Utiligize

Where, When, and How Much Should We Invest Throughout the Green Transition?

A White Paper on Forward-Looking Asset Management Solutions

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UTILIGIZE

Forecast the Impact of Electrification Throughout Your Network

The network of tomorrow must be built today

Utility assets - transformers, cables, lines and switchgear - have lifetimes of 40-70 years, meaning that much of what is in or on the ground now will have to cope with the increased load that electrification brings.

Different challenges for different areas

Electric vehicles (EVs) present the biggest challenge in urban areas because of the high density of car owners. Network capacity added today must be able accommodate the worst-case scenario of 10,000 non-autonomous EVs per 60/10kV transformer. In contrast, 60/10kV networks in rural areas already have significant capacity due to wind and solar. At low voltages, both rural and urban feeders face capacity problems, while rural feeders are especially vulnerable to voltage issues.

Data driven forecasts towards 2040

By combining network topology and customer meta data with smart meter or Scada measurements, it's possible to estimate loading throughout the grid. Modern distributed databases allow smart meter data to be aggregated to estimate low voltage loading where no online measurements are available[i]. Graph theory models calculate the loading of millions of busses for networks that are too big for power flow models to efficiently solve.

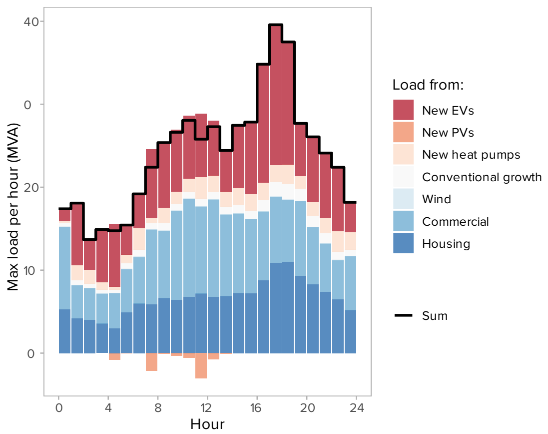
Car detection with aerial photography and AI can identify future charging spots

Areal imagery can be used to identify where cars are parked and when. Machine learning approaches can distinguish between cars and larger transport vehicles that, when combined with charging profiles and preexisting network topology, give qualified estimates of future loading scenarios.

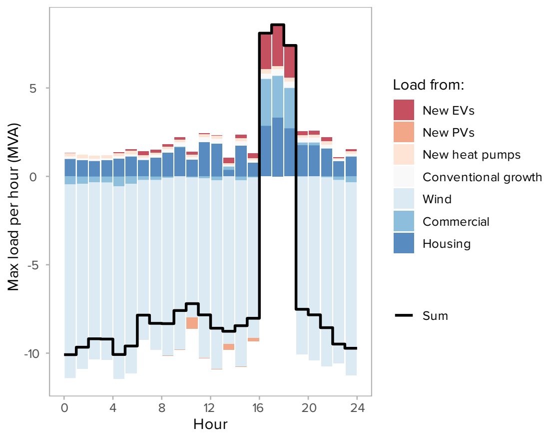
Make the right decisions now

Using detailed models such as the above allows you to understand where and when new technology brought by electrification will impact your grid. Not using detailed models will either result in under- or over-capacity problems in 20 years' time, or a mixture of both depending on location. Invest intelligently today to avoid capacity constraints in the future.

City transformer in 2030 (18MVA in 2018) - over 20MVA reinforcement needed



Countryside transformer in 2030 (12MVA in 2018) – no reinforcement necessary



Demand Response is an Important Asset Management Tool

DR will stop infrastructure costs from exploding

The electrification of our energy, transport and agricultural systems have the potential to leave society with massive network infrastructure bill. Recent experiments with Demand response (DR) have shown that it is possible to increase utilization of existing infrastructure and delay or avoid reinforcement in some areas.

