Independent review of electricity benchmarking model for network companies

D4 report

3 July 2023

Europe Economics

This **fourth deliverable** presents our overall final report

This report is structured into the following sections:

1. Introduction to the study and our methodology.
2. Description of the challenges DSOs face in the Green Transition and potential solutions, including what behaviour should be incentivised.
3. Stakeholder feedback on the benchmarking model and wider regulation, in the context of the above challenges and solution.
4. Description of the benchmarking model and hypotheses of how it might affect incentives for investment in the Green Transition.
5. Description of the wider revenue cap regulation and how it might affect for investment in the Green Transition.
6. A set of worked examples showing how the benchmarking model works and testing various hypotheses about incentives for investment.
7. Our conclusions on the benchmarking model and wider regulation.
8. Annexes with more detailed information.

1. Introduction to the study and our methodology

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Denmark faces ambitious targets to reduce emissions as part of the Green Transition

- Denmark has been a leader in the energy transition in the past two decades, setting ambitious decarbonisation targets across all sectors and radically transforming the domestic energy supply.
- The Danish Government has committed to achieving Net Zero emissions by 2050 alongside a range of targets for 2030, including:
  - Cutting Greenhouse Gas (GHG) emissions by 70 per cent from 1990 levels.
  - Covering 100 per cent of electricity demand with renewables, as well as 55 per cent of overall energy demand.
  - Ending the sale of petrol and diesel cars.
- As an energy system which once relied heavily on coal, gas and oil, Denmark now sees more than **70 per cent of power** generation coming from renewable sources, predominantly wind and solar.
- Achieving such **high penetrations** of renewable generation has required DSOs to adapt to increasingly distributed forms of power generation to meet the demands of Danish consumers.
- These challenges are made greater by the continued push towards greater use of **low-carbon generation**, and increased demand through **electrification of heating** and **transport**.

The Green Transition raises a number of questions about whether the current regulatory regime provides the right incentives to network companies

Increased demand for electricity	The Green Transition is expected to result in a significant increase in demand for electricity as an increasing proportion of energy consumption is electrified, e.g. electric cars (EVs), heat pumps and power-to-X. Network expansion and reinforcement will be needed across the country.
Need to rapidly connect renewable energy	Renewable energy production and use will need to increase in order for Denmark to reach its climate goals. There will be the need for network companies to connect these energy sources rapidly and cost cost-effectively to the grid.
Need for the development of flexibility solutions	Flexibility solutions will be needed to help manage the fluctuating demand and supply of energy related to a greater share of renewable energy and greater demand-side participation. Flexibility solutions can also reduce the need for physical network expansion and investment.

This study examines whether electricity network companies are facing the right incentives to undertake cost-effective investments and respond promptly to the need for rapid network expansion and connection in light of the Green Transition

- The purpose of this study is to assist Energistyrelsen with an impartial review of the benchmarking model, in particular how it incentivises rapid and efficient network expansion and connection, as well as flexibility solutions. The study should also consider how the wider regulatory framework interacts with the benchmarking model and affects the above incentives.
- The requirements of the study were to:
  - Identify the elements of different regulations and initiatives influencing the decisions for providing fast and cost-effective network expansion and connection.
  - Identify current incentives in the benchmarking model and wider regulation for undertaking flexibility solutions.
  - Gather input from industry stakeholders.
  - Calculate worked examples to substantiate conclusions.
  - Provide conclusions and recommendations for adjusting the benchmarking model and/or wider regulation.

- The work is not intended to provide a general evaluation of the benchmarking model or the other regulations, but a focused analysis of elements related to network expansion and connection and flexibility options.

We interviewed a range of large and small DSOs, trade bodies and the Regulator

Stakeholders interviewed

- Forsyningstilsynet
- Green Power Denmark
- Servia
- Better Energy
- Danish Consumer Council
- Selection of large and small DSOs

The interviews explored:

- The types of investments needed to facilitate the Green Transition.
- Key factors and challenges affecting investments for the Green Transition, particularly rapid connections and flexibility solutions.
- Understanding of how the benchmarking model works and its impacts on investment incentives, including penalty sizes.
- The role of wider regulations in incentivising investments.
- Views on challenges with the benchmarking model and regulation.
- Whether stakeholders could provide data on investments e.g. to illustrate distortions in the benchmarking model

The feedback from stakeholders is discussed in the next section and included in more detail in the Annex.

As we did not receive sufficient data from across the stakeholders on illustrative investments with which to test the benchmarking model, we developed our own scenarios.

We also sought to host a workshop to allow other DSOs to participate in the study, but there was no interest shown by the 16 companies we contacted.

We analysed the benchmarking model and wider revenue cap regulation to understand the incentives

- This entailed a number of interactions with the regulator Forsyningstilsynet to obtain the relevant documentation and data, and to confirm our understanding of the model and regulation.
- We developed a detailed description of the model and the related incentives, included in Section 4, and an analysis of the wider regulation included in Section 5.
- The key sources we reviewed included the current benchmarking model and associated data provided by Forsyningstilsynet, as well as a number of regulatory documents setting out the revenue cap framework and the details of the benchmarking model.

We developed a set of worked examples to test the benchmarking model

- Given an insufficient range of data from stakeholders, we prepared a number of illustrative examples of investments.
- The examples were run through the benchmarking model to show how it works and to test various hypotheses about its impact on incentives.
- The results of the examples helped form our conclusions.
- The examples are included in Section 6, with details presented in the Annex.

2. What investments and behaviours are relevant for DSOs to undertake to support the Green Transition in Denmark?

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This section presents our analysis of the challenges and solutions facing DSOs in the context of the Green Transition

The purpose of this section is to:

- Describe the challenges and requirements facing DSOs as a result of the Green Transition.
- Present possible investment solutions to help address these and facilitate the Green Transition.
- Highlight the implications of the above for incentives – what behaviour should be incentivised and how might the current benchmarking model and wider regulation affect this?
- Provide guidance for the types of worked investment examples we could run through the benchmarking model to test the model's incentives in relation to the Green Transition.

The challenge of the changing role of Distribution Network Operators

The Green Transition in Denmark will focus heavily on deploying new low-carbon technologies (LCTs) for both residential and industrial consumers, as well as continuing Denmark's strong renewable generation growth.

The existing primary aims of DNOs will remain unchanged: to deliver safe and reliable networks to their customers at low cost. A third new primary aim of enabling the Green Transition is now also present and DNOs must facilitate both the **decarbonisation of demand** and the **connection of new low carbon generation**.

As customers increasingly **become participants** in the energy system (for example providing flexibility services from residential batteries), the DNOs will have an increasingly important role to ensure that customers are treated equitably and no customers are "left behind" in the transition.

Delivering the rapid change in network infrastructure and operation (including smarter more flexible operation) whilst ensuring costs remain manageable and the supply is reliable for all customer typologies will be a challenge that will require **innovative and novel solutions**.

DSOs in Denmark will need to ensure that:

- Networks do not act as a blocker to deployment of LCTs – delivering the Green Transition will require substantial, rapid investment by both individuals and developers. This includes investment at the **lower voltages** to ensure adequate distribution capacity to customers and their new LCT assets such as EVs and HPs, alongside investment at the **higher voltages** to provide capacity for distribution from supply to source, often not geographically matched. In early phases of the Green Transition, additional capacity may have been obtained through smarter network operation and flexibility, but as this additional headroom is used, more substantive infrastructure investment may be necessary.
- Customers are offered a range of connection products (firm and flexible) which meet their needs and enable faster connections.
- Customers are given clear signals on where to locate and how to adapt their behaviour which help meet the needs of the network and wider energy system.
- Networks can manage and balance loads and demands at different geographic scales – this is a significant change from the traditional top-down approach to delivering electricity to customers.

Longer-term investment planning and uncertain demand present a challenge to DSOs

Given the rate and unpredictability of network loads, there is a need for networks to change their approach to network planning and investment to factor in a **longer time horizon** and a degree of **contingency** to avoid blocking the rollout of LCTs.

- The **rate of change of load** will be much faster than historically, as well as more unpredictable. For example, a small area of low voltage (LV) network may see mass adoption of EVs within a few years, whilst other areas may see the same growth but over a few decades.
- Adoption of other "softer" measures, such as innovative tariffs and associated energy services, could have an even faster impact on networks with **demand profiles changing in a matter of weeks or months** rather than years.
- The current investment and business planning time **horizon (around 10 years) is too short** to provide this forward planning and could lead to short term inefficient investment decisions and stranded assets. (For example, a 20 year horizon could allow for a 'single upgrade' pathway in the face of faster and more sustained load growth, whereas 10 year horizons might result in multiple (more expensive) upgrades).

This will all require a **move away from the traditional model** of network investment, which involves identifying existing constraints and reinforcing the network in response, on the assumption that this reinforcement will be sufficient for many years. Instead, networks will need to anticipate future constraints and reinforce networks **ahead of need**.

- Under the current model, reinforcement may need to be replaced a second time in a few years due to poor anticipation of future load growth, leading to higher long-term costs for customers.
- In practice, this will mean that some reinforcements are **oversized** relative to the current usage of the network, and the uncertainty around future need will mean that some reinforcements may turn out to have been oversized.
- Networks will need to manage the **trade-off** between over-developing the network or doing so ahead of time against failing to deliver capacity when it is needed and blocking LCT deployment.

Implications for incentives and worked examples: how does the benchmarking model and wider regulation incentivise longer-term investment where demand is uncertain?

One solution to demand uncertainty could be greater use of data and digitalisation to monitor networks

- DNOs will face **increasingly uncertain loads** on their networks, which will require enhanced monitoring to ensure that they can identify current and future constraints and invest efficiently.
- Moreover, since network investment is typically expensive, it will be essential that networks are able to **maximise their utilisation** of their existing network infrastructure. Whilst some reinforcement will inevitably be required in the future, improving utilisation can extend the timescales and enable a better understanding of loads to be obtained.

An important step could be for networks to **invest in detailed monitoring of loads** on their networks to understand key areas of constraint, especially at LV level.

This investment includes the installation of **monitoring equipment** on sub-stations (and potentially other infrastructure), and developing the **associated data collection architecture** and management processes. A range of systems are on the market providing this capability.

Improving the quality of network constraint data will support the Green Transition by:

- Helping networks understand the load profiles of new LCTs, such as EVs and HPs, to support their future business planning
- Ensuring that the correct reinforcement is applied to manage a network constraint and maximise the long-term value for money of each investment.
- Creating a signal for customers, especially those deploying renewable generation assets, to connect in areas where there is known to be a network need or spare network capacity.
- Providing the capability to dynamically manage networks and potentially provide signals for real-time balancing and flexibility services which support stable network operation.

One solution to demand uncertainty could be greater use of data and digitalisation to monitor networks

Installing equipment to deliver this enhanced monitoring is likely to **incur higher costs** for distribution network operators in the short-term but will improve their ability to invest efficiently, harness flexibility and deliver reliable, low-cost network capacity to customers. Monitoring may not be considered in the traditional view of network reinforcement but by enabling better use of existing capacity and higher utilisation, it could achieve the same aims.

Case study: Phase Switch Systems (PSS)

Overall electricity demand in Denmark will be driven increasingly by low carbon technologies deployed at the LV level by domestic consumers. These consumers are typically assigned to a **single-phase circuit**, while there will be three independent phases on the associated cable or transformer as a more economical means of transmission. Reinforcement would be triggered on the cable or transformer when one of the phases reaches its rating, so it is important to allocate customers to phases **evenly to maximise the capacity of assets**.

The challenge in the Green Transition will be the rate of uptake of LCT which can cause one phase to have a much higher load than another. For example, if each of the customers it served were to charge their EVs at the same time. It would therefore be beneficial if customers could be **dynamically and automatically reallocated** to different phases to spread the load across the three phases and release additional capacity.

A UK project led by UK Power Networks called 'Phase Switch Systems' (PSS) is trialling the optimisation of connections on phases, and the approach is enabled by detailed network monitoring. In the context of the benchmarking model, this reallocation is a network solution which **doesn't increase network capacity** in a MW-km sense, but instead allows existing network to be utilised more effectively. This may allow more electricity to be supplied or more customers to be connected.

<u>Implications for incentives and worked examples</u>: how does the benchmarking model and wider regulation incentivise investment that does not have a direct impact on network capacity or connections (i.e. like flexibility solutions)?

The use of Flexibility and Energy Efficiency are important for the Green Transition and greater use of green power, and present a challenge to DSOs' traditional roles

- The Green Transition provides a source of **local network flexibility** which can be harnessed to manage constraints. This flexibility may arise from a wide range of sources including **residential assets** (EVs, batteries, etc) and **large scale** commercial and industrial sources. The access to this flexibility will also be diverse and be via direct contracts (especially with large industrial users), specialist flexibility aggregators, or service providers (e.g. EV charge point operators).
- A particularly **valuable source of flexibility will develop with the increased uptake of EVs.** Consumers could be incentivised to charge their vehicles in response to wholesale price signals or network constraints (known as demand side response) or could export power either onto the grid or to meet on-site demand (known as vehicle-to-grid).
- The market for local flexibility products is relatively undeveloped, and its evolution must be partly **led by networks** through innovation. In the short to medium term, flexibility may not replace the need for traditional network reinforcement, but networks should be **incentivised to pursue these options to develop the future marketplace.**
- This may mean that DNOs take on **new roles reflecting their position as a system operator** rather than just network operator, and these may include helping to develop new markets to support their network operation, and participating with a wide range of other energy system stakeholders in operating these markets. Equally, they will need to improve their **monitoring** of their networks, as discussed earlier, to be able to utilise flexibility when it is more readily available.

As a solution to this challenge, DSOs can offer new, more flexible, types of network connections

- The traditional model of network connections is that a customer pays for a 'firm' connection, where they are entitled to import and/or export a certain volume of power. The DSO is required to reinforce the network to accommodate the peak demand of collective group of customers on their network.
- However, in practice not all customers assign the same value to their connection. Recognising the differences between customers and providing **more flexible connections** can improve the number of customers who can be served and improve the utilisation of the network without the need for greater reinforcement.
  - For example, a solar farm may be willing to pay less for a connection which was not available when local renewable generation from wind and solar was high enough to cause constraints on the network.
  - A domestic customer with medical equipment at home will require a more reliable connection than another customer with on-site solar panels and battery storage which can meet their demand.

Traditional connection planning has often been based around the summed peak loads on the network, a worst-case scenario. But smarter network connections can take into account the operation profiles and localised supply and demand mix.

For example, the summation of local supply and demand may have traditionally triggered a large network connection, but if the coincidence of these is well understood the local balancing could enable a smaller network connection.

Safeguards may be required to limit the operation where these conditions are exceeded but this constraint cost may be lower than a traditional connection cost. Providing smarter connections requires new forms of analysis at the planning stage, new connection agreements, and monitoring infrastructure to manage the connections.

DSOs in Denmark already use interruptible connections, where the producer or consumer of electricity can be disconnected if need be. These could be expanded.

As a solution to this challenge, DSOs may need to offer new, more flexible, types of network connections

Case study 2: Active Network Management (ANM)

The Green Transition will require substantial volumes of low-carbon power generation to connect on distribution networks. These networks were not originally designed to meet these loads, which can often lead to constraints and delays with new connections.

One popular approach to enabling additional low carbon generation is to use Active Network Management (ANM). When ANM is implemented, the total load on a network asset is monitored and generation from a solar farm, for example, can be reduced to keep load within the asset's rating at times of high availability.

Through this approach, additional generating capacity can be deployed to make better use of renewable resources and existing network, without the need for additional network reinforcement. The connected generators can be compensated for their non-firm network connection through lower connection costs and network charges.

This approach could equally apply to new and large sources of demand, such as EV charging hubs, where the rate of charge could be moderated to manage network load.

Implications for incentives and worked examples: how does the benchmarking model and regulation incentivise flexible connections, including connections to green power sources?

Reducing the cost of traditional network build

Alongside the procurement of local flexibility services, network operators will continue to be **required to invest in their physical network**.

The key challenge will be to manage the trade-off between **traditional reinforcement and procurement of flexibility** services. This trade-off could be very sensitive to the area of network and the type of customers. The uncertainties around the availability and cost of flexibility could be considerable over the lifetime of a traditional network investment, which makes direct comparison challenging.

In some cases, flexibility may provide the level of capacity required and **remove the need** for any reinforcement, but in others it may simply **delay the point** at which reinforcement is required.

In addition to replacing infrastructure for reinforcement, **lifecycle replacement** also needs to be included in the assessment and there may be cases where it simply makes sense to upgrade infrastructure capacity at end of life. In general the marginal costs associated with capacity are small in comparison to the one-off costs of installing new infrastructure.

Given the continued need for traditional reinforcement, networks should continue to be **incentivised to innovate and develop new solutions**, as well as drive **cost reductions for existing solutions**.

<u>Implications for incentives and worked examples</u>: how does the benchmarking model and regulation incentivise traditional reinforcement investment?

