# Determining the Cost of New Entry (CONE) for Denmark

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## Executive summary

For the purpose of calculation of a Reliability Standard, Denmark has determined Value of Lost Load (VOLL) at 174 DKK/kWh (23.4 €/kWh)[1], identified a number of candidate reference technologies and for these technologies determined a (fixed) Cost of New Entry (CONE). This report goes through the different technologies, with the purpose of sorting out the technologies that are not fit to be a candidate reference technology. The derated costs and potential for entry are then calculated for each reference technologies.

The calculation of CONE is based on the methodology developed by Entso-E and approved by ACER on 2 October 2020: *Methodology for calculating the value of lost load, the cost of new entry and the reliability standard 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.* (This will be referred to in the following as the Entso-E Method).

[1] 2020 price level. VOLL will be recalculated in 2025.

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# Indhold

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## Possible candidate reference technologies (CRT)

According to the Entso-E Method, a number of candidate reference technologies (CRTs) shall be identified for the period 2025-2030. These shall be standard, and reliable cost information must exist, and further development of a CRT must not be significantly constrained[2].

The Danish Energy Agency has used different sources to derive information on cost, expected lifetime, efficiencies etc. for around 50 different electricity producing technologies. The sources are:

- A set of technology catalogues. The catalogues are developed by DEA and are frequently updated. The technology catalogues are created and continuously updated in an open process, where stakeholders are involved in external commenting on new or revised chapters.
- A Danish report published by *Dansk Fjernvarme* (2024), "*Analysis of competitiveness for existing thermal plants to support adequacy of power supply*".

Table 1 lists the possible reference technologies together with their fixed costs per MW and a fixed CONE calculation. The loss of load expectation (LOLE) target values are also displayed, as if each technology were a CRT (which is not the case). For combined heat- and power technologies, it is assumed that an investment in electrical capacity saves investment costs in a heat capacity of the same magnitude as the heat capacity from the CHP plant, which reduces CONE slightly. The saved heat capacity is assumed to be a gas boiler (based on natural gas or biogas).

Table 1 is based on calculations displayed in appendix III "*CONE_EntsoeMethod_DK_14-08-2024*".
The appendix contains also information on:

- Fuel prices for all fuels considered in this analysis (level 2023. DKK/GJ.)
- Carbon prices (level 2023, DKK/ton)
- Other technical characteristics (not listed in table 1).

