Capacity addition potentials for condensing nuclear power.

Candidate Technology	Standard technology?	Potential new entry?	Reference technology?	Potential for additional capacity
				MW
POWER GENERATION				
Condensing power				
1. Nuclear power plants	Yes	Yes	Yes	**1200**

11. Gas engines

b. Biogas

Potential for additional capacity of biogas-fired engines is dependent on available biogas. In this survey only current biogas production is examined (no new digestion capacity). Currently biogas is mostly utilized both in CHP production (gas engines) and as transport fuel. Only transport fuel is considered because the other portion is already utilized in CHP production. Transport fuel use is 79 GWh/year ([3]) which equals to about 10,5 MW total thermal capacity (with 7.000 h full load hours) of which **about 3 MW could be converted to electrical capacity** (electric efficiency 30 %).

13. Biomass-fired power plants

The potential for additional capacity for biomass-fired power plants is evaluated based on the idea of replacing the current peat and biomass-fired heat only boiler (HOB) capacity with CHP capacity. Of the currently operating HOB capacity only 40+ GWh producing boilers (consuming DH networks) are considered viable for CHP production. In 2019 in total 4.180 GWh of heat only production took place. **About 310 MW of HOB replacing biomass-fired CHP capacity** (4.000 h full load hours, 0,3 power-to-heat ratio) could be constructed based on this figure.

14. Waste-to-Energy plants

Evaluation of the full waste-to-energy plant capacity is based on the waste (municipal solid waste and other waste types) available in Finland. In Finland landfilling organic waste was banned in 2016 [4] after which most of combustible waste is utilized in CHP production. Some combustible waste is also exported. In 2019 Finland exported 95.000 tons of mixed municipal waste, domestic waste, treated wood waste, and refuse derived fuel. This amount of waste equals to about 11 MW of power production (10MJ/kg heating value, 7.000 h full load hours, 0,3 power-to-heat ratio). This means that additional capacity potential for waste-to-energy plants is very small in Finland. After finishing the waste-to-energy plant capacity being built currently, presumably even smaller potential for new capacity is left. In addition to this waste combustion is against the official recycling targets in EU. **Therefore, the potential for additional capacity of waste-to-energy plants in this survey is considered 0 MW.**

18. Capacity raise with auxiliary cooling and/or heat storages

CHP plant's power output can be raised with a heat sink like auxiliary cooling to lakes/air or loading heat storage when district heat consumption is low. However, this is usually the situation only during the period between spring and autumn when the available power capacity is not in full use and there is enough capacity to recover from a major disturbance in electric network (see Finnish electricity duration curve in Figure 1). **Therefore, the potential for additional capacity of auxiliary cooling and/or heat storages is considered 0 MW in this survey.**

Table 14. Capacity addition potentials for gas engines, biomass-fired power plants, waste-to-energy plants, and auxiliary cooling and/or heat storages.

Candidate Technology	Standard technology?	Potential new entry?	Reference technology?	Potential for additional capacity
				MW
POWER GENERATION				
Combined Heat and Power (CHP)				
11. Gas engines				
b. Biogas	Yes	Yes	Yes	3
13. Biomass-fired power plants	Yes	Yes	Yes	314
14. Waste-to-Energy plants	Yes	Yes	Yes	0
18. Capacity raise with auxiliary cooling and/or heat storages	Yes	Yes	Yes	0

19. Photovoltaics (PV)

a. Residential rooftop PV

Total potential for residential rooftop PV systems in Finland is 12.000 MW. In the end of the year 2018 the total grid-connected PV capacity (rooftop + other) in Finland was about 120 MW which means that potential for additional residential rooftop PV capacity is still about 12.000 MW. Maximum peak power of the whole residential rooftop potential would be approximately 7.000 MW. [5] **The potential for additional capacity for residential rooftop PV in Finland is considered 7.000 MW in this survey.**

b. Commercial PV

The total rooftop PV potential for public, industrial, and other buildings in Finland is about 20.000 MW. It is assumed that most of this potential allows installation of commercial scale PV systems. Maximum peak power of the whole commercial scale rooftop potential would be approximately 12.000 MW. [5] The given figures don't include ground mounted solar PV potential which could increase the total potential significantly. **The potential for additional capacity for commercial scale rooftop PV in Finland is considered 12.000 MW in this survey.**