Summary: the implications of Green Transition investments for the rest of this study

This section has set out the key challenges and investment solutions facing DSOs in the context of the Green Transition. In light of this, the following investment examples will be relevant to test in the benchmarking model and wider regulation to assess whether these are incentivising the right behaviours:

1. **Investments in capacity where the corresponding update in demand is uncertain**. For example, where costs incurred today may (a) only be matched with increased outputs (connections, power delivered) or lower future costs in future years or (b) may never be matched with increased outputs. How do the regulations incentivise investment in the face of uncertainty?
2. **Investments in flexibility solutions and data-driven monitoring and optimisation.** These imply upfront costs for future cost savings. But in the meantime companies the costs may not be associated with clear outputs. How do the regulations incentivise this behaviour?
3. **Connecting more renewable sources of power and LCTs to the network, at speed?** How do the benchmarking model and wider regulation incentivise this behaviour, including faster connections/higher costs?
4. **Investment in grid capacity in response to changing electricity usage,** for example reducing the density of transformers. How do the benchmarking model and wider regulation incentivise this behaviour, given the likely outputs affected by the investment?

More details on the formulation of the examples are included in Section 6.

3. Stakeholder feedback on the benchmarking model and wider regulation

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In this section, we summarise the key views from stakeholders regarding the benchmarking model and the wider regulation

- As set out in the Introduction, we engaged with a range of stakeholders (representing network companies, generators and consumers) and sought their views on what investments were necessary for the Green Transition, what challenges faced the achievement of the Green Transition, and specific views of the regulation.
- We summarise their views in this section, and highlight how this input shapes the study, in particular the **hypotheses** we test during our analysis of the benchmarking model and the wider regulation, and the **worked examples** we run through the benchmarking model.

Stakeholders think the benchmark model penalises investment

Comments from stakeholders	Hypotheses to test
• The model focuses on classical cost efficiency and incentivises pushing investment far into the future. DSOs that invest first get penalised in the model. • Lags in demand mean high investment costs are only recovered with a lag. • The regulation is based on a steady state situation, not the current transition. • Preparatory costs of investing are not linked to any increase in model output, so these costs look inefficient. • If expected increases in demand do not materialise, investment costs appear inefficient ex-post, though they may have been efficient ex-ante.	• Are companies penalised in the benchmarking model if they undertake investment to expand the grid / connect new power sources? • Does the benchmarking model penalise investment that is not associated with clear outputs, e.g. operational investment? • How does the model treat lags in demand? • How does the benchmarking model treat investment both under the current frontier and also in future regulatory periods (with a re-estimated frontier?) • How does the wider revenue framework address lags in demand and investment costs?

Stakeholders think the benchmark model distorts investment decisions and incentivises gaming

Comments from stakeholders	Hypotheses to test
• Certain investments are favoured – investing in physical assets to increase capacity, rather than IT solutions, as the former increases output in the model • The investments incentivised by the model are not always the optimal long-term investments (e.g. extending an old cable instead of replacing with a new one) • DSOs want to make sure cable usage is high to appear efficient. New cables means lower usage. • Outages are not included in the model	• Does the benchmarking model penalise investment that is not associated with clear outputs, e.g. operational investment? • How are quality issues dealt with in the benchmarking model and the wider regulation?

Stakeholders think the benchmark model does not account for heterogeneity amongst DSOs

Comments from stakeholders	Hypotheses to test
• DSOs are not comparable in terms of area, population or voltage levels and so the model isn't identifying efficiency differences. • Some DEA frontier DSOs have a lot of slack in some drivers before falling off frontier, so little incentive to invest. • Smaller networks are followers, innovation come from the largest networks. But the early R&D costs will punish the larger DSOs in the model. • Norm-grid geographical adjustments only consider the average costs in a geographical zone.	• How does the benchmarking model take account of regional differences? • How do different DSOs fare under the benchmarking model for the same investment? • Are first-movers always disadvantaged in the model, including in future regulatory periods?

4. An overview of the benchmarking model and its incentives

Europe Economics

In this section we describe in detail how the benchmarking model works

- The purpose of this section is to describe how the benchmarking model works.
- We also set out the *potential* impacts it may have on investment incentives.
- For the purposes of this section, we consider the benchmarking model in isolation. In our Conclusions section 7 we take a broader view of the incentives of the benchmarking model and the wider regulation combined.

Overview and purpose of the benchmarking exercise

The **benchmarking exercise** establishes the individual efficiency requirement of companies, which is then used to determine any penalties in the revenues allowed to companies.

The exercise would be straightforward if all companies had similar characteristics, technologies and customer requirements: by comparing costs across companies it would be possible to see the efficient and inefficient firms, and by comparison, establish the level of additional costs (or inefficiency) of the latter compared to the efficient firms.

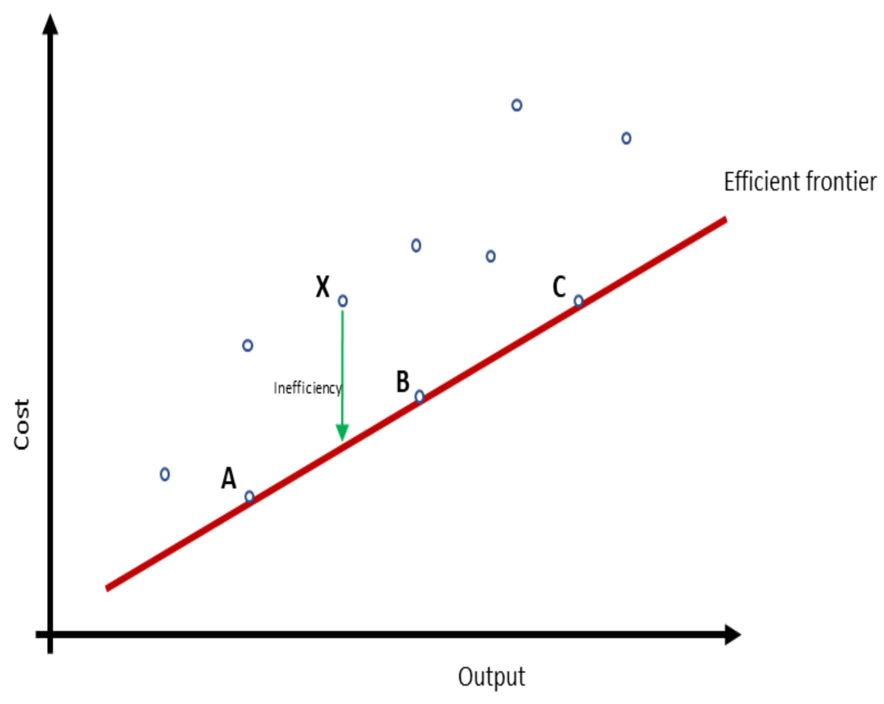
However, because firms have different characteristics (most noticeably, size) and deliver different outputs (most noticeably, the amount of electricity) it is necessary to come up with a method that allows undertaking a like-for-like comparison.

Benchmarking methods allow for a more complete analysis including several outputs: they use the companies' costs and different outputs to estimate an efficient frontier. Each company is then compared with the efficient frontier, and the distance from the frontier is used by the regulator in setting penalties or revenue allowances, depending on the regulatory regime.

One alternative possibility would be to use a "performance ratio", for example, which could make use of total costs divided by a metric to account for the size of the company or to account for output (for example, total electricity delivered). Although such ratios can already provide some good comparisons between companies, they suffer from one important weakness: they only measure efficiency of one output at a time.

Benchmarking - Efficient frontier with one output only

- The efficient frontier is a measure of how outputs can be produced using a number of inputs. It is estimated using data from the industry (containing technologies from efficient and inefficient companies).
- We can illustrate the objectives of benchmarking with a very simple model with one output only. Under this example, for each company we would only have two variables: the total cost and the value of the output.
- The results of a benchmarking model would allow the construction of an efficiency frontier with which to compare the efficiency of the companies in the sample. In this case, companies A, B and C are the most efficient ones and the ones setting the frontier, estimated as a linear combination of the values of the variables for those three firms.
- The rest of companies are relatively less efficient because they are providing services at a higher cost (in comparison with the frontier). The difference between a company's costs and the frontier is the inefficiency (or efficiency requirement).

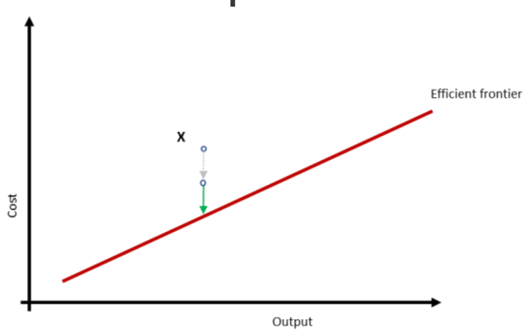


Achieving efficiency in the benchmarking model

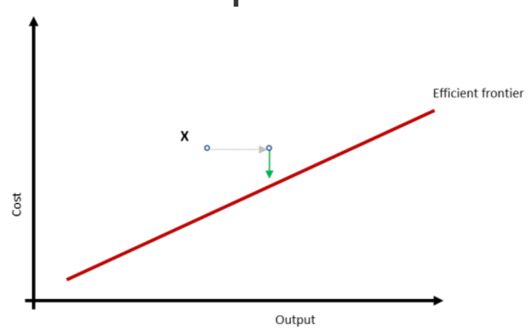
With this simplified model is straightforward to see how companies perform and what companies deemed to be inefficient need to do reduce their inefficiencies: because inefficiency is measured as the distance between a company to the frontier, this inefficiency can always be reduced when each company moves closer to the frontier. This can be done in different ways:

1. By maintaining the same output level with a lower cost (Case A);
2. By producing more outputs with the same amount of costs (Case B); or
3. By moving completely onto another situation (investment or divestment, if this were possible) where the cost-output is closer to the efficient frontier (Case C).

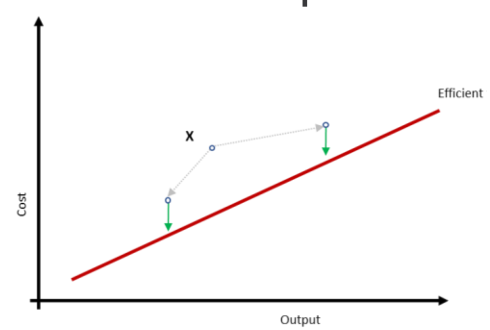
Case A:
Same output lower cost



Case B:
More output same cost



Case C: Investment or divestment r
in more output / cost



Illustrative example of efficiency frontier

Case study 3: Illustrative example

This same idea can be shown with some simulated numbers. We shall assume that the estimated frontier can be expressed as a simple cost-users relationship such as:

*Estimated frontier: Cost = 100,000 * Users*

This shows that an efficient company with a network of 10 users, for example, should be able to provide these at a cost of 1,000,000 (the costs are 2,000,000 for 20 users, and so on for different efficient companies).

A company supplying to 1,000 users at 115 million is clearly inefficient because the frontier establishes that supplying to that number of users can be achieved with 100 million only. Hence the company needs to reduce 15 million from its costs (or alternatively, supply electricity to 1,150 users). The relationship established is very important because it also determines the incentives a company will be facing when trying to expand its network. In this simplified model with only one service, it implies that a company might not expand its network using options that imply more than a 100,000 cost per user. If it does, the company will become less efficient and might be penalised (in the form of less revenue allowances).

The lessons of this simplified example show clearly the way incentives work under the benchmarking model. A company will be always better off expanding the network at costs under 100,000/user (in theory, a company could also divest to become more efficient if by doing so achieves a lower cost-user ratio). It is also true that in this set up, the company will have no incentive to engage in other green electrification, if there are no options cheaper than 100,000/user available.

The Danish benchmarking model and calculations

A 'best-of-two' method is adopted where for each company the most favourable efficiency score from either the MOLS or the DEA approach is chosen. The best-of-two approach has been adopted as a way to account for the advantages and disadvantages in both DEA and MOLS. There are debates about the relative strengths and weaknesses of DEA and SFA/OLS/MOLS.

DEA	SFA/MOLS/OLS
• Does not require assumptions about parameters. • The estimated frontier is not influenced by firms which are inefficient relative to their peers. • It can handle more inputs and outputs.	• Use all available data to generate the frontier. • Incorporate the possibility of measurement error in the data,. • Allow for statistical testing of the parameters.

The current benchmarking model includes three services as the outputs describing the companies' costs:

Electricity Supplied	Total kWh delivered to end users
Customers	Total number of company's customers
Network capacity	Normalized grid, or Norm-Grid, the capacity that a company makes available to consumers, constructed as a weighted average of different grid components

Network Capacity (‘Norm-Grid’)

Europe Economics

Norm-gird is a key output variable that has important complexity – we investigate it further here

Norm-grid is considered to be the capacity that a network company makes available to consumers and which enables consumers to have electricity delivered through the distribution network. Norm-grid accounts for the structure of individual electricity grids. For instance, there are significant differences in the costs for individual network components, and individual network components are stated in different units.

In addition to accounting for the differences in network components, Norm-grid accounts for DSOs operating in different geographical areas. Every geographical area is unique, which means DSOs set up a distribution network which is particularly adapted to its own area. Thus, the regulator chose to correct the norm-grid for density (urban) using GIS data. This means that the grid components are weighted differently in the norm-grid, depending on the GIS zone of the network component.

Norm-grid is a weighted average of the sum of the network components

The sum of each of the 29 network components, measured either in kilometers or number of units, is multiplied with the associated norm-grid weight based on replacement values and operating equivalents.

$$Normgrid = \sum_{z=1}^{4} \sum_{k=1}^{29} (netkomponent_k^z \times \text{vægt}_k^z)$$

Where;

z = GIS zones; k = network components

- Netkomponent = network component, measured in kilometres or number of units.
- vægt = is the weight for network component, located in GIS zone. The weights are constructed on the basis of engineering consultants PAP's weights determined on the basis of replacement prices and COWI's operating equivalents determined for use in adjusting the revenue frameworks.

Each DSO's values for each of the 29 components are multiplied by the relevant component's price weight (vægt) for each GIS zone, and then added together to generate the norm-grid variable.

The regulator chose to convert the replacement prices of network components into annuities that reflect the depreciation horizon and return. Operating weights are then added to the depreciation annuities. The replacement prices and operating costs are added to form one overall price weight.

The regulator selected 29 of the 32 network components in calculating norm-grid

Of the 29 components, around **five** appear to have the largest contribution to the total norm-grid figure for most DSOs

▪ **0.4 kV cable cabinets**	▪ 30-60 kV open field with separator without circuit breaker	▪ 30-60 kV transformer ≥ 20 MVA
▪ **0.4 kV cable**	▪ 30-60 kV open field with circuit breaker	▪ 10-20/0.4 kV grid station, automatic with transformer power < 500 kVA
▪ 0.4 kV overhead line	▪ 30-60 kV gas-insulated field with circuit breaker	▪ 10-20/0.4 kV substation, automatic with transformer power 500-2000 kVA
▪ 10-20 kV field with circuit breaker	▪ 30-60 kV capacitor bank	▪ 10-20/0.4 kV grid station, automatic with transformer power > 2000 kVA
▪ **10-20 kV land cable, PEX**	▪ 30-60 kV overhead line	▪ 10-20/0.4 kV grid station, automatic without transformer
▪ **10-20 kV land cable, APB**	▪ 30-60 kV cable, pressurized oil cable	▪ **10-20/0.4 kV substation, conventional with transformer power < 500 kVA**
▪ 10-20 kV overhead line	▪ 30-60 kV shunt reactor	▪ 10-20/0.4 kV substation, conventional with transformer power 500-2000 kVA
▪ 10-20 kV extinguishing coil	▪ 30-60 kV extinguishing coil	▪ 10-20/0.4 kV substation, conventional with transformer power > 2000 kVA
▪ 10-20 kV cable, lake	▪ 30-60 kV cable, lake	▪ 10-20/0.4 kV substation, conventional without transformer
▪ 30-60 kV cable, others	▪ 30-60 kV transformer < 20 MVA	

Note: Remotely read and non-remotely read meters, and branch lines are not considered in calculating norm-grid.