[2] According to art. 10.4 in the Entso-E Method

| Technology | Unit investments M€/MW | Fixed O&M cost €/MWy | Derating factor | CRT? | CONE derated €/MWy | LOLE target (hours) |
|---|---|---|---|---|---|---|
| **New coal** | 2.10 | 34324 | 95% | No | 204413 | 8.8 |
| **Coal LTE** | 0.26 | 34324 | 90% | No | 64380 | 2.8 |
| **Coal to pellets exist boiler** | 0,53 | 3362 | 95% | Yes | 58632 | 2,5 |
| **Coal to chips new boiler** | 1,71 | 78424 | 95% | Yes | 258402 | 11,1 |
| **Coal to chips exist boiler** | 1,71 | 15073 | 95% | Yes | 193618 | 8,3 |
| **OCGT CHP large** | 0,55 | 17404 | 93% | Yes | 60112 | 2,6 |
| **OCGT CHP small** | 0,68 | 16612 | 93% | Yes | 69298 | 3,0 |
| **OCGT CHP micro** | 1,09 | -3167 | 95% | Yes | 104264 | 4,5 |
| **CCGT CHP large** | 0,88 | 29562 | 93% | Yes | 99941 | 4,3 |
| **CCGT CHP medium** | 1,24 | 28205 | 93% | Yes | 127108 | 5,4 |
| **Gas engine CHP NG** | 0,91 | 7970 | 95% | Yes | 75725 | 3,2 |
| **Waste CHP large** | 8,45 | 196552 | 95% | No | 871127 | 37,3 |
| **Waste CHP medium** | 8,93 | 254193 | 94% | No | 955010 | 40,9 |
| **Waste CHP small** | 10,43 | 399656 | 93% | No | 1232423 | 52,8 |
| **Biomass CHP chips** | 3,43 | 143737 | 91% | Yes | 427708 | 18,3 |
| **Biomass CHP small** | 6,04 | 277633 | 91% | Yes | 773807 | 33,1 |
| **Biomass CHP pellets** | 2,92 | 120284 | 91% | Yes | 361661 | 15,5 |
| **Biomass CHP pellets small** | 5,85 | 267540 | 91% | Yes | 747980 | 32,0 |
| **Biomass CHP, straw large** | 3,30 | 118581 | 91% | Yes | 427048 | 18,3 |
| **Biomass CHP straw medium** | 3,28 | 129870 | 91% | Yes | 427739 | 18,3 |
| **Biomass CHP straw small** | 6,06 | 351444 | 91% | Yes | 914677 | 39,2 |
| **Bio CHP extraction chips** | 2,55 | 68056 | 91% | Yes | 293766 | 12,6 |
| **Bio CHP extraction pellets** | 2,17 | 55295 | 91% | Yes | 247118 | 10,6 |
| **SOFC** | 2,13 | 106337 | 90% | No | 308060 | 13,2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **PEM FC** | 1,17 | 58486 | 90% | No | 233340 | 10,0 |
| **Onshore wind** | 1,15 | 16663 | 21% | No | 443318 | 19,0 |
| **Onshore wind small** | 3,84 | 95704 | 11% | No | 3537599 | 151,5 |
| **Offshore wind** | 1,80 | 39000 | 27% | No | 577209 | 24,7 |
| **Nearshore wind** | 1,38 | 39000 | 25% | No | 512297 | 21,9 |
| **PV roofotop small** | 0,84 | 10700 | 7% | No | 891751 | 38,2 |
| **PV commercial rooftop** | 0,57 | 8900 | 7% | No | 600910 | 25,7 |
| **PV utility scale** | 0,38 | 9500 | 8% | No | 364603 | 15,6 |
| **Wave power** | N/A | N/A | 25% | No | #VÆRDI! | #VÆRDI! |
| **Diesel engine** | 0,36 | 8983 | 99% | Yes | 34990 | 1,5 |
| **Engine, peak medium** | 0,50 | 6646 | 99% | Yes | 42573 | 1,8 |
| **OCGT gas** | 0,47 | 8236 | 99% | Yes | 42094 | 1,8 |
| **OCGT oil** | 0,38 | 8236 | 99% | Yes | 35630 | 1,5 |
| **CC LTE gas** | 0,15 | 24946 | 93% | | 43462 | 1,9 |
| **OCGT LTE** | 0,10 | 9623 | 93% | Yes | 22185 | 0,9 |
| **GE LTE gas** | 0,04 | 7692 | 95% | Yes | 12030 | 0,5 |
| **DSR low FR** | 0 | 15000 | 97% | No | 17068 | 0,7 |
| **DSR high FR** | 0 | 250000 | 97% | No | 284469 | 12,2 |
| **DSR low paper SE** | 0 | 9664 | 20% | No | 49463 | 2,1 |
| **DSR low cooling SE** | 0 | 346309 | 20% | No | 1772416 | 75,9 |
| **DSR low ventilation SE** | 0 | 346309 | 20% | No | 1772416 | 75,9 |
| **DSR low cement SE** | 0 | 9664 | 20% | No | 49463 | 2,1 |
| **Nuclear** | 6,47 | 80000 | 85% | No | 625536 | 26,8 |
| **CAES** | 0,96 | 2616 | 71% | Yes | 84573 | 3,6 |
| **Battery** | 0,21 | 570 | 7% | Yes | 233316 | 10,0 |

*Table 1 Possible technologies and cost information for 2030[3]. Price level: 2023. For CHP plants, gas boiler investment costs of 0.05 M€/MW and fixed O&M costs of 1900 €/MWy (price level 2015) have been subtracted.*
*Investments referred to in this table for CHPs are calculated according to Regulation (EU) 2019/943 article 11, 1.d. considering country specific prices, characteristics and requirements.*

[3] *The calculations behind the table are documented in an Excel spreadsheet named CONE_EntsoeMethod_DK_14-08-2024.xlsx.*

Each technology in Table 1 has been evaluated to determine if it is *standard*, if *reliable cost information* exists and if there are *constraints* of a technical or political nature that make them irrelevant as CRT's. The following criteria have been applied:

- Wind and solar are continuously being installed in the Danish electricity system in great numbers. There is more than 50 % wind and solar in the Danish power system. For small penetrations of wind and solar, the equivalent firm capacity of 1 MW installed capacity of wind power equals the average wind production[4], i.e. 0.3-0.5 MW, depending on the wind site. For large wind or solar penetrations, the equivalent firm capacity drops significantly. Therefore, the derating of wind and solar in Denmark is very high resulting in a very high LOLE target. Moreover, since expected energy not served (EENS) is expected to occur in periods with low wind and solar, increasing the amount of wind and solar in Denmark will not alleviate power inadequacy very much. Though in principle wind and solar could be CRT, they are not considered further.
- Coal-fired power plants are being phased out as part of national energy policy and company decisions. The last coal-fired plant was commissioned in 1998, and new coal-fired plants are unlikely to be built. Thus, coal-fired technologies are not considered as CRT.
- Biomass is being used in a number of large power stations (that used to be coal-fired) and likewise in some medium-size combined heat and power plants. There are still some coal-fired plants left that potentially could be converted into biomass. However, these coal plants are more likely to close. Thus, the remaining potential for biomass electricity is small. However, biomass is considered as CRT.
- Waste incineration CHP plants are not considered as CRT because of Government policy to reduce incineration capacity with 30 % in 2030. The waste capacity is determined by the amount of waste to be incinerated – and is not driven by the electricity market.
- Gas-fired combined or single cycle turbines based on either natural gas or biogas are considered as CRT because of relatively low investment costs and the existence of a nation-wide gas grid.
- In 2023 there were 579 decentralized CHP plants with a capacity of 1612 MW. 506 MW was combined cycle (14 plants). 62 MW was OCGT (4 plants) and 1044 MW were combustion engines (561 plants). [Source: Danish Energy Agency annual statistics][5]. The majority of this capacity is gas-fired. The plants were built in the late 1990's. Many of the plants have

[4] *Calculating the Capacity Credit of Wind Power. Martin & Diesendorf. Proceedings of 4'th biennial conference University of Queensland, 27-29 August 1980.*
[5] *Results of the Danish Energy Production calculations from 2023: https://ens.dk/sites/ens.dk/files/Statistik/resultater_af_energiproducenttaellingen_for_2023.pdf*

therefore reached their technical lifetime. A liftetime extension (LTE) of gas-fired CHP plants however seems in many cases to be a real possibility with relatively low costs. Hence LTE of decentralized gas-CHP is considered a CRT. The estimated potential for introducing capacity through lifetime extension of decentralized gas-fired plants depends on a number of assumptions. The report by *Dansk Fjernvarme* describes the potential for these plants and the associated barriers.

- In 2023, there were 364 MW of centralized oil-fired plants (10 plants). Of this, 311 were OCGT (7 plants) and 53 MW (3 plants) were diesel. [Source: Danish Energy Agency annual statistics]
- DSR (demand side response) has been considered as a CRT in Denmark. However, no reliable cost information has been found so far. Demand response is already assumed to a large extent in the resource adequacy assessments for a number of demand sectors. This applies to Power-to-X, electrical boilers and heat pumps in the district heating sector, electrical vehicles etc. Including a CONE value for DSM would need cost data for demand sectors other than those already considered flexible. DSM cost data from Sweden[6] and France[7] have been considered, leading to CONE's in the range ~17,000 to ~1,770,000 €/MW/y or LOLE targets in the range 0.7 to 76. These cost data are not considered applicable to Denmark due to differences in industry structure etc. Hence demand response is not considered as a CRT.
- Nuclear: The Parliament decided against nuclear in March 1985. Even though the nuclear debate has re-emerged to some extent, the decision still stands. Hence nuclear is not considered a CRT. A number of small modular reactors are under development by various Danish and foreign firms. Cost data for these are currently not well documented. Hence CONE for nuclear is based on data for large plants (~1000 MW).
- Batteries: Two types of electricity storage have been considered as CRT's: Li-ion batteries and CAES storages. Due to limitations in energy storage contents vs discharge capacity, the derating is quite high, notably for Li-ion batteries, leading to relatively high CONE's.
- Fuel cells and wave power technologies have initially been included in the analysis but been excluded at non-CRT's due to either lack of data or insufficient level of technological development.