20. Wind power

a. Onshore wind

There are several ways to determine potential for additional capacity for wind power. Theoretical wind power production potential on land in Finland is as big as 198 TWh (capacity factor 25 % or more, 3 MW turbines with 90 m rotor diameter), [6] meaning about 92 GW of wind power capacity. This is however only theoretical potential. In studied 100 % renewable energy scenarios for 2050 onshore wind power capacity is between 30 and 36,5 GW in Finland. [7] In real life by February 2020, onshore wind power projects worth of 18.500 MW had been published in Finland. [8] **Based on these figures the potential for additional capacity for onshore wind power in Finland is considered 18.500 MW within the considered timeframe in this survey.**

b. Offshore wind

Theoretical offshore wind power production potential in Finland is 466 TWh (capacity factor 25 % or more, 3 MW turbines with 90 m rotor diameter), [6] which means about 216 GW of offshore wind power capacity. In studied 100 % renewable energy scenarios for 2050 onshore wind power capacity is between 5.000 and 6.000 MW in Finland. [7] By February 2020 worth of 2.700 MW onshore wind power development projects had been published in Finland. [8] **Based on these figures the potential for additional capacity for offshore wind power in Finland is considered 2.700 MW within the considered timeframe in this survey.**

Table 15. Capacity addition potentials for photovoltaics and wind power.

Candidate Technology	Standard technology?	Potential new entry?	Reference technology?	Potential for additional capacity MW
POWER GENERATION				
Power Only				
20. Photovoltaics (PV)				
a. Residential rooftop PV	Yes	Yes	Yes	7000
b. Commercial PV	Yes	Yes	Yes	12000
21. Wind power				
a. Onshore wind	Yes	Yes	Yes	18500
b. Offshore wind	Yes	Yes	Yes	2700

23. Battery storages

a. Buildings-grid connected storages

Buildings integrated battery systems, especially systems with photovoltaic production, are assumed to increase in near future as the capacity prices of Li-ion battery packs are decreasing and markets are developing. Residential and commercial battery sizes vary form a few kW to MW installations. Also, large building-grid integrated batteries has already been installed in Finland: 2MW/2,1MWh (Shopping Mall Sello) and for industrial building 2,6MW/2,6MWh (Lidl Logistic Center). New industrial building-grid connected 20MW battery is planned. [9] [10] [11] **Based on these figures, the increase in 10-year time horizon is assumed to be continue similar and in this survey 1.000 MW new battery power capacity considered. Capacity of battery storages has no theoretical limit.**

b. Utility-grid connected storages

Utility-grid battery installations has been recently made or planned in Finland for over 50 MW and nearly 40 MWh, to support wind power production [12]. First ever high-power electricity battery unit in Nordic region is built in Ylikkälä Finland, capacity 30MW/30MWh. **Due to increase in wind power and solar power capacity, increase in 10-year time horizon is assumed to be continue similar and new battery power capacity of 1.000 MW. Capacity of battery storages has no theoretical limit.**

Table 16. Capacity addition potentials for battery storages.

Candidate Technology	Standard technology?	Potential new entry?	Reference technology?	Potential for additional capacity
POWER STORAGES				
23. Battery storages				
a. Buildings-grid connected storages	Yes	Yes	Yes	**1000**
b. Utility-grid connected storages	Yes	Yes	Yes	**1000**

24. Demand Side Management

a. DSM1: Households

Over 95 % of electricity consumers have AMR-meter (Automatic Meter Reading), enabling already many years residential sector to attend implicit Demand Response, through smart meter and dynamic tariffs. New total potential of houses and small consumers demand side response has been estimated in several surveys. Potential is to be significant, especially in electrically heated buildings. Load control potential based on the enquiry to Finnish DSOs is over 1.000 MW for ToU (Time of Use) and direct control 800 MW. Potential is much larger, if all heating, electric car heaters and residential saunas are included. [13] **According to this, considered potential is 1.000 MW in this survey.**

b. DSM2: Real estates and Service Sector

Part of electricity consumers have controllable power load for faster/real time explicit Demand Response. HVAC (Heating, Ventilation, Air and Cooling) systems, Refrigeration and freezer warehouses can shave peak load with smart controls. Demand response has already been partly harnessed with smart control of BACS (Building Automation Control System) or HEMS (Home Energy Management System). Estimated new control potential is 500 – 1.000 MW, not including electrical vehicle potential [13] [14]. Smaller loads can be clustered with aggregator services for example to VPP (Virtual Power Plant), which are already active in Finnish demand response markets. **According to this, considered potential is 1.000 MW in this survey.**

Table 17. Capacity addition potential for demand side management in real estates.