Of the 29 components in the Norm-grid calculation, the same 5 do most of the work for almost all the networks

	0.4 kV cable cabinets	0.4 kV cable	10-20 kV land cable, PEX	10-20 kV land cable, APB	10-20/0.4 kV substation, conventional with transformer power < 500 kVA
CERIUS A/S	12%	35%	19%	9%	9%
DINEL A/S	11%	34%	23%	7%	8%
ELEKTRUS A/S	9%	39%	9%	31%	7%
ELINORD A/S	11%	36%	5%	19%	3%
EL-NET KONGERSLEV A/S	14%	42%	0%	0%	7%
ELNET MIDT A/S	10%	38%	15%	15%	2%
FLOW ELNET A/S	13%	37%	14%	15%	7%
FORSYNING ELNET A/S	11%	42%	14%	12%	0%
GEV NET A/S	14%	26%	13%	15%	5%
HAMMEL ELFORSYNING NET A/S	15%	42%	9%	21%	3%
HJERTING TRANSFORMATORFORENING	21%	79%	0%	0%	0%
HURUP ELVÆRK NET A/S	7%	61%	17%	7%	2%
IKAST VÆRKERNE NET A/S	14%	43%	20%	6%	5%
KONSTANT A/S	12%	34%	17%	9%	5%
L-NET A/S	11%	37%	13%	17%	2%
LÆSØ ELNET	13%	50%	26%	0%	7%
MIDTFYNS ELFORSYNING A.M.B.A	28%	67%	0%	0%	2%
N1 A/S	10%	31%	21%	8%	9%
N1 RANDERS A/S	12%	32%	11%	16%	4%
NAKSKOV ELNET A/S	14%	43%	15%	15%	3%
Netselskabet Elværk A/S	11%	35%	26%	3%	10%
NKE-ELNET A/S	13%	37%	3%	34%	3%
NOE ELNET A/S	10%	35%	27%	4%	10%
NORD ENERGI NET A/S	11%	36%	15%	11%	8%
RADIUS ELNET A/S	10%	34%	10%	20%	4%
RAH A/S	12%	33%	25%	3%	10%
RAVDEX A/S	14%	34%	19%	8%	6%
SUNDS ELFORSYNING A.M.B.A	7%	93%	0%	0%	0%
TARM ELVÆRK NET A/S	14%	40%	34%	0%	7%
TRE-FOR EL-NET A/S	10%	34%	17%	11%	7%
TREFOR EL-NET ØST A/S	11%	30%	17%	13%	10%
VEKSEL A/S	12%	36%	24%	2%	11%
VESTJYSKE NET 60 KV A/S	0%	0%	0%	0%	0%
VIDEBÆK ELNET A/S	12%	36%	19%	20%	4%
VILDBJERG ELNET A/S	26%	74%	0%	0%	0%
VORES ELNET A/S	10%	32%	18%	10%	7%
ZEANET A/S	13%	43%	14%	18%	1%
AAL EL-NET A.M.B.A	29%	71%	0%	0%	0%
AARS-HORNUM NET A/S	19%	72%	0%	0%	4%

The table shows the % contribution to each DSO's normgrid value across a subset of the components

- Almost all the networks' normgrid va;lue depends on primarily on the same five variables (so they are similar in this regard).
- However the weights for the five are different, thus reflecting differences across the networks.

Implications of norm-grid

The Norm-grid figure is primarily affected by the **volume** of the network components specific to each DSO, and the **price weights** assigned to the network components in each zone. Some DSOs have more or less of certain components compared to others, which affects the overall norm-figure for that component. For instance, some DSOs may already have invested significantly in high price-weight network components (such as "30-60 kV transformer ≥ 20 MVA"), which in turn increases their norm-grid figure.

Green Transition

Investments related to the Green Transition may affect different DSO's norm-grid variable differently, depending on the price-weight for a specific network component in a specific zone. For instance, green transition could mean that DSOs need to invest in more **transformers** because consumption per household is expected to increase (e.g. usage of EVs and electric heat pumps in the future). An increase in transformers, a network component with relatively high price-weights, in the network grid could imply a significant increase in the norm-figure for a DSO.

We therefore will test whether the same investment has a different impact of different DSOs in terms of the benchmarking results.

Estimation methods: DEA and MOLS

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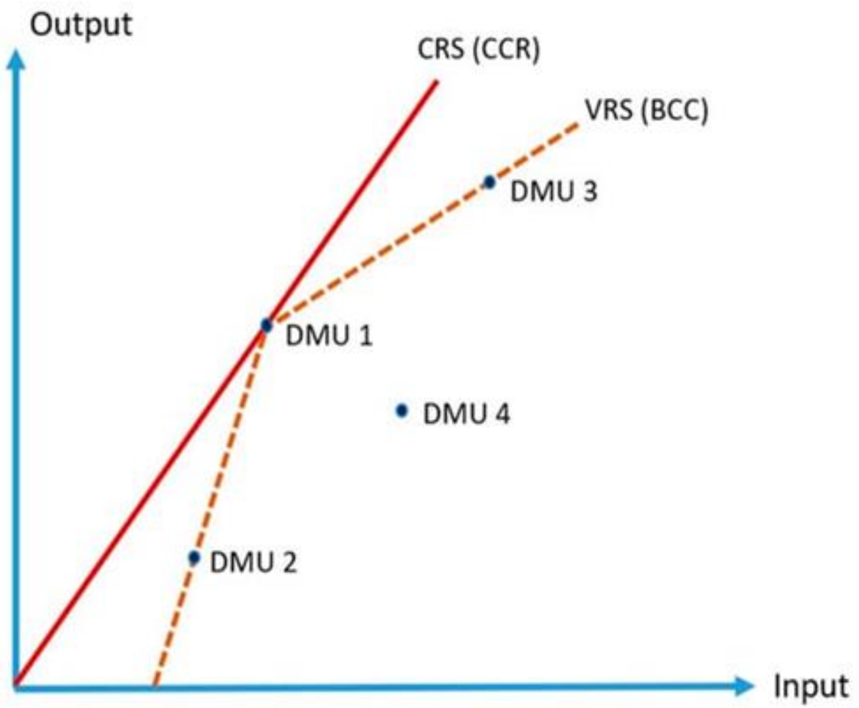
Estimation method 1: Data Envelopment Analysis (DEA)

- DEA is a non-parametric method that can be used to evaluate the relative efficiency of firms that use multiple inputs to produce a multiple output. The efficiency of each firm is measured by the ratio of the amount of totex relative to the amounts of electricity supplied, customers, normgrid and overhead networks.
- DEA involves constructing an efficiency frontier, which is a boundary that separates the efficient DSOs from the inefficient ones. The efficient DSOs are those that are on the frontier, while the inefficient ones are those that are inside the frontier. The efficiency frontier is constructed by finding the optimal weights for the inputs that maximize the ratio of output to input for each DSO.
- DEA is non-parametric, which means it does not require assumptions about the distribution of data. It can handle multiple inputs, and can be used to compare DSOs with different combinations of inputs.

DEA illustration

As illustrated here, DEA creates a polygon around the industry points such that it "envelopes" the data. In the illustration, DMU1 could reduce its output and/or increase its costs considerably and still be considered to be on the frontier in both constants returns to scale and variable returns to scale. DMU2 and DMU3 have scope for the same under variable returns to scale. With multiple dimensions, the same principle can still apply – firms on the frontier will have some "slack" where they can incur extra cost or deliver less output and still be considered efficient.



On the basis of two methods, "super efficiency"[3] and "significant change"[4], the regulator identified two grid companies as outliers to be excluded from the DEA model. The identified outliers are:

- **Hjerting Transformer Association**
- **Vildbæk Elnet A/S**

Companies forming the frontier for the next period

- In the next period (2023-2027) of benchmarking of network companies' financial efficiency, the draft Appendix states that there are 13 network companies that form the front in DEA:

Electrics A/S	Hammel Elforsyning Net A/S	Constant Net A/S	L-net A/S	Elnet Midt A/S	Midtfyns Elforsyning amba	N1 A/S
Nord Energi Net A/S	RAH Net A/S	RAVDEX A/S	Tarm Elværk Net A/S	VEKSEL A/S	Aal El-net amba	

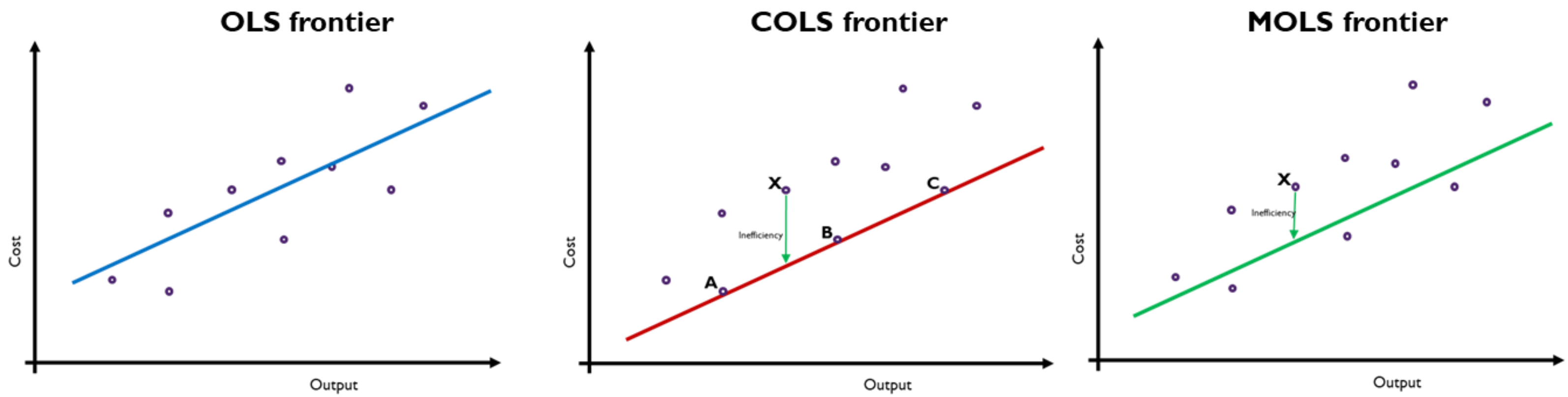
Network companies on the efficient front may still have potential for efficiency gains if their costs calculated on the basis of a four-year average are higher than their costs calculated on the basis of a two-year average.

Similar to DEA, the Regulator has excluded a number of observations from the sample used to estimate the MOLS. The exclusions and criteria used are the following:

1. **Insufficient delivery quality:** Companies that underperformed in the quality delivered in the years 2019, 2020 and 2021. Excluded observations are: "TRE-FOR El-net A/S" and "Netselskabet Elværk A/S".
2. **No GIS division:** Companies that did not report GIS data (needed to calculate the density-corrected norm-grid). Excluded observations are: "HURUP ELVÆRK NET A/S" and "SUNDS ELFORSYNING".
3. **Other:** Some other observations are excluded in the R code. Excluded observations are: "N1 RANDERS A/S", "VESTJYSKE NET 60 KV A/S" and" VILDBJERG ELNET A/S".
4. **Influencing observations:** Outliers influencing the OLS estimates (based on criterion of Cook's distance). Excluded observations are: "Hjerting Transformer Association", "GEV Elnet " and "El-net Kongerslev A/S".

Estimation method 2: Modified Ordinary Least Squares (MOLS)

- MOLS is a regression method for estimating an efficient frontier, where it is assumed that the distance between the individual company and the production front is not only constituted by inefficiency, but also by statistical noise.
- Modified OLS specifies an aggregate cost: output relationship (line) across all firms, being modified with a constant term to ensure that the predicted line lies between OLS (where some individual firms' inefficiency may be negative) and Corrected OLS (which creates a very stringent frontier). This is illustrated in the figure below.



OLS equation

A regression model is estimated using OLS, with TOTEX as the dependent variable and four drivers, with a log-linear specification:

LN(TOTEX) = 9.54 + 0.58 * LN(NORMGRID) + 0.37 * LN(CONNECTIONS) + 0.08 * LN(KWH_DELIVERED) + 0.00 * OVERHEAD

Where;

- TOTEX: Total costs 2020-2021 average.
- NORMGRID: Capacity that a grid company makes available to consumers, and which makes it possible for consumers to be supplied with electricity through distribution network. It is calculated as a weighted average of the sum of the grid components. This has the largest coefficient in the model.
- CONNECTIONS: Number of customers (based on data from Energinet).
- KWH_DELIVERED: Amount of electricity delivered (kWh delivered to the end user).
- OVERHEAD: costs for overhead distribution networks (not logged).

Calculation of efficiency scores from MOLS

Efficiency is measured as company's costs in relation to the relationship established in the estimated OLS model , and some additional transformations (calculations that modify the OLS results to make them operational in terms of efficiency estimates).

The model coefficients are used together with each companies' output variables to predict the costs it *should have* incurred. This is compared to its actual costs.

$$\text{EFFICIENCY\_SCORE} = \frac{1}{EXP\left(\hat{u} + RMSE\left(\sqrt{2}/\sqrt{\pi}\right)\right)},$$

- Where $\hat{u}$ is the OLS residual (the difference between a firm's actual costs and the costs that the model predicts it will incur); and
- $RMSE$ is the square root of the average of the squared residuals (root mean squared-errors).

The penalties are calculated using a PENALTY_SCORE, which is calculated as 1 - EFFICIENCY_SCORE.

There is an adjustment on the range of the PENALTY_SCORE: only positive numbers are allowed and an upper ceiling of 0.24 (based on calculations carried out by the regulator) is imposed on the upper bound. Hence:

- PENALTY_SCORE = 0 if PENALTY_SCORE < 0.
- PENALTY_SCORE = 0.24 if PENALTY_SCORE > 0.24.

Penalties and modifications

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Penalty for being inefficient

The efficiency penalty is calculated on the basis of the firm's cost base, the penalty score and an implementation rate.

PENALTY = TOTEX_BASE_COST * PENALTY_SCORE * IMPLEMENTATION_RATE

Where,

- TOTEX_BASE_COST is established as the 2018-2021 Totex average.
- PENALTY_SCORE as the minimum score of DEA and MOLS.
- IMPLEMENTATION_RATE. This takes into consideration that the efficiency improvement needs to be reasonable and achievable by companies. To do so it sets an implementation rate which reflects the feasibility of reducing costs during the regulatory period. The implementation rate is calculated as 0.07.

This IMPLEMENTATION RATE is calculated as:

IMPLEMENTATION_RATE = OPEX_POT * OPEX_SHARE + CAPEX_POT * CAPEX_SHARE = (0.2 * 0.19) + (0.04 * 0.81) = 0.07.

The following assumptions have been made:

- **OPEX_POT** is the estimated amount that companies annually improve on operating costs. It has been set as 20% annually.
- **OPEX_SHARE** share of opex in total costs (estimated at 19%).
- **CAPEX_POT** estimated amount that companies can annually improve on capital costs. It is set at 4%.
- **CAPEX_SHARE** share of capex in total capital costs (estimated at 81%).

Modifications to the efficiency requirements

The benchmarking model includes modifications to the efficiency requirements facing firms to make them less stringent.

- The model takes a "best-of-two methods" approach, such that for each company the minimum penalty score from MOLS and DEA is used. This reflects the most favourable outcome for the company (its maximum efficiency score under MOLS/ DEA).
- Penalty scores are capped (currently at 0.24, based on calculations carried our by the Regulator) such that companies with higher penalty scores will not be penalised further. There is also an "implementation rate" applied to the penalties which reduces them (currently 0.07) to reflect the need for a feasible path to reducing costs within a regulatory period.
- There are options for companies to discount costs from the TOTEX figure entering the model, thus making the costs in the model smaller and reducing the inefficiency gap, in particular for flexibility services.

Other adjustments for costs exist in the wider regulation framework which we discuss later.

Promoting incentives in the model

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Implications for incentives in the model

The efficiency frontier for the benchmarking model (either the coefficients for MOLS or the frontier for DEA) would be estimated by the regulator at the beginning of the regulatory period. This sets the **relationship between costs and the outputs for the period**, and the efficiency frontier. The efficiency scores are calculated by the regulator **every five years**, based on cost and output data received from companies.

Investment towards promoting network expansion and connection, or support in flexible services, all add up to **more costs for companies**. However, the impact on their performance, as measured by the benchmarking model, will in turn depend on how much these are also **correlated with the different drivers (outputs).**

The next slide discusses potential incentive mechanisms/questions of the benchmarking model in relation to **investments for the Green Transition**.

In this slide, we set out hypotheses to test for how the benchmarking model may affect incentives for investment in relation to the Green Transition

Increasing demand for electricity

Consumers and households will demand more electricity for EVs and heat pumps as the Green Transition progresses. Investments (e.g. grid reinforcements and more connections) will increase DSO's costs but **may not result in a corresponding increase** in the three output variables in the benchmarking model.

In particular, if take-up of increased demand is slower than expected then KWh and number of customers will not increase in line with the investment (totex). This may result in the DSO appearing inefficient in the benchmarking model, resulting in the DSO incurring penalties in the current period.

The extent to which this may happen will also depend on the impact of the investment on the third variable, Norm-grid. This variable both has the largest coefficient in the MOLS model, and is the most likely to be directly impacted by investment (i.e. as the DSO lays more cables / installs more transformers). Therefore investment may not be inefficient if Norm-grid increases sufficiently.

Increasing investment with uncertain demand will be tested in our worked examples.

Increasing supply of renewable electricity sources

The need for rapid connection of renewable power sources is key for the Green Transition's goals. The costs of such connections are also **linked with uncertain impacts** on the benchmarking outputs – connecting new sources of power may not be clearly linked customers or volume of power delivered. Therefore, there is the potential for the benchmarking model to penalise such investments if totex increases by more than what is predicted given the value of the variables.

The speed of the connection may also increase investment costs (e.g. needing to work overtime, or use machinery less efficienctly) without an increase in the output variables of the model, thus making a more rapid connection appear less efficient.

Connecting to green power sources will be tested in our worked examples.

In this slide, we set out hypotheses to test for how the benchmarking model may affect incentives for investment in relation to the Green Transition

Better utilisation of existing assets

Grid reinforcement and security of supply. It may be beneficial for DSOs to be investing in flexibility solutions and data-based monitoring to better utilise the grid and better utilize sources of green power. This could help in managing demand and optimise costs spent on reinforcing and extending the grid (i.e. where more optimal usage can avoid this investment).

However, the costs incurred in flexibility solutions may not be linked with output variables in the model. In particular in this case, costs may not even be captured by norm-grid if they are not linked to the 29 elements that are included (e.g. if they are related to IT solutions or operational expenditure.)