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[6] *Calculations are based on data from the Swedish DNV-GL report "Samhällsekonomiska costnader och nyttor av smarta elnät" from march 2021: https://www.ei.se/download/18.1a478d39178a69490b746/1617712863057/DNV%20GL-Samh%C3%A4llsekonomiska-kostnader-och-nyttor-av-smarta-eln%C3%A4t.pdf*

[7] *Calculations are based on data from the French RTE report "Smart Grids Socioeconomic value and optimal flexibility portfolios" from June 2017: https://assets.rte-france.com/prod/public/2020-12/Smart%20grid%20-%202017%20abridged%20report.pdf*

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- <u>All the technologies</u> have also been valued in regards to the criterion that a CRT is not to emit 350 kg $CO_2$ pr. Installed kW capacity pr. year. The natural gas-fired technologies emit a maximum of around 500 g $CO_2$ pr. kWh. The max limit of 350 kg will be complied with if installations on natural gas operate up to 700 hours per year. However, there is an increasing amount of biogas in the Danish gas grid, and by around 2030, biogas will constitute 100% on an annual basis, hence $CO_2$ emissions will be zero. For oil-fired technologies, bio-oil with zero $CO_2$ emission can be used instead of fossil oil. This will reduce CO2 emissions to zero but increase variable costs. However, the variable costs are negligible in a CONE context.

## Fixed Cost of New Entry (CONE) for CRT's.

In Table 2 the CRT's with the lowest CONE are summarized in ascending order, including the resulting LOLE target (calculated as CONE/VOLL). Only CRT's with LOLE target below 10 are included. It is noted that all the CRT's are "green" in the sense that they emit little or no $CO_2$ since gas is mostly biogas around 2030 and oil can be procured a bio-oil.

| CRT | Fixed CONE derated (€/MWy) | LOLE target (hours) | Potential |
|---|---|---|---|
| **GE LTE gas** | 12030 | 0,5 | 1044 MW |
| **OCGT LTE** | 22185 | 0,9 | 62 MW |
| **Diesel engine** | 34990 | 1,5 | Unlimited investment potential |
| **OCGT oil** | 35630 | 1,5 | Unlimited investment potential |
| **Engine, peak medium** | 42573 | 1,8 | Unlimited investment potential |
| **OCGT gas** | 42094 | 1,8 | Unlimited investment potential |
| **CC LTE gas** | 43462 | 1,9 | 506 MW |
| **Coal to pellets exist boiler** | 58632 | 2,5 | N/A |
| **OCGT CHP large** | 60112 | 2,6 | N/A |
| **OCGT CHP small** | 69298 | 3,0 | N/A |
| **Gas engine CHP NG** | 75725 | 3,2 | N/A |
| **Gas engine CHP biogas** | 81822 | 3,5 | N/A |
| **CAES** | 84573 | 3,6 | N/A |
| **CCGT CHP large** | 99941 | 4,3 | N/A |
| **OCGT CHP micro** | 104264 | 4,5 | N/A |
| **CCGT CHP medium** | 127108 | 5,4 | N/A |
| **Coal to chips exist boiler** | 193618 | 8,3 | N/A |

Table 2 Fixed CONE (derated) and corresponding LOLE target (in ascending order) for CRT's from Table 1 Possible technologies and cost information for 2030. Price level: 2023. For CHP plants, gas boiler investment costs of 0.05 M€/MW and fixed O&M costs of 1900 €/MWy (price level 2015) have been subtracted.
Investments referred to in this table for CHPs are calculated according to Regulation (EU) 2019/943 article 11, 1.d. considering country specific prices, characteristics and requirements. The capacity needed to satisfy a certain Reliability Standard – compared to the expected development - is currently not well known and depends on a large number of uncertain assumptions. The capacity need is not further evaluated in this report. However, it is clear from Table 2, that investments in OCGT are unlimited. It means there is no incentive to invest in one of the more expensive technologies. The potential for new capacity is therefore not evaluated for technologies with a higher fixed CONE, than for OCGT.

According to The Entso-E method the entity calculating CONE may compute either a single CONE to apply over the whole timeframe or a different value for each of the years. As there are no known indications of any expected developments that can affect the economic and technical parameters in the timeframe of the following 5 years, the CONE is based on a single value, i.e. ~35,000 €/MWy.

## Variable CONE

The variable CONE has been calculated for the technologies considered in Table 1, see Figure 1. Fuel and carbon prices are those used by the Danish Energy Agency for planning purposes[8].

The variable CONE's are all below ~300 €/MWh. This is negligible compared to VOLL (~23,000 €/MWh), i.e. the variable CONE's are two orders of magnitude (or more) lower than VOLL. Therefore, the variable CONE's are not considered further, cf. Entso-E Method, article 16.8.