Candidate Technology	Standard technology?	Potential new entry?	Reference technology?	Potential for additional capacity
DEMAND SIDE MANAGEMENT (DSM)				
DSM 1: Households				
24. Electric heating and other loads	Yes	Yes	Yes	**1000**
DSM 2: Real estates and Service Sector				
25. HVAC, lighting and other loads	Yes	Yes	Yes	**1000**

3. CALCULATION OF CONE

The cost of new entry (CONE) is calculated based on the methods presented by ACER for all reference technologies.

3.1 CONE$_{fixed}$

EAC (fixed annuity equivalent to capital (CC) and annual fixed costs (AFC)) value needed for CONE$_{fixed}$ is calculated with the following equation:

$$EAC = \left[\sum_{i=1}^{X} \frac{CC(i)}{(1+WACC)^i} + \sum_{i=X+1}^{X+Y} \frac{AFC(i)}{(1+WACC)^i}\right] \cdot \frac{WACC \cdot (1+WACC)^{X+Y}}{(1+WACC)^Y - 1}$$

Where:

- i represents each year over the construction period and economic lifetime;
- X is the construction period (in years);
- Y is the economic lifetime (in years);
- $CC(i)$ is the best estimate of the capital costs incurring each year of the construction period (in local currency per MW);
- $AFC(i)$ is the best estimate of the annual fixed costs incurring each year during the economic lifetime (in local currency per MW); and
- $WACC$ is the best estimate of WACC. WACC is the cost of capital applicable to a private investor investing in a reference technology. WACC should be technology specific (to account for risks, hedging opportunities, private investor’s profile etc.)

The actual CONE$_{fixed}$ value (cost of new entry) is calculated by dividing EAC with the de-rating factor.

$$CONE_{fixed,RT} = \frac{EAC_{RT}}{K_{\mathrm{d,RT}}}$$

Where:

- EAC_{RT} represents the EAC of a given reference technology (in local currency per MW); and
- $K_{\mathrm{d,RT}}$ is the de-rating capacity factor of the reference technology. De-rating capacity factor reflects the expected contribution of a reference technology to resource adequacy [15]

3.2 CONE$_{var}$

The CONE$_{var}$ cost elements considered are:

a) fuel costs estimated based on the efficiency of the generation reference technology and the expected price of fuel during the applied timeframe;

b) CO2 emission costs estimated based on the expected emission factor of the generation reference technology and the expected price of CO2 allowances during the applied timeframe;

c) Other variable OPEX costs consisting of the expected cost of consumable materials (ammonia, limestone, water, etc.), by-products handling (ash, slug, etc.), etc., as well as variable operating and maintenance cost estimated based on the number of expected operating hours and/or start-stop cycles of the generation or charge-discharge cycles of storage resource;

d) minimum activation prices for DSR resources;

e) taxes and levies which relate to variable production. [15]

3.3 Values Used in Calculation

Values for capital cost, annual fixed cost, economic lifetime, WACC, and de-rating factor used in CONE calculation are shown in table 18. Values are based on the literature sources shown on 'Source' columns.

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Table 18. Values for capital cost, annual fixed cost, variable operating cost, economic lifetime, WACC, and de-rating factor used in CONE calculation.