This may mean that the model could penalise / disincentivise flexibility solutions even when they are the efficient solution.

Investing in flexibility solutions will be tested in our worked examples.

First-mover impacts

A related driver of incentives in the model could be the first-mover impacts, linked with an outdated model specification. Being the first to undertake innovative investment can make the DSO appear inefficient *vis a vis* peers if the nature of the investment has a different cost-output ratio to historical investments which are driving the current benchmarking model specification.

New investments for the green transition can imply a different relationship and thus companies undertaking such investment may appear inefficient. This could also work in the opposite direction in some cases, in that the ratios of costs to outputs may favour first movers for some investments, which makes them look more efficient compared to their peers.

If the benchmarking model frontiers are re-estimated, with new data, then first-moves could look more efficient compared to peers. This reflects some regulatory uncertainty.

The impact on investments where the frontier is re-estimated will be tested in the worked examples.

5. An overview of the wider revenue cap regulation's incentives.

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This section provides an overview of how the benchmarking model fits into the overall regulatory framework affecting DSO's incentives

The purpose of this section is to:

- Outline the overall revenue cap regulation governing DSOs, including the benchmarking model
- Set out how these other elements of the regulatory framework might affect networks' incentives to make investments for the Green Transition
- Identify other features that might affect the willingness and ability of networks to make investments for the Green Transition
- Provide context on the relative importance of the benchmarking model, relative to other regulatory features, in driving the incentives of DSOs

The benchmarking model is only one part of the overall revenue cap regulation of network companies

Revenue cap (excl. benchmarking)

- Average costs (sum of depreciation and opex) over the previous regulation period (§ 6), indexed to the price level
- Rate of return (WACC) to reward the invested capital (§ 7)
- Plus a general efficiency challenge calculated on the basis of changes in labour productivity in the construction sector and the overall economy

+

Benchmarking adjustment

- Cost allowances determined based on efficiency scores estimated comparing the performance (costs and outputs) of DSO

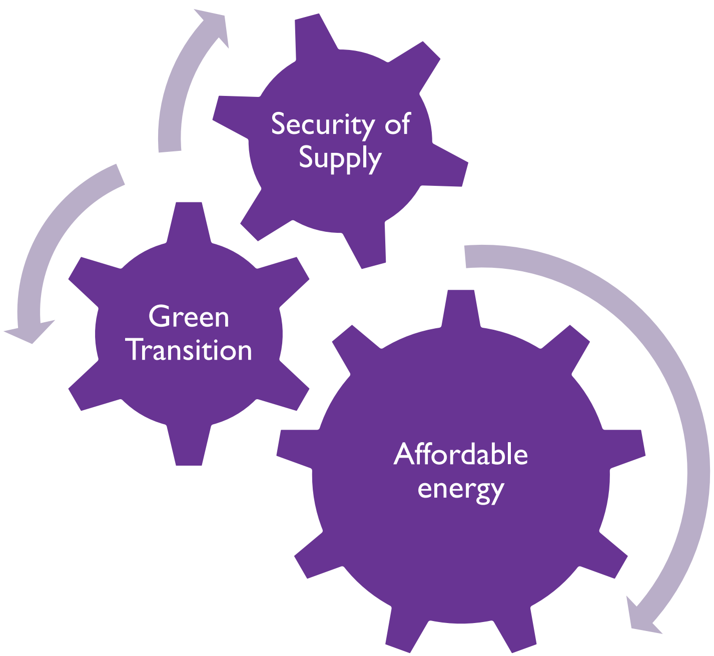
+

Other adjustments within period*

- Quality of supply adjustments - reduced cap if quality of supply inadequate, i.e. if measured interruptions exceed a set target (changing to a modelled social optimum from 2023).
- Automatic indicators –changes to the cap where activity levels change (measured by number of electricity meters and network stations).

* A **new indicator** under consideration would compensate the grid companies for additional costs due to increased load on the grid from relatively homogeneous groups such as electric cars and heat pumps.

The benchmark model has been developed and used within a regulatory framework that primarily has as its goal creating incentives for networks to manage costs efficiently, so as to promote affordable energy prices



- The DSOs are subject to revenue cap regulation, capping the total revenues that each network can collect. This type of framework is used in many jurisdictions across sectors where firms are perceived to be a natural monopoly.
- Absent such regulation, the concern is that such firms may set high prices to earn monopoly profits and/or fail to control their cost base as effectively as they could since the threat of losing market share to a more efficient competitor is not present.
- The overall design of the revenue cap also aims to affect DSOs' incentives so that they behave in ways that align with other policy goals, such as ensuring security of supply or expand the network.
- Changing individual elements of the revenue cap framework, such as the benchmarking model, may have implications for how well these other policy goals are realised. However, we cannot meaningfully attribute all or some of the failure to achieve a given policy goal to a single element of the revenue cap regulation.
- The revenue cap regulations consists of a package of elements that collectively affect incentives for the DSOs. Hence, changing other aspects of this package could have the same or more pronounced effects on the Green Transition as changes to the benchmarking model.

The basic model for determining allowed revenues is backward looking, based on costs in the previous period. During periods in the investment cycle when costs are high, this can create lags before the network can recover all its costs

The Cost Framework

- The allowed costs are calculated as the average of operating costs and depreciation for the previous regulatory period.
- A DSO is able to collect revenues equal to costs in the previous period, subject to adjustments to reflect the regulator's opinion on what efficiency savings the DSO ought to be able to make this period.
- A general efficiency challenge is applied to all DSOs, consistent with the idea that the sector should be able to realise productivity gains over time.
- In addition, DSOs deemed by the benchmarking model to be less efficient then their peers have their revenue allowance adjusted down further.
- When the expenditure required each period is roughly the same, this approach broadly aligns revenues with costs each period.
- This backwards-looking revenue allowance means that DSOs' allowed revenues for the current regulatory period are fixed ex-ante. This implies that there might be a lag between the time investments are undertaken and the costs are recovered (via the next price cap regulation).
- However, automatic indicators and possible supplements (described later) can adjust the revenue cap intra-regulation period (i.e. in the year that costs increase), although with some degree of uncertainty.

Implications of the Green Transition

- New investments necessary for the green transition – connecting more renewable power sources or reinforcing the grid to allow for greater electricity usage by consumers – may create an imbalance between the costs form the previous period and the costs to be incurred at the present period.
- Some of these investments may be very costly. For example, reinforcements to allow uptake of EVs over a large area might trigger the need for much higher voltage investment in other parts of the grid, requiring a 'step-change' in investment.
- The potential for a mismatch between allowed revenues and costs may make DSOs more cautious when deciding to undertake such green investments.
- It is possible that the pace at which these investments are undertaken (based on purely incentives of efficiency, as provided in the regulation) is slower than the one desired at the policy level.

Various adjustments to the cost framework exist that may alleviate, imperfectly, DSO concerns about the mismatch in the forthcoming period between revenue allowed and the extra costs required to fund green investments

Application-based supplements

- The Revenue Framework Executive Order (§§27-42) sets out the supplements whereby a DSO can apply to the regulator to increase its income allowance and/or its calculated return or profit base.
- Supplements of particular relevance include §§31-33:
  - Significant additional costs as a result of the connection of a new supply area, a major new electricity consumer or a major new production unit, or as a result of changes to a supply area in connection with urban development.
  - Additional costs as a result of the connection of new renewable energy plants.
  - Necessary costs that the network companies have been imposed on pursuant to Section 67 of the Electricity Supply Act and Section 30 of the Renewable Energy Promotion Act.

Automatic indicator adjustments

- Within a regulatory period, DSO's cost framework and total return basis are adjusted annually for changes in the network company's activity level.
- Adjustments are calculated using what is referred to as "automatic indicators". These are specified in executive order on revenue frameworks for network companies no. 1127 of 1 June 2021 and are calculated using an increase in the cost base used to calculate the allowed return.
- Adjustment are obtained using a formula that accounts for an increase in electricity meters and stations.
- The Regulator recognises that it is difficult to set an automatic indicator that exactly compensates the grid companies for their additional costs when the level of activity changes. If the indicator undercompensates DSOs then they may be too financially challenged to undertake the investments.

There are also other provisions to exclude certain costs from the benchmarking model, and further adjustments are planned

Benchmarking cost exclusions

- The Revenue Framework allows for some data to be excluded from the costs used in the calculations for individual requirements.
- Costs that can be excluded are described under § 10, PCS. 3 and include four points:
  - 1) energy saving efforts,
  - 2) costs for research, development and demonstration projects (with public co-financing),
  - 3) costs for official processing, and
  - 4) "other data that Forsyningstilsynet chooses not to be included in the benchmarking".
- Of interest is the fact that Forsyningstilsynet has been of the view of allowing costs from flexibility services to be part of these "other data" (and hence exclude these from the efficiency benchmark calculations).
- The consideration of such special cost items follows a specific application from the grid company which is assessed by the Forsyningstilsynet on the basis of the criteria described above.

New indicator and supplement

- There is a political agreement to introduce a new automatic indicator and a new application-based additional system in order to make the income framework regulation ready for the increased electrification, by 1 January 2024.
- The new automatic indicator would compensate DSOs for their additional costs due to increased load on the electricity grid from relatively homogeneous groups such as **electric cars and heat pumps**.
- The new application-based supplementary system would compensate the network companies for their additional costs to larger and different electricity customers, such as **PtX system and large heat pumps**.
- Whilst these revisions to the framework have not yet been implemented, they should provide **incentives to DSOs to invest in the necessary grid reinforcements** to connect more electric vehicles, which should compensate for some of the disincentives for such investment in other parts of the regulation.
- The extent to which these revisions will help incentives for green investment depend on how they are formulated.

Other aspects of the revenue cap regulation will influence DSO's incentives regarding investments for the Green Transition

Quality of supply adjustment
▪ The Regulator monitors the interruption frequency and duration of DSOs (i.e. blackouts), and reduces a grid company's revenue framework if (under the current framework) the measured interruptions exceed set targets, also called insufficient delivery quality. From 2023, supply interruptions will be regulated by a model that incentivizes a social optimum of quality rather than a set target. ▪ Electricity grid companies with an insufficient supply quality will have a 1-year deduction set in their income framework two years after the regulatory year in which the insufficient supply quality occurred. ▪ Therefore, DSOs are **incentivised not to under-invest** too much so as to avoid this penalty. As electricity demand increases (e.g. take-up from EVs), DSO may risk supply interruptions if they have not adequately invested. ▪ However, feedback from stakeholders suggests that DSOs are not very able to predict insufficient supply quality events, especially as demand for increased electrification is not yet apparent. This penalty therefore may not be sufficiently strong to incentivise DSOs to undertake costly investments now for future demand growth.

Other features of the current landscape may also be affecting investment incentives

Whilst these points are beyond the scope of this current study as they do not relate directly to the benchmarking model or to the regulatory framework, they nevertheless provide some insight into DSO's incentives and may affect the impact of any changes to the benchmarking model.

- **Licence and administration processes** for connecting new power sources can be slow, and DSOs cannot charge producers for time spent preparing for connection until the producer has committed to the connection.
- The **lead-time** required for some reinforcement investments (e.g. the purchase of additional transformers) is high and means that DSOs need to incur costs for investment before they are certain about the take-up of demand.
- **Uncertainty about licence renewal conditions**. A stakeholder commented that uncertainty about licence renewal inhibits investment certainty and the ability to borrow funds.

Summary: the benchmarking model is not the only aspect of the regulatory framework affecting DSO incentives to support the Green Transition

The incentives of DSOs to support the Green Transition do not depend uniquely on the benchmarking model. It is just one of a number of elements that make up a regulatory framework seeking to realise a number of policy goals, including affordable energy, security of supply and Green Transition. Other aspects of the regulatory framework affect incentives to support the Green Transition

1. **DSOs may be reluctant to incur a step-increase in costs to fund investments (also green investments) if their revenue allowance for the forthcoming period is based on average costs in the recent past.** Application-based supplements and indicator adjustments can address these concerns, but not perfectly. There will likely always remain some green investments which are not captured by the available adjustments, or where the proposed adjustment is inadequate for the specific investment a DSO is considering
2. **Delaying green investments indefinitely may not be credible assuming the quality of supply adjustment remains in place.** A DSO has to weigh up any short-term gains from delaying network reinforcement or adopting flexibility solutions. DSO should also consider the risk of foul and subsequent penalties for supply disruption.
3. **Revenue-cap regulation is not the only factor DSOs cite as an impediment to supporting the Green Transition**. For example, some DSOs claimed that connecting new power sources is slowed by license and administration processes and further deterred by their inability to charge producer for preparatory work until the producer commits to the investment.

6. Worked examples

Europe Economics

This section presents a range of worked investment examples run through the benchmarking model

The range of data examples we chose are intended to test:

- The impact on the benchmarking model of the variety of **typical green investments** that DSOs might need to undertake, based on our analysis in Section 2.
- **Certain claims / complaints** from stakeholders, set out in Section 3.
- The **dynamics of the benchmarking model** more generally, e.g. as set out in Section 4.

The exercise uses the benchmarking model and data provided by the Regulator in conjunction with our investment examples. We use the benchmarking model to examine the impact of an investment on TOTEX and the three output variables, and in turn the impact on companies' efficiency scores and penalties.

The following slide presents a summary of the examples and their rationale.

We attempted to reflect a range of investment types in our worked examples

Worked example		Rationale
A	2% increase TOTEX, no change in any outputs	Illustrative, to test dynamics of the model. Could also mirror impacts of investing in flexibility solutions (e.g. IT systems; research and development) which increase TOTEX but do not change the other variables in the benchmarking model. This is a risk of the Green Transition, and also a concern raised by DSOs.
B	10% increase in Norm-grid, TOTEX increases inferred from MOLS equation, no change to electricity delivered or connections.	Illustrative, to test dynamics of the model. Could also mirror impacts of expanding network capacity (e.g. for more EVs or heat pumps) with no associated increase in demand. This is a risk of the Green Transition, and also a concern raised by DSOs.
C	10% increase in Norm-grid, TOTEX increases inferred from MOLS equation, 10% increase to electricity delivered and connections.	As above, but also increasing electricity delivered and/or connection variables. This is to simulate scenarios where investment is made in Norm-grid and where demand also increases.
D	10% increase in transformers, 5% electricity delivered, TOTEX increase inferred from Norm-grid model	Impacts of expanding the network to support increased demand for electricity, by reducing the density of transformers to enable greater electricity flow (but no new connections).
E	50% increase in transformers, 25% electricity delivered, TOTEX increase inferred from Norm-grid model	Same as above, but modelling a larger-scale investment.
F	Connection of small windfarm – 5 2.5MW turbines. Total capacity 12.5 MW. Increases in Norm-grid and TOTEX, but no other outputs	Impacts of connecting renewable power sources (small). The number of customer connections and power delivered do not change – only the source of the power.
G	Connection to a small windfarm as above, but with 100% higher cost to reflect 'rapid' connection	Impacts of connecting renewable power sources (small) more quickly, at a greater cost.

Given the lack of concrete examples provided by industry, we used hypothetical examples in two main forms

- The DSOs and trade bodies to whom we spoke have been unable to provide any concrete examples of Green Transition-related investments which they have either undertaken, are planning to undertake, or have been disincentivised from undertaking.
- To address this, we developed worked examples using two forms of data:
  - **Hypothetical percentage increases** in the key model variables to illustrate the types of investments we wished to model. E.g. examples A-E. The context for these examples was informed by our engineering partner Delta and industry (i.e. we're attempting to mimic real-world scenarios) but the variable increases are illustrative.
  - **Case study examples** based on analysis by Delta of actual investment requirements (example F and G).
- A challenge in developing **real-world case studies** is determining exactly what investment requirements would be needed and how these would affect normgrid and TOTEX. Delta's case study provides a best-estimate of what would be required to connect a small windfarm and how this might translate into normgrid and hence TOTEX.
- A further challenge relates to **representativeness:** the requirements (and thus costs) of an investment will vary considerably across DSOs, and across different areas for the same DSO, depending e.g. on the state of the existing network, topography, density of customers, relation to neighbouring higher voltage networks etc. Therefore it is not possible to develop a case study for a 'representative wind farm connection' or any other 'representative' investment. This would be the same whether we were using actual examples from DSOs rather than our own case studies.

Given the lack of concrete examples provided by industry, we used hypothetical examples in two main forms

- We used two approaches to estimating the TOTEX associated with an increase in the Norm-grid variable (the key variable determining the type of assets to be included in the investment).

1. The first approach uses the **indicative asset values** for each element of Norm-grid embedded in the model we received from the Regulator. For the purposes of approximating a TOTEX figure for these illustrative examples we consider this suitable (a view shared by the Regulator). This approach will not perfectly represent the TOTEX associated with a change in Norm-grid as the asset values are aggregated, and are also based on estimates at least 5 years old.

2. The second approach uses the **MOLS equation** to estimate an efficient TOTEX associated with a given increase in the Norm-grid variable. For example, the current parameters are shown as follows:

LN(TOTEX) = 9.54 + 0.58 * LN(NORMGRID) + 0.37 * LN(CONNECTIONS) + 0.08 * LN(KWH_DELIVERED) + 0.00 * OVERHEAD

We estimate for each relevant company what a 10% increase in Norm-grid would imply for that company's TOTEX.