[8] *Calculations are based on data from the Danish Energy Agency report "Samfundsøkonomiske beregningsforudsætninger for energipriser og emissioner" from February 2022: https://ens.dk/media/3563/download*

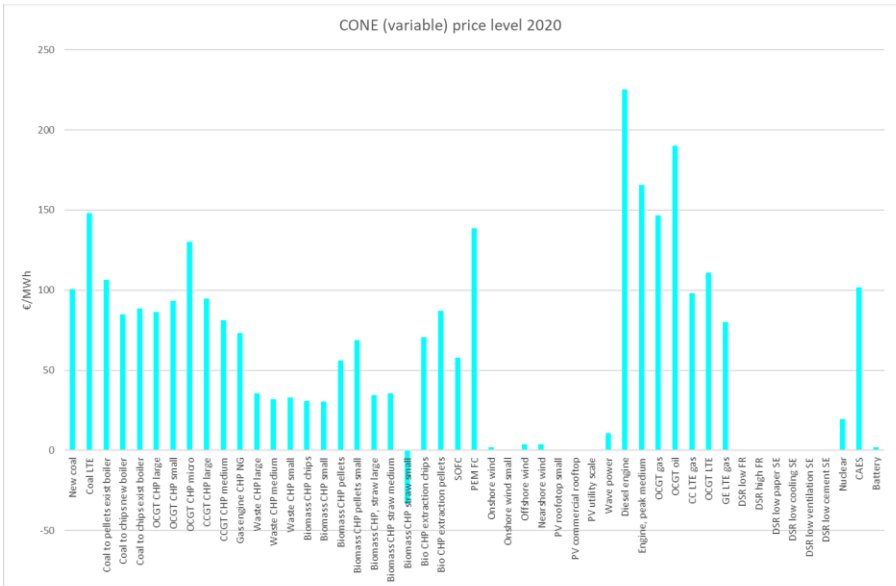


*Figure 1 Variable CONE for the technologies considered.*

## Weighted Average Cost of Capital (WACC)

There are both theoretical frameworks and established methods that market actors can use to estimate required rates of return in different industries and for individual companies. Danish energy companies use both equity and borrowed capital to finance their operations. For borrowed capital, companies pay interest to the lender. For equity, typically shares in the company, dividends are paid.

If companies act rationally, they choose a mix of equity and borrowed capital to minimize total financing costs. The optimal mix of borrowed and equity capital depends on several factors, including the perceived risk of the operations and the capital intensity of the industry in which the company operates. The estimation however, is complex and is subject to various assumptions, that lead to different results. For the purpose of calculating CONE some assumptions must be made and with limited data access, the focus on this exercise has been to minimize the uncertainty and therefore rely on the existing data and methods already in place.

To estimate the cost of capital, for the purpose of calculating the cost of new entry in the Danish energy market, the calculations have been based on the Danish ministry of Finance socio-economic discount rate[9]. The socio-economic discount rate contains both a risk-free interest rate and a risk premium (systematic and non-diversifiable). The socio-economic discount rate cannot be directly observed, and there is no unanimously correct method for how it should be determined. The

[9] *Finansministeriet (2021) Dokumentationsnotat – den samfundsøkonomiske diskonteringsrente: https://fm.dk/media/eywl4qvh/dokumentationsnotat-for-den-samfundsoekonomiske-diskonteringsrente_7-januar-2021.pdf*

Ministry of Finance has therefore set a recommended discount rate to rely on in socio-economic analyses. The Danish Ministry of Finance has set the discount rate for public and semi-public investments at 3.5 %. Whereas the risk-free interest rate is to 2 % and the risk premium is set to 1.5 %.

For the purpose of calculating a socio-economic reliability standard, this socio-economic discount rate has been used in a modified way. According to the Entso-E methodology, "*the WACC calculated by the entity calculating CONE should be applicable in its territory for a rational private investor investing in the reference technology...*" the socio-economic discount rate is considered to be compliant with the Entso-E method if adding an appropriate risk premium, which has led to the modification of the already recommended discount rate at 3,5 % set by the Ministry of Finance.

The Ministry of Finance sets the risk premium at 1.5%, which is estimated by combining the assumed risky return on equity investments with the yield of risk-free government bonds, as stated:

$$risk\ premium * \beta \ \rightarrow$$

$$2{,}8\ pct. \ * \frac{1}{2} \approx 1{,}5\ pct.$$

The risk premium for public projects (the $\beta$-value in a CAPM model) is half the amount as for private ones, i.e., $\beta = \frac{1}{2}$. In order to comply with the Entso-E method the risk premium is adjusted, so it only reflects the risk private investors face. This is done by adjusting the $\beta$-value from ½ to 1, so it only contains risk financed of private investors on the stock market. This yields a risk premium at:

$$2{,}8\ pct. \ * 1 \ \approx 3\ pct.$$

For an elaboration of the calculation of the risk premium and the underlying conditions, see Appendix 1.