Candidate Technology	Capital cost [k€/MW]	Source	Annual fixed cost [k€/MW]	Source	Variable operating cost [€/MWh]	Source	Economic Lifetime [y]	Source	Construction Time [y]	Source	WACC %	Source	De-rating factor %	Source
POWER GENERATION														
Condensing power														
1. Nuclear power plants	3700	3606 [16], 3332-4832 [17]	42	41,6 [16]	7	5,2 [16], 6-25 [17]	40	40 [16]	6	6 [16]	10	10 [17]	81,22	81,22 [18]
POWER GENERATION														
Combined Heat and Power (CHP)														
11. Gas engines														
b. Biogas	1500	1500 [19]	57	56,5 [19]	120	VOM 15,5 [19] + 104 (traffic fuel cost) [39]	30		2	2 [19]	7		94,98	94,98 [18]
13. Biomass-fired power plants	3700	1562-5508 [17], 2170-3910 [20], 3550 [21]	74 (2 % of capex)	4-6 % of capex [20], 114 [21], 1-6 % of capex [22]	25	VOM 2-4 [23], 4-62 [17], 4 [21] + 22 fuel [23]	25	20 y [17], 25 y [16]	4		7	7 [17]	93,6	93,6 [24], 90 [18]
Power Only														
19. Photovoltaics (PV)														
a. Residential rooftop PV	1300	1200-1400 [25], 1400 [26]	30	2,5 % of capex [25], 9 [26]	0	0 [25]	25	25 [25]	1		3,8	3,8 [25]	1,5	1,17-1,76 [27]
b. Commercial PV	1000	600-1000 [25], 1000 [26] 1080 [16]	12	2,5 % of capex [25], 9 [26], 12 [16]	0	0 [25], 3 €/MW [16]	25	25 [25]	2		4,1	4,1 [25]	1,5	1,17-1,76 [27]
20. Wind power														
a. Onshore wind	1500	1500-2000 [25], 1360 [16], 1600 [26]	30	30 [25], 13 [16], 30 [26]	5	5, [25], 5 [16]	25	25 [25]	1		4,6	4,6 [25]	8,5	8,5 [27]
b. Offshore wind	4700	3100-4700 [25], 3800 [21], 3000 [16], 3600 [26]	100	100 [25], 100 [21], 60-110 [26]	5	5 [25]	25	25 [25]	2		6,9	6,9 [25]	13	13 [27]
POWER STORAGES														
22. Battery storages														
a. Residential battery storages	900	800-1400 [28] , [30], [32]	2,64	40 % of O&M fixed 6,6 [28]	0,3	0,3 [28]	15	10-15 [28]	1		7	7-10, [29], [33]	20,43	20,43-57,94 [18]
b. Large-scale battery storages	1200	800-1400 [28] , [30], [32]	6,6	6,6 O&M [28]	0,3	0,3 [28]	15	10-15 [28]	2		7	7-10, [29], [33]	20,43	20,43-57,94 [18]
DEMAND SIDE MANAGEMENT (DSM)														
DSR 1: Households														
24. Electric heating and other loa	70	Estimated from sources: 66-166 [13], [35] , [36]	8	7-10 [13]	9,3		15	[13]	1	[13]	10	7 [34]	86,14	86,14 [33]
DSR 2: Real estates and Service Sector														
25. HVAC, lighting and other load	38	Estimated from sources: 10 - 40 [13] , [35]	8	7-10 [13]	9,3		15	[13]	1	[13]	10	7 [34]	84,14	86,14 [33]

3.4 Results

Calculated $CONE_{fixed}$, and $CONE_{var}$ values and potentials for additional capacity in table 19.

Table 19 $CONE_{fixed}$, and $CONE_{var}$ values and potentials for additional capacity.

Reference Technology	$CONE_{fixed}$ [k€/MW]	$CONE_{var}$ [€/MWh]	Potential for additional capacity MW
POWER GENERATION			
Condensing power			
1. Nuclear power plants	537	7	1200

Reference Technology	$CONE_{fixed}$ [k€/MW]	$CONE_{var}$ [€/MWh]	Potential for additional capacity MW
POWER GENERATION			
Combined Heat and Power (CHP)			
11. Gas engines			
b. Biogas	214	120	3
13. Biomass-fired power plants	456	25	314

Reference Technology	$CONE_{fixed}$ [k€/MW]	$CONE_{var}$ [€/MWh]	Potential for additional capacity MW
POWER GENERATION			
Power Only			
20. Photovoltaics (PV)			
a. Residential rooftop PV	7431	0	7000
b. Commercial PV	5128	0	12000
21. Wind power			
a. Onshore wind	1583	5	18500
b. Offshore wind	3430	5	2700

Reference Technology	$CONE_{fixed}$ [k€/MW]	$CONE_{var}$ [€/MWh]	Potential for additional capacity MW
POWER STORAGES			
23. Battery storages			
a. Buildings-grid connected storages	570	0,3	1000
b. Utility-grid connected storages	694	0,3	1000

Reference Technology	$CONE_{fixed}$ [k€/MW]	$CONE_{var}$ [€/MWh]	Potential for additional capacity MW
DEMAND SIDE MANAGEMENT (DSM)			
DSM 1: Households			
24. Electric heating and other loads	20	9,3	1000
DSM 2: Real estates and Service Sector			
25. HVAC, lighting and other loads	22	9,3	1000

3.5 Additional Technologies

Turbines and engines running on natural gas were not considered reference technologies because of lacking capacity development in Finland lately, currently or in near future. Still gas turbines (OCGT) and gas engines are seen as potential solutions in supporting electrical resource adequacy in the future. This is why $CONE_{fixed}$ and $CONE_{variable}$ values are calculated in this survey also for these technologies. Values used in CONE calculation are presented in table 20 and $CONE_{fixed}$ and $CONE_{variable}$ values in table 21.

Table 20 Values for capital cost, annual fixed cost, economic lifetime, WACC, and de-rating factor used in CONE calculation.