We used the worked examples to estimate whether and by how much the benchmark model might penalise a candidate investment

- Consider a potential investment for company i.
- Consider its costs (TOTEX) and expected impact on drivers (NORMGRID, CONNECTIONS, DELIVERED).
- Add these to data for company i and calculate a new EFFICIENCY score and PENALTY.

The difference between pre- and post-investment results will give us the impact

$$\text{IMPACT}_i = \text{PENALTY}_i^1 - \text{PENALTY}_i^0$$

If **IMPACT > 0** this means that company is worse off (has a greater penalty) undertaking the investment.

Our approach considered both a backward-looking and forward-looking approach to the benchmarking, as described on the following slides.

The backward-looking approach assumes a fixed efficiency frontier – changes to a company's investment costs and outcomes will change its position in relation to the frontier

Backward looking approach:

- We built a model that estimates EFFICIENCY and PENALTIES taking the MOLS and DEA frontiers as fixed, e.g. betas in MOLS unchanged
- We add TOTEX and/or the three outputs to the existing totals for all DSO.
- We compare before and after results.

This shows the impact on a firm's efficiency scores of undertaking different investments if the frontier remained unchanged.

It is a simple way of applying the same investment to all companies at the same time.

It also tests the dynamics of how the model works, e.g. what size of inefficiency penalty could result from a certain investment and related changes to outputs, and how large is that penalty in relation to the investment cost?

This exercise shows what every company should be aiming to achieve (in terms of efficiency) during the regulatory period. To the extent that they can get closer to the existing frontier, they should expect to increase their efficiency score. This exercise is a proxy of what the company might expect in the next regulatory period.

In practice, the frontier is estimated having regard to the firm's data. Moreover, investments today will not affect the previously estimated frontier or penalties, but firms will be interested in how the regulator will estimate an updated frontier and the impact of any investment they make today on such an estimation (and associated penalties). We therefore also use a forward-looking approach.

The forward-looking approach assumes a re-estimation of the efficiency frontier using the data of the investment example

Forward looking approach:

- We estimate current EFFICIENCY and PENALTIES scores for the firms
- We add TOTEX and/or the four outputs to the existing totals for a single network operator.
- We built a model that re-estimates the MOLS and DEA frontiers and estimate the EFFICIENCY and PENALTIES
- We compare before and after results.
- The exercise seeks to isolate the effect of a single worked example if only **one firm** undertakes that investment while all other networks carry on as before.
- We chose three frontier companies on which to test these examples: **N1, Konstant and Rah**. The aim was to choose companies with potentially different efficiency drivers (these three cover a range of urban and rural).
- In practice, the frontier will be re-estimated in the next regulatory period, and investments that are made today will be included in this estimation.
- Although it is only a single companies' data that change, because the frontiers are re-estimated conclusions about other firms' efficiency (and corresponding penalties) can also change even though their behaviour is unchanged.
- Current frontier companies will be evaluated against a new frontier and may face a change in their efficiency score.
- Non-frontier companies may also be affected if they are closer to or further away from the new frontier, through the size of their inefficiency score and penalty.

The table below summarises our set of worked examples including the changes to the variables for the fixed frontier

Scenario	TOTEX	NormGrid	Electricity supplied	Customers	Companies affected	Frontier
A1	2%	-	-	-	ALL	Fixed
B1	Inferred (MOLS)*	+10%	-	-	ALL	Fixed
C1	Inferred (MOLS)*	+10%	+10%	+10%	ALL	Fixed
D1	Inferred (NG)*	+10% transformers	+ 5%	-	ALL	Fixed
E1	Inferred (NG)*	+ 50% transformers	+ 25%	-	ALL	Fixed
F1	Inferred (NG)*	Connection**	-	-	ALL	Fixed
G1	Inferred (NG)* and doubled	Connection**	-	-	ALL	Fixed

Note: Inferred (NG)* denotes that the value has been inferred from the simulated change in Normgrid. This will be different for each company.
Inferred (MOLS)* denotes that the value has been inferred from the MOLS relationship between Norm-grid and TOTEX
Connection** includes: one 30 – 60kV open field circuit breaker, 5 km of 30 – 60kV overhead line for connection to HV network, and one 30 – 60 kV <20MW transformer. Again the impact on Norm-Grid will be different for each company.

The table below summarises our set of worked examples including the changes to the variables, for the re-estimated frontiers

Scenario	TOTEX	NormGrid	Electricity supplied	Customers	Companies affected	Frontier
A2	+2.00% *	-	-	-	NI	Re-evaluated
B2	+6.20% **	+10.00%	-	-	NI	Re-evaluated
B3	+6.18% **	+10.00%	-	-	Konstant	Re-evaluated
B4	+5.92% **	+10.00%	-	-	Rah	Re-evaluated
C3	+12.35% **	+10.00%	+10.00%	+10.00%	Konstant	Re-evaluated
D2	+0.38% *	+0.26%	+ 5%	-	NI	Re-evaluated
E2	+1.88% *	+1.28%	+ 25%	-	NI	Re-evaluated
F2	+0.02% *	+0.01%	-	-	NI	Re-evaluated
G2	+0.04% *	+0.01%	-	-	NI	Re-evaluated

Note: * Totex value has been inferred from the simulated change in Normgrid. This will be different for each company.
** Totex value has been inferred from the MOLS relationship between Norm-grid and TOTEX

The examples

Example A – 2% increase in TOTEX, no change in other variables

Rationale for the example

- This example represents a scenario where a DSO undertakes an investment, with no change in any of the outputs in the benchmarking model except TOTEX.
- This could represent investment in **flexibility solutions** or data monitoring, which entails IT and operational investment with no direct impact on Norm-grid, connections or the volume of electricity delivered.
- The example also tests the dynamics of the benchmarking model i.e. what are the impacts of increasing cost with no increase in any outputs. This is an illustrative, conservative example.

Example set-up

- In this scenario, the DSO invests in IT and other data-monitoring capabilities such that its TOTEX increases by 2%.
- As the investment items are not included in Norm-grid, this output is not affected. Electricity delivered and number of customers are also not affected. (We consider this conservative as in reality electricity delivered may increase if the grid is more efficient because of the flexibility solution).

Parameter	Change	Rationale
Normgrid	No change	Flexibility solutions require investments that are not included in Norm-grid. Could also reflect purely operational expenditure.
KWh delivered	No change	Represents the scenario where demand and electricity delivered remains the same.
Connections	No change	Represents the scenario where demand and number of connections remains the same.
TOTEX	2% increase for all DSOs	Illustrative 2% increase in TOTEX for all DSOs due to the investment.

Example A – 2% increase in TOTEX, no change in other variables

Hypothesis to test

- If a firm's TOTEX increases with no corresponding increase in any of the other variables then we would expect it to appear less efficient in the benchmarking model. How material would this efficiency change be in terms of efficiency scores and penalties?

Results – fixed frontier (A1)

- The backwards looking approach applies this investment change to **all DSOs** in the **current benchmarking model (with the frontier unchanged)** by increasing all their TOTEX by 2%. New efficiency scores and penalties are then calculated.
- The results show that all DSOs would become less efficient, and that some would incur a penalty whereas previously they had none (See the results in the Annex). However, the magnitude is small, with the largest change in penalty being 0.14% of TOTEX (e.g. for Dinel and Veksel).

Results – re-estimated frontier for N1 (A2)

- This represents the scenario where a single firm (N1) undertakes the investment before its peers. In the future the frontier would be re-estimated with this data.
- After re-estimating the frontier, N1 is evaluated as efficient (because of the way efficiency scores are calculated, N1 actually shows a marginally higher score, although this has no financial implications for the company). Twelve other companies are also deemed more efficient with the re-estimated frontier because the inclusion of N1's cost increase makes the frontier more achievable to these companies which have not incurred any extra costs.
- A handful of companies are now less efficient with the newly estimated frontier. Whilst this may seem counterintuitive (N1's costs should have made the frontier more achievable), it may be that the inclusion of N1's costs in the re-estimated frontier changes the slope or shape of the frontier, such that some companies are now further away from it and thus less efficient than their peers.

Example A – 2% increase in TOTEX, no change in other variables

Conclusions

- The example shows that under a fixed frontier, an increase in TOTEX with no corresponding increase in output would reduce the efficiency of all companies relative to a fixed frontier. This is as expected. This may deter companies from investing in solutions with a high proportion of operational or IT expenditure which does not relate to any Norm-grid assets or other outputs, if they are only considering performance relative to the current frontier.
- However, in the case of flexibility solutions the wider regulation may have permitted the investment to be excluded from the benchmarking model (through an application by the DSO), such that TOTEX would not have increased anyway for the purposes of the benchmarking model.
- In the case of the re-estimated frontier, an increase in TOTEX with no related increase in output may not disadvantage a firm in the next regulatory period if this investment data is used to re-estimate the frontier. An increase in TOTEX may result in a re-estimated frontier that is more achievable for that firm (and for other firms). This suggests that investments like flexibility solutions would not necessarily be penalised in the benchmarking model in future regulatory periods.

Example B - 10% increase in Norm-grid, TOTEX increases inferred from the MOLS equation

Rationale for the example

- This example represents a scenario where a DSO expands its network capacity to prepare for increased demand for electricity, e.g. electrification for EVs in a suburb. However, in this scenario demand does not materialise in the current period (e.g. EV take-up is much slower than expected).
- We chose this example as it is a realistic consequence of the Green Transition, where DSOs are needed to prepare for increased electrification in advance, but where demand take-up (or the timing thereof) is uncertain. It is also something that DSOs have complained about as a reason for deterring investment.
- The example also tests the dynamics of the benchmarking model i.e. what are the impacts of changing certain parameters. We deliberately chose a "worst case scenario" whereby investment costs are material with no change in demand.
- We therefore test whether a DSO making such a decision might be deterred from investing, if they expect a material penalty from the benchmarking model in the event that demand is slow to materialise.

Example set-up

- In this scenario, the DSO invests in various capital items (cables, transformers etc) needed to prepare for increased electrification. The 10% increase in Norm-grid reflects this – this is an illustrative increase.
- Totex increases by the amount implied by a the MOLS equation for a corresponding 10% increase in Norm-grid.
- The other outcome variables remain the same, representing no take-up in demand. This is summarised below:

Parameter	Change	Rationale
Normgrid	10% increase	Represents investment in assets needed to expand the grid for increased electrification.
KWh delivered	No change	Represents the scenario where demand and electricity delivered remains the same.
Connections	No change	Represents the scenario where demand and number of connections remains the same.
TOTEX	6.2% increase for N1; 5.9% increase for Rah; 6.8% for Konstant	We calculated the costs associated with a 10% increase in the Norm-grid variable using the MOLS relationship parameters. We report for N1, Rah and Konstant.

Example B - 10% increase in Norm-grid, TOTEX increases inferred from the MOLS equation

Hypothesis to test

- If a firm's TOTEX increases then we would expect it to appear less efficient in the benchmarking model. However, if Norm-grid also increases, then the impact on efficiency is less certain. Would the increase in this output (Norm-grid) outweigh the lack of increase in the other outputs, making the investment appear more efficient in the benchmarking model even in the face of uncertain demand (captured by KWh and connections)?

Results – fixed frontier (B1)

- The backwards looking approach applies this investment change to **all DSOs** in the **current benchmarking model (with the frontier unchanged)** by increasing all their TOTEX and Norm-grid variables, whilst leaving KWh and connections unchanged. New efficiency scores and penalties are then calculated.
- The results show that increasing Norm-grid, without any corresponding increase in connections or electricity supplied would **move all but four DSOs further from the frontier.** This means that for the majority the extra totex would not be justified by the increase in Norm-grid alone, and the companies would be considered to have made an inefficient investment. This is the case even though the Norm-grid variable has the largest coefficient in the MOLS equation (such that it *might* have been expected to offset the increase in totex).
- However, the most and least efficient firms would not incur any **additional** penalties, as the penalties are constrained by thresholds. Four other firms would in fact appear more efficient (with a slight decrease in penalties of between 0.02 and 0.04% of TOTEX). For the others, the maximum penalty change is minor (highest change is 0.37% of totex for Trefor in the results table in the Annex, amounting to DKK1.5 million). As an example, N1's penalty increase is 0.15% of totex, compared to an increase in totex of 6.2% from the investment. The absolute penalties as a share of TOTEX are also small and all below 2%.

Example B - 10% increase in Norm-grid, TOTEX increases inferred from the MOLS equation

Results – re-estimated frontier (B2 N1)

- This represents the scenario where a single firm, N1, undertakes the investment before its peers.
- The results show that if N1 (a frontier company) invested in expanding its capacity with no change in demand, and the frontier was re-estimated using this new data, then it would be deemed more efficient than it currently is. This is likely due to the fact that the re-estimated frontier includes the new cost data from N1 (an increase in TOTEX of DKK156 million) and changes the slope or shape of the frontier, such that N1 appears more efficient.
- As the frontier has changed, some other firms would also now appear more efficient than currently – N1's revised numbers cause the frontier to shift inwards. Some companies would even incur a reduction in their current penalties, without them having changed anything.
- Some companies appear less efficient than currently, although in very small changes. As with Example A, it is likely the re-estimation to include N1's costs has changed the slope of the frontier such that some firms are now further away. The re-estimation may also have changed which variables are dictating companies' efficiency (in a DEA model).

Results (B3 Konstant)

- To test other companies which might have different efficiency drivers to N1, we tested the example on Konstant. The results show that Konstant would be deemed less efficient if it had undertaken this investment even with a re-estimated frontier. However, the decrease in its efficiency score is negligible and it doesn't incur any additional penalties. The investment (TOTEX) for Konstant would be DKK36 million. (Example C below illustrates the time dimension by showing results for the same investment by Konstant but with an uptake in demand and connections.)

Example B - 10% increase in Norm-grid, TOTEX increases inferred from the MOLS equation

Results (B4 Rah)

- Rah is deemed more efficient in a re-estimation of the frontier using its investment data, although its efficiency score does not change. Many of the other firms remain the same – this could be due to the very small investment amount undertaken by Rah (DKK12 million).

Conclusions

- In this example, an investment which increases a DSO's assets and capacity but is not accompanied by any increase in KWh delivered or the number of connections would make most DSOs appear less efficient in the current model (the backwards-looking approach). Whether the DSO would actually incur a penalty depends on where they currently are in relation to the frontier. DSOs may not be incentivised to undertake investments if there is significant uncertainty about whether KWh and connection variables will actually increase and the DSO benchmarks itself against the existing frontier.
- For this worked example, the results suggest that N1 and Rah would however be at an advantage if they were the only company to undertake the investment and the frontiers were re-estimated using the updated data for these firms. This is because the changes in input and output are not necessarily proportionate – e.g. a 10% increase in Norm-grid results in an increase in TOTEX of between 5.9% and 6.8% for the three companies under study.
- The investment amounts for this example are relatively small, such that the changes in efficiency (and penalties) are all very small.

Example C – 10% increase in Norm-grid, electricity delivered and connections, TOTEX increases inferred from the MOLS equation

Rationale for the example

- This example represents an extension of Example B, namely a scenario where a DSO expands its network capacity to prepare for increased demand for electricity, e.g. electrification for EVs in a suburb. In this scenario, demand also increases such that the electricity delivered and connections variables both increase by 10% as well. (We understand from the Regulator that new public EV charging stations would typically be counted as new connections, with the possibility that charging stations connected to pre-existing installations – e.g. homes – could be made statistically visible in the future.)
- We chose this example as an extension to Example B, to show how the benchmarking model might affect incentives in scenarios where demand is not uncertain, or where it materialises in future time periods.

Example set-up

- In this scenario, the DSO invests in various capital items (cables, transformers etc) needed to prepare for increased electrification. The 10% increase in Norm-grid reflects this – this is an illustrative increase. The other variables representing demand also increase by 10%.
- Totex increases by the amount implied by a the MOLS equation for a corresponding 10% increase in Norm-grid, KWh delivered and number of connections.
- Given that N1 and Rah were still considered efficient in the re-estimated frontier in Example B, we only focus on Konstant in this worked example.

Parameter	Change	Rationale
Normgrid	10% increase	Represents investment in assets needed to expand the grid for increased electrification.
KWh delivered	10% increase	Represents the scenario where demand and electricity delivered remains the same.
Connections	10% increase	Represents the scenario where demand and number of connections remains the same.
TOTEX	12% for Konstant	We calculated the costs associated with a 10% increase in the three variables using the MOLS relationship parameters.

Example C – 10% increase in Norm-grid, electricity delivered and connections, TOTEX increases inferred from the MOLS equation

Hypothesis to test

- We would expect firms in this example to appear more efficient in the benchmarking model compared to Example B, as here the initial investment in TOTEX is accompanied by an increase in all 3 output variables as demand materialises – Norm-grid, KWh delivered and number of customers/connections. This example represents the time-dimension of the benchmarking model, whereby the efficiency of an investment can be affected over time as and when demand changes. However, as TOTEX is linked to KWh and number of customers in the MOLS equation, the approximated TOTEX also increases in this example.