The WACC for the purpose of calculating the cost of new entry in the Danish energy market is thus set at **5%** (2% + 3%).

A robustness check has been made, comparing the WACC for calculating CONE for Danish energy companies among other countries, who have already established a capacity mechanism. This comparison allows for a robustness check across reference technologies, which is valuable with limited national data published. This study showed no significant differences in the estimation of the cost of capital. Especially regarding the risk premium, which is the most complex calculation, the results did not differ much.

There are no indications showing any differentiated discount rate for the different reference technologies. Therefore, WACC is set at 5 % for all technologies. In this process private investors and other institutions have been presented with the WACC results for the different reference technologies. They did not provide any other insight or challenged the socio-economic WACC, that could lead to another calculation.

# Appendix I

**Risk Premium[10]:**
The recommended discount rate consists of, in addition to the risk-free rate of return, a risk premium for systematic, non-diversifiable risk.

For all policy measures, it is the case that future returns and costs will be associated with some degree of uncertainty to a greater or lesser extent. The uncertainty about future conditions entails that there will be a certain degree of risk associated with any measure.

To the extent that the uncertainty is specifically linked to the particular measure, it should, as a starting point, be addressed in sensitivity analyses rather than through discounting. Such project-specific risk is called unsystematic risk.

The argument for not directly incorporating this type of risk into discounting is that these uncertainty factors for different projects are, as a starting point, independent of each other. Therefore, it can be expected that the uncertainty factors will offset each other across the overall government portfolio of investments. Thus, the unsystematic risk can be diversified away, making it unnecessary to increase the general required rate of return due to unsystematic risk in discounting.

The recommendation that the socio-economic discount rate should not include project-specific risk also follows from the recommendation of the European Commission.

However, there also exists another type of risk, which is considered to be general across projects across sectors of the economy, and therefore cannot be diversified away across the overall public project portfolio. This is the so-called systematic risk.

This type of risk should be viewed in the context that the returns from socio-economic investments will vary with the overall economic development, thereby introducing uncertainty about how much a project/initiative will contribute to societal welfare. The relationship between economic growth and the pros and cons of projects means that decreasing returns in one project are not offset by increasing returns in other projects.

In light of this, it is deemed appropriate to capture systematic, non-diversifiable risk through a risk premium added to the discount rate in discounting. If a risk premium

[10] *Finansministeriet (2021) Dokumentationsnotat – den samfundsøkonomiske diskonteringsrente: https://fm.dk/media/eywl4qvh/dokumentationsnotat-for-den-samfundsoekonomiske-diskonteringsrente_7-januar-2021.pdf*

is not included in the discount rate, all else being equal, it would increase the likelihood of making investments that, ex post, turn out to be detrimental to society.

Since a risk premium for systematic risk is not directly observable, an attempt has been made to estimate the risk premium as a general average for all public projects. Specifically, this has been done by initially considering the difference between the average, risky return on equity investments and the risk-free government bond yield. Subsequently, adjustments have been made for tax considerations and an assumed difference in risk profile between publicly financed investments and those financed through the stock market.

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# Appendix II

## Abbreviations

| | |
|---|---|
| ACER | EU Agency for the Cooperation of Energy Regulators |
| CAES | Compressed Air Energy Storage |
| CAPM | Capital Asset Pricing Model |
| CCGT | Combined Cycle Gas Turbine |
| CC LTE | Combined Cycle LifeTime Estimation |
| CHP | Combined Heat and Power |
| CHP NG | Combined Heat and Power Natural Gas Fired |
| CONE | Cost of New Entry |
| CRT | Candidate Reference Technology |
| DSR | Demand Side Response |
| Entso-E | European Network of Transmission System Operators for Electricity |
| LTE | Life Time Extension |
| LOLE | Loss of Load Expectations |
| OCGT | Open-cycle Gas Turbines |
| PEM FC | Proton-Exchange Membrane Fuel Cells |
| PV | PhotoVoltaic |
| SOFC | Solid Oxide Fuel Cell |
| VOLL | Value of Lost Load |
| WACC | Weighted Average Cost of Capital |