Additional Technology	Capital cost	Source	Annual fixed cost	Source	Variable operating cost	Source	Economic Lifetime	Source	Construction Time	Source	WACC	Source	De-rating factor	Source
	[k€/MW]		[k€/MW]		[€/MWh]		[y]		[y]		%		%	
POWER GENERATION														
Power Only														
Gas turbine (OCGT), 200 MW	470	470 [19]	15,4	15,4 [19]	86	VOM 6,3 [19] + 68 fuel + 12 CO2	25	[19]	2	[19]	7		94,98	[18]
Gas engine, 80 MW	860	860 [19]	32,3	32,3 [19]	67	VOM 4,1 [19] + 51 fuel + 12 CO2	25		2	[19]	7		94,98	[18]

Table 21. $CONE_{fixed}$ and $CONE_{var}$ values and factor used in their calculation for large gas turbines (OCGT) and engines.

Reference Technology	$CONE_{fixed}$	$CONE_{var}$
	[k€/MW]	[€/MWh]
POWER GENERATION		
Power Only		
Gas turbine (OCGT), 200 MW	60	86
Gas engine, 80 MW	114	67

4. CORP

4.1 $CORP_{fixed}$

$CORP_{fixed}$ (cost of renewal or prolongation) means "the total annual net revenue per unit of de-rated capacity (net of variable costs) that an existing capacity resource, which is renewed or whose lifetime is prolonged, would need to receive over its remaining economic lifetime in order to recover the incurred capital costs related to the renewal or prolongation and annual fixed costs". [15]

4.2 $CORP_{var}$

The variable cost of renewal or prolongation represents the variable costs of the power production capacity after the renewal or prolongation (construction/reparation work etc.). The considered $CORP_{var}$ cost elements are the same as the ones used in $CONE_{var}$ calculation:

a) fuel costs estimated based on the efficiency of the generation reference technology and the expected price of fuel during the applied timeframe;

b) CO_2 emission costs estimated based on the expected emission factor of the generation reference technology and the expected price of CO_2 allowances during the applied timeframe;

c) Other variable OPEX costs consisting of the expected cost of consumable materials (ammonia, limestone, water, etc.), by-products handling (ash, slug, etc.), etc., as well as variable operating and maintenance cost estimated based on the number of expected operating hours and/or start-stop cycles of the generation or charge-discharge cycles of storage resource;

d) minimum activation prices for DSR resources;

e) taxes and levies which relate to variable production. [15]

4.3 Decommissioned Power Plant Capacity

Decommissioned (precise state unknown, demolition might have started) power production capacity (2020-10-26) [37] in Finland is listed by Energy authority. The total decommissioned electricity production capacity is currently 1 482 MW which consists of 19 different power and CHP production facilities. 603 MW of the capacity uses medium heavy and heavy distillates, 600 MW of coal and 274 MW peat, and 71 MW wood-based fuels as main fuel. Most of the capacity is commissioned in 1970's.

Based on the following aspects it is considered that the decommissioned power plant capacity is not suitable to support electrical resource adequacy in the future and is therefore disregarded in the calculation of cost of renewal and prolongation.

- Fuel selection of the decommissioned capacity and prospects of fossil fuels (coal ban, uncertain future of peat),
- age of the decommissioned capacity,
- separate (auctioned) reserve capacity in Finland,
- owner's decision to decommission the facility, and
- uncertain state of decommissioning process.

For these reasons costs of renewal and prolongation were not calculated in this survey.

RAMBOLL

5. CONCLUTIONS

In this survey nuclear power, biogas-fired engines, biomass-fired power plants, photovoltaics, onshore and offshore wind power, battery storages, and different demand side management applications were selected as reference technologies. All these technologies were found having new entry potential and were considered standard technology. Capacity addition potentials varied a lot ranging from a couple megawatts to almost 20 gigawatts within the next five to ten years. Capacity of battery storages is currently limited by the investment cost but in case their prices fall in the future the additional capacity potential is basically unlimited.

Some uncertainties for DSM still occur to as a standard technology. Calculations show that demand response capital cost has a relation to clustered unit/load size (kW to MW) and variation for operating costs, depending on the characteristics of current markets and operation services. These have effect to low $CONE_{fixed}$ estimation. The adequacy for main demand response capacity has strong correlation to heat production needs in Finland, capacity is major during wintertime.

Calculations show that despite having relatively low capital cost and very low operating costs technologies like photovoltaics and wind power end up having high $CONE_{fixed}$ values. This is the case mainly because of their low de-rating values, especially for photovoltaics.

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