Results - fixed frontier (C1)

- The backwards looking approach applies this investment change to all DSOs in the current benchmarking model (with the frontier unchanged) by increasing all their TOTEX, Norm-grid, KWh delivered and connections variables. New efficiency scores and penalties are then calculated.
- The majority of DSOs (all but four) appear less efficient following this investment, against the current frontier. A number incur additional penalties, the largest change being 0.64% of TOTEX.

Results – re-estimated frontier (C3 Konstant)

- The results show that if Konstant had undertaken the investment in Norm-grid and there was an accompanying increase in demand, then in the following period with a re-estimated frontier Konstant would appear more efficient. This contrasts with example B3 where Konstant was still less efficient in the re-estimated frontier when there was no increase in demand. Konstant performs better than many of its peers – 23 appear less efficient against the re-estimated frontier.

Conclusions

- Including an increase in demand (proxied by the increase in KWh delivered and number of connections) moves our example DSO Konstant from inefficient to efficient compared to the Example B3 where the TOTEX increase was only associated with an increase in Norm-grid. This result is consistent with the types of incentives we would want – an investment where demand materialises is treated more favourably by the benchmarking model than an investment expanding a network with no corresponding increase in demand. However, examples B2 and B4 show that the benchmarking model will not always penalise investments reinforcing the network where demand does not materialise.

Example D - 10% increase in transformers, 5% electricity delivered, TOTEX increase inferred from Norm-grid

Rationale for the example

- This example represents a scenario where a DSO undertakes an investment to expand the grid to enable an increase in the amount of electricity delivered. This could represent investment in additional transformers to reduce the density of transformers-to-customers and allow customers to draw increased volumes of electricity, e.g. to power EVs or heat pumps. This example was provided by one DSO we interviewed (although it was not able to provide an estimate of the number of new transformers that might be needed).
- We chose this example as it relates to a clear element of the Green Transition (increased electrification) and should be relevant to a range of DSOs.

Example set-up

- In this scenario, the DSO increases its investment in transformers by 10%. For each DSO this will have a different impact on its Norm-grid variable and its TOTEX. We present the results for N1 in the summary table below.
- We infer the increase in TOTEX using the increase in Norm-grid and the associated proxy costs embedded in that model.
- The increased capacity will enable electricity delivered to increase by 5%.

Parameter	Change	Rationale
Normgrid	0.26%	Norm-Grid increases with the 10% increased investment in transformers. We present the Norm-grid increase for N1, as all DSOs would be different.
KWh delivered	5% increase	Represents the scenario electricity delivered increases due to additional capacity.
Connections	No change	Represents the scenario where the number of connections remains the same.
TOTEX	0.38%	TOTEX increases with the investment in transformers. We present the increase for N1 as all DSOs would be different.

Example D - 10% increase in transformers, 5% electricity delivered, TOTEX increase inferred from Norm-grid

Hypothesis to test

- The example will test whether a DSO investing in expanding the grid to allow for greater electricity usage among households would be deemed more/less efficient in the benchmarking model. The hypothesis is that if this is an efficient investment (the increases in Norm-grid and KWh delivered justify the increase in costs) then the DSO should not be penalised.

Results – fixed frontier (D1)

- The results show that the impact of the example investment would differ across the different DSOs. Some would move away from the current frontier and thus be deemed less efficient. Others would become relatively more efficient compared to the current frontier.
- How firms would fare against the current benchmarking frontier under this worked example is not perfectly correlated with their current efficiency ranking in the model. There are some poorly performing firms that would be deemed more efficient, while better performing firms would be deemed less efficient and vice versa. The current mix of assets in their Norm-Grid calculations will be decisive.
- Overall, changes in penalties are minor (e.g. increase of 0.01% of TOTEX for N1 compared to a 0.38% increase in totex from the investment).
- This implies that the impacts of the model on firms' incentives would be mixed, and that not all would be disincentivised from undertaking such an investment even with the current fixed frontier.

Example D - 10% increase in transformers, 5% electricity delivered, TOTEX increase inferred from Norm-grid

Results – re-estimated frontier (D2 – N1)

- We applied the investment to N1 only (frontier company), and re-estimated the frontier using this new data. The results show that N1 would be deemed less efficient against the new frontier if it was the only network to undertake the investment envisaged under this scenario. However, it would not receive a greater penalty (which is different to the fixed frontier approach, where N1 was one of the companies to received a greater inefficiency score and penalty as a result of the investment).
- Again, some companies appear more and some less efficient with the re-estimated frontier, explained by the changing shape of the frontier line and potentially a change in the output variable dictating the position on the frontier.

Conclusions

- This example suggests that companies could still be disincentivised from undertaking an investment to facilitate greater electrification. Whilst some would not be deemed less efficient in the current model, others would move away from the frontier and receive greater penalties. This risk might act as a disincentive.
- That said, this example disproves the general complaint of DSOs that 'any investments' penalise them in the benchmarking model.
- The forward-looking approach shows that companies would not necessarily be worse off in the future with a newly estimated frontier if they undertook the investment – at least not in terms of a greater penalty.

Example E - 50% increase in transformers, 25% electricity delivered, TOTEX increase inferred from Norm-grid

Rationale for the example

- This example represents a scenario where a DSO undertakes an investment to expand the grid to enable an increase in the amount of electricity delivered.
- This could represent investment in additional transformers to reduce the density of transformers-to-customers and allow customers to draw increased volumes of electricity, e.g. to power EVs or heat pumps.
- This is similar to Example D, but with a larger-scale investment in order to test how the model treats investments of different sizes.

Example set-up

- In this scenario, the DSO increases its investment in transformers by 50%. For each DSO this will have a different impact on its Norm-grid variable and its TOTEX. We present the results for N1 in the summary table below.
- We infer the increase in TOTEX using the increase in Norm-grid and the associated proxy costs.
- The increased capacity will enable electricity delivered to increase by 25%.
- The number of customers would remain unchanged.

Parameter	Change	Rationale
Normgrid	1.28%	Norm-Grid increases with the 50% increased investment in transformers. We present the Norm-grid increase for N1, as all DSOs would be different.
KWh delivered	25% increase	Represents the scenario electricity delivered increases due to additional capacity.
Connections	No change	Represents the scenario where the number of connections remains the same.
TOTEX	1.88%	TOTEX increases with the investment in transformers. We present the increase for N1 as all DSOs would be different.

Example E - 50% increase in transformers, 25% electricity delivered, TOTEX increase inferred from Norm-grid

Hypothesis to test

- If a firm's TOTEX increases along with an increase in two of the outputs – Norm-grid and electricity delivered, then if it is an efficient investment we would expect the company to be no worse off in the benchmarking model. This example tests the impact of a larger investment on the model.

Results – fixed frontier (E1)

- The backwards looking approach applies this investment change to **all DSOs** in the **current benchmarking model (with the frontier unchanged).** The results are similar to Example D. A number of companies are now less efficient compared to the current frontier, although the change in efficiency is greater than in Example D and more would not incur a penalty. This is likely due to the larger scale of the investment. N1 would move off the frontier and incur a penalty of 0.06% of TOTEX.

Results – re-estimated frontier for N1 (E2)

- This represents the scenario where a single firm (N1) undertakes the investment before its peers. In the future the frontier would be re-estimated with this data.
- The results show that whilst N1 would be considered less efficient under the re-estimated frontier, it would not incur a penalty.
- A number of other firms would now be more efficient under the new frontier, more so than with Example D. This is likely due to the larger investment here contributing to a more achievable frontier compared to Example D.

Conclusions

- Similar to Example D this shows that not all firms would be penalised for such an investment in the benchmarking model under the current frontier or a re-estimated one. Any penalties are likely to be small.

Example F - Connection of small windfarm – 5 2.5MW turbines. Total capacity 12.5 MW

Rationale for the example

- This example represents a scenario where a DSO invests to connect to a renewable power source – in this case a small windfarm. We assume that the windfarm consists of five 2.5 MW turbines with a total capacity of 12.5 MW.
- This represents a key type of investment many DSOs will face given the move towards renewable energy. We note that not all DSOs will be connecting renewables (as these generators are usually located in more rural areas).

Example set-up

- In this scenario, the DSO's costs increase from investing in one 30 – 60kV open field circuit breaker, 5 km of 30 – 60kV overhead line for connection to HV network, and one 30 – 60 kV <20MW transformer. We infer the increase in TOTEX using the increase in Norm-grid and the associated proxy costs.
- The number of customers will remain unchanged. The volume of electricity delivered will also remain unchanged, as the connection will only change the *source* of power rather than the volume delivered.

Parameter	Change	Rationale
Normgrid	0.01%	Norm-Grid increases with the investment in assets. We present the Norm-grid increase for N1, as all DSOs would be different.
KWh delivered	No change	Represents the scenario where electricity delivered remains the same.
Connections	No change	Represents the scenario where the number of customers remains the same.
TOTEX	0.02%	TOTEX increases with the investment in Norm-grid assets. We present the increase for N1 as all DSOs would be different.

Example F - Connection of small windfarm – 5 2.5MW turbines. Total capacity 12.5 MW

Hypothesis to test

- If a firm's TOTEX increases then we would expect it to appear less efficient in the benchmarking model. However, if Norm-grid as an output also increases, then the impact on efficiency is less certain. Would the increase in Norm-grid outweigh the lack of increase in the other outputs?

Results – fixed frontier (F1)

- The backwards looking approach applies this investment change to **all DSOs** in the **current benchmarking model (with the frontier unchanged).** The results show that all firms would appear less efficient against the current frontier. This may disincentivise firms from undertaking these types of investments in this period for fear of incurring penalties.
- Not all firms would incur penalties, depending on the scale of their efficiency decrease.

Results – re-estimated frontier for N1 (F2)

- This represents the scenario where a single firm (N1) undertakes the investment before its peers. In the future the frontier would be re-estimated with this data.
- The results show that N1 is deemed less efficient against the re-estimated frontier, although the reduction in its efficiency is very small and it doesn't incur a penalty. A number of other companies are deemed more efficient which can be expected. Some are deemed less efficient (with very small reductions in efficiency) as a result of the re-estimated frontier.

Conclusions

- This example shows that connecting a small windfarm would make all DSOs appear less efficient against the current frontier, although the increase in penalties is minor. This could disincentivise this behaviour if DSOs are using the current frontier as a guide for their decisions.
- A firm may also be less efficient against a re-estimated frontier, although the magnitude of this may again be very small.

Example G – "Rapid" connection of small windfarm – 5 2.5MW turbines and total capacity 12.5 MW.

Rationale for the example

- This example is similar to Example E – connecting to a small windfarm. We assume that the windfarm consists of five 2.5 MW turbines with a total capacity of 12.5 MW.
- However, we increase the TOTEX by an additional 100% to represent the increased costs of connecting the windfarm **more quickly.** Increased costs could arise from needing to use overtime labour, less efficient use/planning of equipment, or needing to access land/roads at more costly times. This represents an 'extreme' example.

Example set-up

- In this scenario, the DSO's costs increase from investing in one 30 – 60kV open field circuit breaker, 5 km of 30 – 60kV overhead line for connection to HV network, and one 30 – 60 kV <20MW transformer. We infer the increase in TOTEX using the increase in Norm-grid and the associated proxy costs. We then uplift the costs by 100%
- The number of customers will remain unchanged. The volume of electricity delivered will also remain unchanged, as the connection will only change the *source* of power rather than the volume delivered.

Parameter	Change	Rationale
Normgrid	0.01%	Norm-Grid increases with the investment in assets. We present the Norm-grid increase for N1.
KWh delivered	No change	Represents the scenario where electricity delivered remains the same.
Connections	No change	Represents the scenario where the number of customers remains the same.
TOTEX	0.04%	TOTEX increases with the investment in Norm-grid assets. We present the increase for N1 as all DSOs would be different.

Example G – "Rapid" connection of small windfarm – 5 2.5MW turbines and total capacity 12.5 MW.

Hypothesis to test

- We would expect firms to be worse off in terms of efficiency in this scenario compared to Example E as TOTEX is 100% higher whilst the other outputs remain the same.

Results – fixed frontier (G1)

- The backwards looking approach applies this investment change to **all DSOs** in the **current benchmarking model (with the frontier unchanged).** The results show that all companies are less efficient against the current frontier. The reduction in efficiency is materially greater compared to Example E which is expected given the much higher cost.

Results – re-estimated frontier for N1 (G2)

- The results show that N1 is more efficient against the re-estimated frontier, and that so are many other companies. This can be explained by the large cost increase from N1 making the frontier more achievable.

Conclusions

- Under the current frontier, firms are likely to be disincentivised from undertaking more rapid connections that entail a significant increase in cost for no increase in related output, as they could incur material penalties.
- Whilst faster connections to green power will have benefits to society (reduced emissions and also potentially reduced costs e.g. in the current situation with Ukraine), these benefits are not reflected in the benchmarking model's outputs. The only variable that is relevant is the included costs.
- In the following regulatory period, a company may benefit compared to its peers from undertaking such investments, but this will depend on how the rest of the companies' costs change and how the frontier is re-estimated.

7. Conclusions

This section sets out our conclusions

- It summarises the results from our worked examples and presents some summary observations.
- It then discusses the whether and how the benchmarking model and wider regulatory framework could be adjusted to support the Green Transition.

For most of our worked examples DSOs undertaking the envisaged investment would move further away from the current estimated efficiency frontier, although this would not always imply them having to pay a higher penalty

Summary of examples – fixed frontier model

Scenario	TOTEX	NormGrid	Elec supplied	Customers	Companies affected	Impact on DSOs
A1	2%	-	-	-	ALL	All become less efficient. Some increase penalties. Penalty increases as a % of TOTEX small (max 0.14%)
B1	Inferred (6.2% for N1)	+10%	-	-	ALL	Most, but not all, become less efficient. Some increase penalties. Penalty increases as a % of TOTEX small (max increase 0.37% of TOTEX).
C1	Inferred (12% for Konstant)	+10%	+10%	+10%	ALL	Most, but not all, become less efficient. Some increase penalties. Penalty increases as a % of TOTEX higher than B (max increase 0.64% of TOTEX) as TOTEX for this example is higher.
D1	Inferred (+0.38% for N1)	+10% transformers	+ 5%	-	ALL	Varying impact on DSOs – some become more and some become less efficient. Minor impacts E.g. increase of 0.01% of TOTEX for N1 compared to a 0.38% increase in TOTEX from the investment
E1	Inferred (+1.88% for N1)	+ 50% transformers	+ 25%	-	ALL	Varying impact on DSOs – some become more and some become less efficient. Larger penalty increase for N1 (0.06% of TOTEX)
F1	Inferred (0.02% for N1)	Connection	-	-	ALL	All become less efficient. Some increase penalties. Largest penalty increase 0.76% of TOTEX.
G1	Inferred doubled (0.04% for N1)	Connection	-	-	ALL	All become less efficient. Some increase penalties. Largest penalty increase 0.91% of TOTEX.

Simply looking at the investment costs compared to the existing frontier may prompt inaccurate conclusions about how an efficient firm might fare in future benchmarking. Focussing just on the current frontier may deter DSOs from undertaking investments.

However, allowing for the fact that investment decisions today will feed into estimates of the frontier for future benchmarking exercises tends to reduce any disincentive to invest that might be attributed to benchmarking

Scenario	TOTEX	NormGrid	Electricity supplied	Customers	Companies affected	Efficiency change	Penalty change as % of TOTEX	Absolute penalty as % of totex
A2	2.00%	-	-	-	NI	More efficient	No penalty	No penalty
B2	+6.2%	+10.00%	-	-	NI	More efficient	No penalty	No penalty
B3	+6.8%	+10.00%	-	-	Konstant	Less efficient	No penalty	No penalty
B4	+5.9%	+10.00%	-	-	Rah	More efficient	No penalty	No penalty
C3	+12%	+10.00%	+10.00%	+10.00%	Konstant	More efficient	No penalty	No penalty
D2	+0.38%	+0.26%	+ 5%	-	NI	Less efficient	No penalty	No penalty
E2	+1.88%	+1.28%	+ 25%	-	NI	Less efficient	No penalty	No penalty
F2	+0.02%	+0.01%	-	-	NI	Less efficient	No penalty	No penalty
G2	+0.04%	+0.01%	-	-	NI	More efficient	No penalty	No penalty

Note: in many cases the reduction in efficiency was so minor that no penalty was incurred.
In some examples, companies receive a better efficeincy score after the frontier is re-estimated.

Summary observations about the examples

1. Our examples show that where investment is accompanied by no changes in any of the output variables (A1, F1 and G1), then all companies appear less efficient under the benchmarking model in the fixed frontier, which is as expected. This may affect DSO's perceptions about whether a given investment would be deemed efficient under benchmarking.

2. However, where the frontier is re-estimated with the selected company's investment costs, it often appears more efficient than its peers (examples A2 and G2). With a re-estimated frontier, it cannot be claimed that the model will automatically penalise investments with no associated outputs (e.g. a 'worst case' investment).

3. For other investments that entail increases in some or all of the output variables alongside an increase in TOTEX, the benchmarking model does not always penalise investments by making companies appear less efficient, even under the fixed frontier. In particular, companies are not always deemed inefficient even where the associated output changes are limited, such as in a case of unrealised demand, as simulated in Example B1. Companies undertaking these investments are often more efficient under the re-estimated frontier (Examples A2, B2, B4, C3, G2).

Summary observations about the examples

4. The value of TOTEX influences the benchmarking results. As expected, the higher the investment cost the more marked the results (e.g. the penalties associated with inefficiency). Although not reported in this report, our results for example B1-B4 using higher TOTEX estimates derived using Norm-Grid numbers generating benchmarking results less favourable to the company making the investment. The benchmarking model favours firms choosing more efficient, lower-cost investment solutions.

5. The benchmarking model will not necessarily penalise 'flexibility solutions' e.g. that entail TOTEX but do not lead to any material change in the relevant output variables (e.g. if the investment is purely in IT systems). This is suggested by Example A2 in the re-estimated frontier.

6. Where expected demand growth is un-realised at the moment of investment, companies will not always be deemed to have made an inefficient investment (e.g. examples B1, B2 and B4). Even where companies are inefficient (e.g. example B3) then an upturn in outputs associated with demand (KWh and number of connections) can reverse the implications for the efficiency score (example C3). An extension of Example B3 shows that Konstant would need an increase in KWh delivered of 16% or number of connections by 3% to make an investment that increased Norm-grid by 10% appear efficient in a re-estimated frontier.

The worked examples and economic theory allow us to draw out some observations about how the benchmarking model affects incentives relating to the Green Transition (1/5)

1. **The model will influence network companies' investment in network expansion, connection and flexibility solutions.** However, the incentive as measured by the likely impact on resulting financial penalties may not always be especially strong, as our worked examples illustrate. Moreover, some "green investments" may improve a network companies' efficiency score – the incentives from the model will not always be to deter such investments. The relative importance of the model in affecting network companies' investment decisions is not easily quantified. It will depend on the specific investments the company is considering, the company's understanding of how the benchmarking model will treat the investment (which cannot be certain given that future updates of the model may include changes to the variables included in the model and/or how the model is estimated, and will depend on decisions made by other companies as well), and other factors affecting the company.
2. **The Green Transition may raise network companies' costs such that they can no longer realise outcomes that accord with the previously estimated frontier. This is not necessarily a problem.** For example, if real wages went up significantly, it would be very difficult for network companies to deliver the same outputs for the same level of totex as in the past. However, benchmark competition could still work as all the companies would face the same challenge of how best to control the rise in costs associated with increased labour costs. Likewise, the Green Transition may mean that all companies will incur higher costs in the coming years e.g. as they invest to expand connections and reinforce the grid – the benchmarking exercise, designed well, should create incentives for the network companies to facilitate this transition in a cost-effective manner.

The worked examples and economic theory allow us to draw out some observations about how the benchmarking model affects incentives relating to the Green Transition (2/5)

3. **Future demand uncertainty is a feature of the Green Transition but does not necessarily undermine the value of the benchmarking model.** In some cases, companies will need to invest in capabilities to support the Green Transition well in advance of demand for that capacity materialising. Companies that invest expanding their network may incur costs in the model without associated demand variables increasing (e.g. KWh delivered or number of connections). Our examples show that the benchmarking model may – but not always – penalise such investments as being inefficient. However, such investments may be deemed efficient in the future when demand materialises. Companies that made a large upfront investment today could be better off than those who leave the expansion until the last minute and then have to undertake a more expensive investment to catch up.
   Each approach (investing now or waiting for demand to materialise) contains risk. The problem facing DSOs is one firms in more competitive markets with demand uncertainty face: is the best strategy to invest today, or wait a while and collect more information about demand trends even though this delay may mean higher investment costs in the future? There are incentives for firms to become better at demand forecasting, as that will improve the basis on which they make investment decisions (although it would be naïve to expect any company to generate perfect forecasts,) There are also incentives for companies to make more effective use of flexibility solutions, as this will give them more scope to delay big lump sum investments until demand is clearer ("wait and see").

The worked examples and economic theory allow us to draw out some observations about how the benchmarking model affects incentives relating to the Green Transition (3/5)

4. **Assuming that more rapid expansion of the network will be more expensive, the benchmarking model treats speedier expansion as more inefficient on the part of the networks.** The extent to which this will feed through to penalties is uncertain, as the company incurring extra totex to speed up expansion may nevertheless still find itself on or close to the updated frontier. This will turn crucially on the precise numbers involved. However, the benchmark model does not explicitly incentivise faster connections.
5. **Changing individual elements of the revenue cap framework, such as the benchmarking model, may have implications for network companies' incentives to invest in network expansion and connection.** However, we cannot meaningfully attribute all or some of the failure to achieve a given policy goal, such as faster connections to new power sources, to a single element of the revenue cap regulation. The revenue cap regulations consists of a package of elements that collectively affect incentives for the DSOs. Changing other aspects of this package could have the same or more pronounced effects on the Green Transition as changes to the benchmarking model.

The worked examples and economic theory allow us to draw out some observations about how the benchmarking model affects incentives relating to the Green Transition (4/5)

6. **The benchmarking model focusses on the cost efficiency of network companies, and this may not always align with efficiency requirements in relation to the green transition.** The example of how the benchmarking model may penalise a network company that incurs extra totex to connect to new power sources faster illustrates this point. The interests of all stakeholders (i.e. wider society) may be better served if the connection happens sooner, such that the benefits to these other stakeholders may exceed the extra costs the network company incurs. Yet the benchmarking model by design only looks at the costs of the network company. The benchmarking model's key aim is to drive efficiency and it to some extent mimics elements of a competitive market (e.g. where companies are making investment choices in the face of uncertainty). Other policy goals such as faster connections or highly anticipatory network expansion ahead of demand may require additional policy tools.
7. **Other elements of the revenue framework should also drive companies' incentives to invest in the Green Transition:**
   - The revenue framework reimburses investment costs, albeit delayed by a period. Well-functioning capital markets should enable DSOs to fund these investments in the mean time. The WACC also allows a return on investments which should provide further incentive to DSO to invest in the Green Transition.
   - Automatic adjustments and application-based supplements provide some in-period revenue increases which should incentivise efficient investments.
   - Quality of Supply incentives may deter DSOs from delaying investments too far into the future, (although stakeholder feedback suggests DSOs appear not to consider these much)

The worked examples and economic theory allow us to draw out some observations about how the benchmarking model affects incentives relating to the Green Transition (5/5)

8. **However, it would be very difficult to structure the benchmarking model so as to ensure neutrality in the incentives to choose between flexibility solutions, network expansion and connection.** It is not even clear what would constitute neutrality as there is considerable uncertainty about how the green transition will evolve (e.g. what will be the take-up of EVs?) and how individual investments will contribute (e.g. how well will a given flexibility solution work?). Solutions that seem promising today may, with the benefit of hindsight, prove to have been inappropriate. Moreover, how the benchmark model affects the incentives of network companies to choose between flexibility solutions, network expansion and connection would need to have regard to other regulations that may influence the incentives of the network companies, and also factors influencing the behaviour of other stakeholders which may have implications for whether flexibility solutions, network expansion or connection should be preferred.
   Nevertheless, the current benchmark model has properties that generally create incentives consistent with the concept of technology neutrality. The use of TOTEX means that the model does not favour solutions simply because their accounting treatment deems the associated expenditure to be opex or capex. It favours low cost solutions, all else equal, so favours flexibility solutions where network expansion is relatively more expensive and vice versa. It is unlikely that the best solution will always be network expansion, or always be increased use of flexibility. Areas where network expansion will be especially challenging and expensive are where DSOs should make relatively more use of flexibility solutions and vice versa.

Changes to the current benchmarking model could be made to support the network companies' efforts with a fast and cost-effective network expansion and connection

Perceived problem with current regulatory set-up	Possible changes to the benchmarking model
Some green investments will be deemed inefficient by the benchmarking model	**Cease benchmarking.** By definition, the benchmarking model can no longer disincentivise any types of green investment if it is no longer being used
Uncertainty about future demand may deter investments in network expansion	**Change the definition of the "delivered" driver.** Instead of electricity delivered, for define this driver with relation to the expected level of demand which prompted the investment. If demand does not subsequently materialise, the firm is no longer penalised in the benchmarking model
Undertaking faster connections increases a network companies' costs without any offsetting benefits and the risk that they will be penalised by the benchmarking model	**Include an additional driver that measures the speed with which new connections were made.** Firms that complete connections quicker will be deemed more efficient than if they undertook connections more slowly

However changing the benchmarking model to speed network expansion and connection is likely to come at a cost of reduced incentives to manage costs efficiently

1. **Ceasing to use the model would lose the benefits associated with benchmark competition.** Network companies would no longer have a financial or reputational incentive arising from the benchmarking model to match or out-perform other networks in terms of how efficiently they manage their costs. (This presupposes that the benchmarking model is working as intended. This study has not considered the merits of arguments that the benchmarking model is not fit for purpose because, for example, of the significant differences in size of the networks included in the sample.)
2. **Changing the definition of the delivered driver.** The consequences of changing the definition of any driver in the benchmark model warrants careful consideration of the possible consequences. With the exception of costs associated with network expansion, totex is likely to depend more on actual delivery rather than expected delivery. Conclusions from the benchmark model about which network companies are managing their costs most effectively may be distorted, favouring companies with low actual delivery relative to the delivery planned for when they expanded the network. The relative importance of actually managing costs effectively to fare well in the benchmarking model may be diminished.
3. **Including extra drivers in the benchmark model is likely to increase the number of firms estimated to be on the frontier.** With each additional driver added to the model, over-fitting of the frontier becomes more of a risk. There is greater scope to construct a frontier which encompasses almost all the firms. The corollary of this is that the benchmarking exercise will conclude few, if any, firms are not on the frontier. The model may cease to incentivise network companies to manage their networks more efficiently than other networks.

8. Annex – results of worked examples

Europe Economics

Worked example A1: 2% increase in totex – backward-looking approach (fixed frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	Less efficient		
hjerting	Less efficient		
sunds	Less efficient		
vildbjerg	Less efficient		
videbaek	Less efficient		
hurup	Less efficient		
randers	Less efficient		
aal	Less efficient		
konstant	Less efficient		
hammel	Less efficient		
tarm	Less efficient		
midtfyns	Less efficient		
ravdex	Less efficient		
laesoe	Less efficient	inf	0.04%
nordenergi	Less efficient	inf	0.06%
rah	Less efficient	inf	0.08%
midt	Less efficient	inf	0.09%
n1	Less efficient	inf	0.12%
dinel	Less efficient	inf	0.14%
veksel	Less efficient	3521%	0.14%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	350%	0.14%
elinord	Less efficient	168%	0.14%
elektrus	Less efficient	121%	0.14%
zeanet	Less efficient	42%	0.13%
vores	Less efficient	34%	0.13%
radius	Less efficient	32%	0.13%
lnet	Less efficient	32%	0.13%
noe	Less efficient	17%	0.12%
ikast	Less efficient	16%	0.12%
nakskov	Less efficient	13%	0.12%
nke	Less efficient	12%	0.12%
cerius	Less efficient	12%	0.12%
flow	Less efficient	11%	0.12%
netselskabet	Less efficient	9%	0.11%
aars	Less efficient	8%	0.11%
oest	Less efficient	3%	0.04%
forsyning	Less efficient		
kongerslev	Less efficient		
gev	Less efficient		

- The table shows that all DSOs appear less efficient in relation to the current frontier once they have had their totex and Norm-grid increased, keeping KWh and connections unchanged.
- The penalty change is relatively small – maximum 0.14% of totex.
- 'Inf' means that the penalty is changing from zero, and thus the %increase is technically 'infinite'.

Worked example A2: 2% increase in totex for N1– forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	No Change		
hjerting	Less efficient		
sunds	No Change		
vildbjerg	No Change		
videbaek	No Change		
hurup	More efficient		
randers	No Change		
aal	Less efficient		
konstant	More efficient		
hammel	Less efficient		
tarm	No Change		
midtfyns	No Change		
ravdex	No Change		
laesoe	More efficient		
nordenergi	More efficient		
rah	No Change		
midt	No Change		
n1	More efficient		
dinel	More efficient		
veksel	No Change		

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	No Change		
elinord	More efficient	-3%	0.00%
elektrus	No Change		
zeanet	Less efficient	0%	0.00%
vores	No Change		
radius	No Change		
lnet	No Change		
noe	No Change		
ikast	No Change		
nakskov	No Change		
nke	No Change		
cerius	More efficient	-2%	-0.02%
flow	More efficient	0%	0.00%
netselskabet	More efficient	-1%	-0.01%
aars	Less efficient	0%	0.01%
oest	More efficient	-7%	-0.11%
forsyning	More efficient	0%	0.00%
kongerslev	No Change		
gev	No Change		

- The shift in the frontier as a result of N1 increasing totex by 2 per cent would mean that N1 is not penalised by the benchmarking model. As much as 12 firms would actually benefit from the fact that N1 had increased its totex.

Worked example B1: 10% increase in Norm-grid – backward-looking approach (fixed frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	Less efficient		
hjerting	Less efficient		
sunds	Less efficient		
vildbjerg	Less efficient		
videbaek	Less efficient		
hurup	Less efficient		
randers	Less efficient		
aal	Less efficient		
konstant	Less efficient		
hammel	Less efficient		
tarm	Less efficient		
midtfyns	Less efficient		
ravdex	Less efficient		
laesoe	Less efficient	inf	0.26%
nordenergi	Less efficient	inf	0.32%
rah	Less efficient	inf	0.34%
midt	Less efficient	inf	0.27%
n1	Less efficient	inf	0.15%
dinel	Less efficient	inf	0.13%
veksel	Less efficient	4975%	0.19%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	932%	0.37%
elinord	Less efficient	214%	0.17%
elektrus	Less efficient	319%	0.36%
zeanet	Less efficient	83%	0.26%
vores	Less efficient	39%	0.15%
radius	Less efficient	79%	0.32%
lnet	Less efficient	85%	0.35%
noe	Less efficient	29%	0.21%
ikast	Less efficient	12%	0.10%
nakskov	Less efficient	31%	0.29%
nke	Less efficient	30%	0.29%
cerius	More efficien	-2%	-0.02%
flow	More efficien	-2%	-0.02%
netselskabet	Less efficient	21%	0.26%
aars	More efficien	-2%	-0.04%
oest	Less efficient	3%	0.04%
forsyning	More efficien		
kongerslev	Less efficient		
gev	Less efficient		

- Increasing Norm-grid by 10 per cent, without any corresponding increase in connections or electricity supplied would move most firms further from the frontier. The extra totex would not be justified by the increase in Norm-grid alone. The most and least efficient firms would not incur any additional penalties.

Worked example B2: 10% increase in Norm-grid for N1– forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	Less efficient		
hjerting	Less efficient		
sunds	Less efficient		
vildbjerg	More efficient		
videbaek	No Change		
hurup	Less efficient		
randers	No Change		
aal	More efficient		
konstant	More efficient		
hammel	More efficient		
tarm	No Change		
midtfyns	No Change		
ravdex	No Change		
laesoe	Less efficient		
nordenergi	Less efficient	inf	0.04%
rah	No Change		
midt	No Change		
n1	More efficient		
dinel	Less efficient	inf	0.07%
veksel	No Change		

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	0%	0.00%
elinord	Less efficient	6%	0.00%
elektrus	No Change		
zeanet	More efficient	0%	0.00%
vores	Less efficient	0%	0.00%
radius	No Change		
lnet	Less efficient	0%	0.00%
noe	Less efficient	0%	0.00%
ikast	Less efficient	0%	0.00%
nakskov	No Change		
nke	More efficient	0%	0.00%
cerius	More efficient	0%	0.00%
flow	Less efficient	0%	0.00%
netselskabet	Less efficient	4%	0.05%
aars	More efficient	0%	0.00%
oest	Less efficient	3%	0.04%
forsyning	More efficient		
kongerslev	Less efficient		
gev	Less efficient		

- N1 would become more efficient in the benchmarking model if it was the only network to invest in expanding capacity (as measured by a 10% increase in Norm-grid) and the frontier was re-estimated. Most of the other companies are worse off (although in very small changes).

Worked example B3: 10% increase in Norm-grid for konstant– forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	More efficient		
hjerting	Less efficient		
sunds	No Change		
vildbjerg	More efficient		
videbaek	No Change		
hurup	No Change		
randers	More efficient		
aal	More efficient		
konstant	Less efficient		
hammel	More efficient		
tarm	Less efficient		
midtfyns	More efficient		
ravdex	Less efficient		
laesoe	No Change		
nordenergi	No Change		
rah	More efficient		
midt	More efficient		
n1	More efficient		
dinel	Less efficient	inf	0.07%
veksel	More efficient	0%	0.00%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	More efficient	-100%	-0.04%
elinord	More efficient	-100%	-0.08%
elektrus	Less efficient	0%	0.00%
zeanet	More efficient	-4%	-0.01%
vores	More efficient	-100%	-0.38%
radius	More efficient	-31%	-0.12%
lnet	Less efficient	0%	0.00%
noe	No Change		
ikast	More efficient	-5%	-0.04%
nakskov	No Change	0%	0.00%
nke	More efficient	-1%	-0.01%
cerius	More efficient	0%	0.00%
flow	Less efficient	0%	0.00%
netselskabet	More efficient	0%	0.00%
aars	More efficient	-1%	-0.01%
oest	No Change		
forsyning	More efficient		
kongerslev	More efficient		
gev	More efficient		

- Konstant would become less efficient but it would not incur a penalty form the benchmarking model if it was the only network to invest in expanding capacity and the frontier was re-estimated. Most companies are better off, with some moving into the frontier..

Worked example B4: 10% increase in Norm-grid for Rah– forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	No Change		
hjerting	Less efficient		
sunds	No Change		
vildbjerg	More efficient		
videbaek	No Change		
hurup	No Change		
randers	No Change		
aal	Less efficient		
konstant	More efficient		
hammel	More efficient		
tarm	No Change		
midtfyns	No Change		
ravdex	Less efficient		
laesoe	No Change		
nordenergi	No Change		
rah	More efficient		
midt	No Change		
n1	Less efficient		
dinel	No Change		
veksel	No Change		

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	No Change		
elinord	No Change		
elektrus	No Change		
zeanet	No Change		
vores	No Change		
radius	No Change		
lnet	No Change		
noe	Less efficient	2%	0.01%
ikast	No Change		
nakskov	No Change		
nke	No Change		
cerius	More efficient	0%	0.00%
flow	More efficient	0%	0.00%
netselskabet	Less efficient	5%	0.07%
aars	More efficient	0%	0.00%
oest	No Change		
forsyning	Less efficient		
kongerslev	No Change		
gev	No Change		

- Rah would become more efficient in the benchmarking model if it was the only network to invest in expanding capacity and the frontier was re-estimated.

Worked example C1: 10% increase in Norm-grid, 10% increase in electricity delivered and 10% increase in connections, backward-looking approach (fixed frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	Less efficient		
hjerting	Less efficient		
sunds	Less efficient		
vildbjerg	Less efficient		
videbaek	Less efficient		
hurup	Less efficient		
randers	Less efficient		
aal	Less efficient		
konstant	Less efficient		
hammel	Less efficient		
tarm	Less efficient		
midtfyns	Less efficient		
ravdex	Less efficient	inf	0.01%
laesoe	Less efficient	inf	0.52%
nordenergi	Less efficient	inf	0.46%
rah	Less efficient	inf	0.44%
midt	Less efficient	inf	0.29%
n1	Less efficient	inf	0.17%
dinel	Less efficient	inf	0.16%
veksel	Less efficient	5539%	0.22%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	1623%	0.64%
elinord	Less efficient	238%	0.19%
elektrus	Less efficient	556%	0.63%
zeanet	Less efficient	85%	0.27%
vores	Less efficient	40%	0.15%
radius	Less efficient	138%	0.55%
lnet	Less efficient	117%	0.47%
noe	Less efficient	27%	0.20%
ikast	Less efficient	11%	0.09%
nakskov	Less efficient	42%	0.39%
nke	Less efficient	40%	0.39%
cerius	More efficient	-3%	-0.03%
flow	More efficient	-3%	-0.03%
netselskabet	Less efficient	28%	0.35%
aars	More efficient	-4%	-0.06%
oest	Less efficient	3%	0.04%
forsyning	More efficient		
kongerslev	Less efficient		
gev	Less efficient		

- Increasing Norm-grid by 10 per cent, with corresponding increase in connections and electricity supplied would move most firms further from the frontier. This is driven by the excess totex from increased connections and electricity delivered. The most and least efficient firms would not incur any additional penalties.

Worked example C3: 10% increase in Norm-grid, 10% increase in electricity delivered and 10% increase in connections for Konstant (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	More efficient		
hjerting	More efficient		
sunds	No Change		
vildbjerg	More efficient		
videbaek	No Change		
hurup	No Change		
randers	More efficient		
aal	More efficient		
konstant	Less efficient		
hammel	More efficient		
tarm	Less efficient		
midtfyns	No Change		
ravdex	More efficient		
laesoe	No Change		
nordenergi	No Change		
rah	Less efficient		
midt	More efficient		
n1	Less efficient		
dinel	More efficient		
veksel	More efficient	0%	0.00%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	More efficient	-100%	-0.04%
elinord	More efficient	-100%	-0.08%
elektrus	Less efficient	0%	0.00%
zeanet	More efficient	-3%	-0.01%
vores	More efficient	-37%	-0.14%
radius	More efficient	-22%	-0.09%
lnet	Less efficient	0%	0.00%
noe	No Change		
ikast	More efficient	-9%	-0.07%
nakskov	Less efficient	0%	0.00%
nke	More efficient	-1%	-0.01%
cerius	More efficient	-1%	-0.01%
flow	More efficient	0%	0.00%
netselskabet	Less efficient	0%	0.00%
aars	More efficient	0%	0.00%
oest	No Change		
forsyning	More efficient		
kongerslev	More efficient		
gev	No Change		

- Konstant would become less efficient if it was the only network in expanding capacity (along with an increase in connections and electricity) and the frontier was re-estimated. However, it would not incur a penalty form the benchmarking model. Most companies are better off, with few moving into the frontier.

Worked example D1: 10% increase in transformers and 5% in electricity delivered – backward-looking approach (fixed frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	No Change		
hjerting	More efficient		
sunds	No Change		
vildbjerg	No Change		
videbaek	No Change		
hurup	No Change		
randers	Less efficient		
aal	More efficient		
konstant	More efficient		
hammel	More efficient		
tarm	Less efficient		
midtfyns	No Change		
ravdex	No Change		
laesoe	Less efficient		
nordenergi	Less efficient		
rah	Less efficient		
midt	Less efficient		
n1	Less efficient	inf	0.01%
dinel	Less efficient	inf	0.02%
veksel	Less efficient	738%	0.03%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	53%	0.02%
elinord	Less efficient	35%	0.03%
elektrus	No Change		
zeanet	No Change		
vores	Less efficient	5%	0.02%
radius	Less efficient	3%	0.01%
lnet	Less efficient	7%	0.03%
noe	No Change		
ikast	No Change		
nakskov	Less efficient	3%	0.03%
nke	Less efficient	2%	0.02%
cerius	More efficient	-2%	-0.02%
flow	More efficient	-2%	-0.02%
netselskabet	No Change		
aars	More efficient	-2%	-0.02%
oest	Less efficient	1%	0.02%
forsyning	More efficient		
kongerslev	No Change		
gev	Less efficient		

- How firms would fare against the current benchmarking frontier under this worked example is not perfectly correlated with their current efficiency ranking in the model. There are some poorly performing firms that would be deemed more efficient, while better performing firms would be deemed less efficient and vice versa. The current mix of assets in their norm-grid calculations will be decisive.

Worked example D2: 10% increase in transformers and 5% in electricity delivered for N1– forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	More efficient		
hjerting	More efficient		
sunds	No Change		
vildbjerg	No Change		
videbaek	No Change		
hurup	More efficient		
randers	No Change		
aal	More efficient		
konstant	Less efficient		
hammel	Less efficient		
tarm	No Change		
midtfyns	More efficient		
ravdex	No Change		
laesoe	More efficient		
nordenergi	More efficient		
rah	No Change		
midt	No Change		
n1	Less efficient		
dinel	More efficient		
veksel	Less efficient	0%	0.00%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	No Change		
elinord	More efficient	0%	0.00%
elektrus	No Change		
zeanet	No Change		
vores	More efficient	0%	0.00%
radius	No Change		
lnet	No Change		
noe	No Change		
ikast	Less efficient	0%	0.00%
nakskov	Less efficient	0%	0.00%
nke	No Change		
cerius	Less efficient	0%	0.00%
flow	More efficient	0%	0.00%
netselskabet	Less efficient	0%	0.00%
aars	More efficient	0%	0.00%
oest	More efficient	0%	-0.01%
forsyning	Less efficient		
kongerslev	Less efficient		
gev	No Change		

N1 acting alone in this worked example would result in an updated benchmarking frontier where it becomes less efficient. However, it results in no additional penalty for N1 as it remains on the frontier.

Worked example E1: 50% increase in transformers and 25% in electricity delivered – backward-looking approach (fixed frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	No Change		
hjerting	More efficient		
sunds	More efficient		
vildbjerg	No Change		
videbaek	No Change		
hurup	No Change		
randers	Less efficient		
aal	More efficient		
konstant	More efficient		
hammel	More efficient		
tarm	Less efficient		
midtfyns	More efficient		
ravdex	No Change		
laesoe	Less efficient	inf	0.01%
nordenergi	Less efficient	inf	0.05%
rah	Less efficient	inf	0.11%
midt	Less efficient	inf	0.02%
n1	Less efficient	inf	0.06%
dinel	Less efficient	inf	0.03%
veksel	Less efficient	3236%	0.13%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	263%	0.10%
elinord	Less efficient	119%	0.10%
elektrus	No Change		
zeanet	No Change		
vores	Less efficient	19%	0.07%
radius	Less efficient	16%	0.06%
lnet	Less efficient	35%	0.14%
noe	No Change		
ikast	More efficient	-1%	-0.01%
nakskov	Less efficient	17%	0.16%
nke	Less efficient	10%	0.10%
cerius	More efficient	-8%	-0.08%
flow	More efficient	-11%	-0.11%
netselskabet	No Change		
aars	More efficient	-7%	-0.11%
oest	Less efficient	3%	0.04%
forsyning	More efficient		
kongerslev	No Change		
gev	Less efficient		

- Similar to C1, there are some poorly performing firms that would be deemed more efficient, while better performing firms would be deemed less efficient and vice versa. The current mix of assets in their norm-grid calculations will be decisive.

Worked example E2: 50% increase in transformers and 25% in electricity delivered for N1– forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	More efficient		
hjerting	More efficient		
sunds	More efficient		
vildbjerg	More efficient		
videbaek	No Change		
hurup	More efficient		
randers	No Change		
aal	More efficient		
konstant	Less efficient		
hammel	Less efficient		
tarm	No Change		
midtfyns	More efficient		
ravdex	No Change		
laesoe	More efficient		
nordenergi	More efficient		
rah	More efficient		
midt	No Change		
n1	Less efficient		
dinel	More efficient		
veksel	No Change		

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	More efficient	0%	0.00%
elinord	More efficient	-2%	0.00%
elektrus	No Change		
zeanet	No Change		
vores	More efficient	0%	0.00%
radius	No Change		
lnet	More efficient	0%	0.00%
noe	More efficient	0%	0.00%
ikast	Less efficient	0%	0.00%
nakskov	No Change		
nke	More efficient	0%	0.00%
cerius	Less efficient	0%	0.00%
flow	More efficient	-1%	-0.01%
netselskabet	Less efficient	2%	0.02%
aars	More efficient	-1%	-0.01%
oest	More efficient	-1%	-0.02%
forsyning	Less efficient		
kongerslev	Less efficient		
gev	More efficient		

Even with the larger investment in transformers than assumed in worked example D2, N1 would not incur a penalty if it was the only network to undertake the investment envisaged under this scenario. Although N1 becomes less efficient, it remains on the frontier..

Worked example F1: Connection of small windfarm – backward-looking approach (fixed frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	Less efficient		
hjerting	Less efficient		
sunds	Less efficient		
vildbjerg	Less efficient		
videbaek	Less efficient		
hurup	Less efficient		
randers	Less efficient		
aal	Less efficient		
konstant	Less efficient		
hammel	Less efficient		
tarm	Less efficient		
midtfyns	Less efficient		
ravdex	Less efficient	inf	0.51%
laesoe	Less efficient		
nordenergi	Less efficient		
rah	Less efficient		
midt	Less efficient	inf	0.34%
n1	Less efficient		
dinel	Less efficient	inf	0.01%
veksel	Less efficient	2625%	0.10%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	67%	0.03%
elinord	Less efficient	82%	0.07%
elektrus	Less efficient	101%	0.11%
zeanet	Less efficient	23%	0.07%
vores	Less efficient	1%	0.01%
radius	Less efficient	0%	0.00%
lnet	Less efficient	17%	0.07%
noe	Less efficient	13%	0.09%
ikast	Less efficient	97%	0.76%
nakskov	Less efficient	5%	0.04%
nke	Less efficient	2%	0.02%
cerius	Less efficient	0%	0.00%
flow	Less efficient	38%	0.39%
netselskabet	Less efficient	12%	0.15%
aars	Less efficient	8%	0.12%
oest	Less efficient	1%	0.01%
forsyning	Less efficient		
kongerslev	Less efficient		
gev	Less efficient		

This worked example suggests that the current benchmark frontier does not look favourably on investments connecting to small windfarms. The scenario assumes, however, no increase in electricity delivered. However, the penalty change is relatively small – maximum 0.76% of totex.

Worked example F2: Connection of small windfarm to N1– forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	No Change		
hjerting	Less efficient		
sunds	More efficient		
vildbjerg	More efficient		
videbaek	Less efficient		
hurup	More efficient		
randers	No Change		
aal	Less efficient		
konstant	More efficient		
hammel	More efficient		
tarm	No Change		
midtfyns	No Change		
ravdex	No Change		
laesoe	More efficient		
nordenerg	More efficient		
rah	No Change		
midt	No Change		
n1	Less efficient		
dinel	More efficient		
veksel	Less efficient	0%	0.00%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	0%	0.00%
elinord	More efficient	0%	0.00%
elektrus	No Change		
zeanet	Less efficient	0%	0.00%
vores	Less efficient	0%	0.00%
radius	No Change		
lnet	Less efficient	0%	0.00%
noe	More efficient	0%	0.00%
ikast	Less efficient	0%	0.00%
nakskov	No Change		
nke	No Change		
cerius	More efficient	0%	0.00%
flow	More efficient	0%	0.00%
netselskab	More efficient	0%	0.00%
aars	Less efficient	0%	0.00%
oest	More efficient	0%	0.00%
forsyning	More efficient		
kongerslev	Less efficient		
gev	Less efficient		

Although the windfarm investment would not move a firm closer to the current frontier, if N1 was the only one to make such an investment and the frontiers re-estimated, the updated model would not penalise N1 for the investment.

Worked example G1: Connection of small windfarm (+100% cost mark-up) – backward-looking approach (fixed frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	Less efficient		
hjerting	Less efficient		
sunds	Less efficient		
vildbjerg	Less efficient		
videbaek	Less efficient		
hurup	Less efficient		
randers	Less efficient		
aal	Less efficient	inf	0.49%
konstant	Less efficient		
hammel	Less efficient		
tarm	Less efficient		
midtfyns	Less efficient	inf	0.20%
ravdex	Less efficient	inf	1.14%
laesoe	Less efficient		
nordenergi	Less efficient		
rah	Less efficient		
midt	Less efficient	inf	0.69%
n1	Less efficient		
dinel	Less efficient	inf	0.02%
veksel	Less efficient	5175%	0.20%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	134%	0.05%
elinord	Less efficient	163%	0.13%
elektrus	Less efficient	199%	0.22%
zeanet	Less efficient	46%	0.15%
vores	Less efficient	3%	0.01%
radius	Less efficient	1%	0.00%
lnet	Less efficient	33%	0.13%
noe	Less efficient	25%	0.19%
ikast	Less efficient	117%	0.91%
nakskov	Less efficient	9%	0.09%
nke	Less efficient	3%	0.03%
cerius	Less efficient	0%	0.00%
flow	Less efficient	62%	0.65%
netselskabet	Less efficient	23%	0.29%
aars	Less efficient	17%	0.24%
oest	Less efficient	1%	0.02%
forsyning	Less efficient		
kongerslev	Less efficient		
gev	Less efficient		

Similar to E1, this worked example suggests that the current benchmark frontier does not look favourably on investments connecting to small windfarms. However, DSOs are worse-off in this scenario (compared to E1) as they bear a cost mark-up of 100% for the new investments.

Worked example G2: Connection of small windfarm to N1 (+100% cost mark-up) – forward-looking approach (re-estimated frontier)

Name	Efficiency	% change in penalty	Penalty change / Totex
vestjyske	No Change		
hjerting	Less efficient		
sunds	More efficient		
vildbjerg	More efficient		
videbaek	Less efficient		
hurup	More efficient		
randers	No Change		
aal	Less efficient		
konstant	More efficient		
hammel	More efficient		
tarm	No Change		
midtfyns	No Change		
ravdex	No Change		
laesoe	More efficient		
nordenerg	More efficient		
rah	No Change		
midt	No Change		
n1	More efficient		
dinel	More efficient		
veksel	Less efficient	0%	0.00%

Name	Efficiency	% change in penalty	Penalty change / Totex
trefor	Less efficient	0%	0.00%
elinord	More efficient	0%	0.00%
elektrus	No Change		
zeanet	Less efficient	0%	0.00%
vores	Less efficient	0%	0.00%
radius	No Change		
lnet	Less efficient	0%	0.00%
noe	More efficient	0%	0.00%
ikast	Less efficient	0%	0.00%
nakskov	No Change		
nke	No Change		
cerius	More efficient	0%	0.00%
flow	More efficient	0%	0.00%
netselskat	More efficient	0%	0.00%
aars	Less efficient	0%	0.00%
oest	More efficient	0%	0.00%
forsyning	More efficient		
kongerslev	Less efficient		
gev	Less efficient		

Similar to E2, if N1 was the only one to make such an investment and the frontiers re-estimated, the updated model would not penalise N1 for the investment.