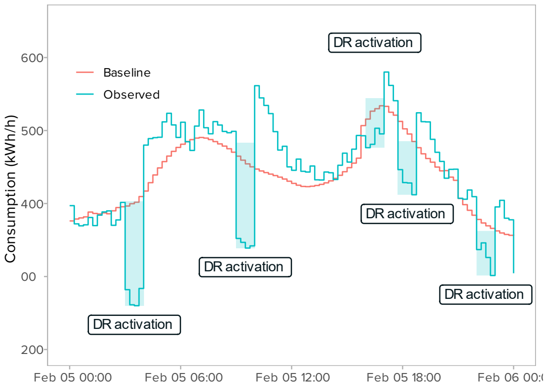
EcoGrid 2.0 shows a 40% load shift is possible

EcoGrid 2.0 was a demonstration of DR on the Danish island of Bornholm, where Utiligize was employed to develop market clearing and load forecasting algorithms and verify the amount of DR delivered. The project showed that 30-40% of gross household consumption could be moved during the six winter months several times per day and in a reliable way. Scaling the results to Denmark reveals that, today, without EVs, it is possible to shift 10% of the national load by several hours[ii]. Evidence that EVs will be able to shift around 50% of their consumption by several hours provides further flexibility when avoiding grid reinforcements[iii].

MIP simulates consumer response to tariffs

Mixed-integer programming (MIP) can be used to simulate the tariff-response of EVs, batteries, heat pumps and decentralize production by emulating the cost minimization strategy of smart devices responding to national and local prices. If utilities decide to employ dynamic tariffs, MIP models will be continually run at DSO headquarters to minimize cost over the next 24 hours. Keeping fixed-energy based tariffs is not a good option for utilities, since simulations show that batteries will increase peak load due to significant spot price arbitrage potentials during peak hours[iv].

30-40% of the gross load can be shifted with heat pumps several times per day in EcoGrid



Tariffs vs DR marketplaces

Aggregators in DSO marketplaces earn the marginal cost (with uplift payment) for the DR activated, plus a reservation fee. The use of aggregators resulted in a much more reliable response than dynamical energy tariffs previously trailed on Bornholm. Time of use, dynamic energy or capacity tariffs are likely cheaper and simpler than DSO marketplaces, but the DR provided is less reliable. Show your customers that you are saving money with intelligent deployment of demand response.

Simplified asset management decision for a 60/10 kV, 20MVA transformer

In the below example, demand response is the cheapest option for an area with a growing peak load. The cost of demand response can either be paid directly to an aggregator or be a redistribution of revenue away from customers on this transformer to customers on other, less strained transformers.

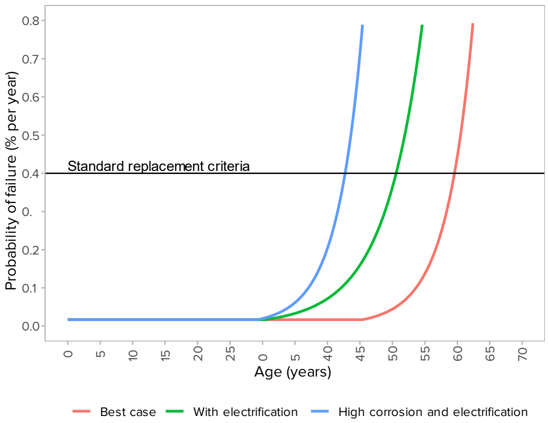
	With demand response (-20% peak load)	Forced air cooling (+20% rated capacity)	Reinvestment
Price (annuity) EUR	3,080	3,750	3,570

Knowing the Probability of Failure is at the Core of Utility Digitization

Failure statistics are gold to society

A transformer with a 50-year technical lifetime can actually last 40 years in one part of the country and 60 years in another. Exploiting these differences ensures a more efficient use of resources than assuming the worst case. To understand how long assets live, Probability of Failure (PoF) models give tailored estimates based on dozens of variables.

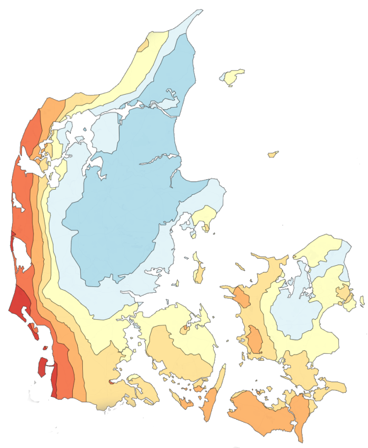
Transformer lifetime ranges from 40 to 60 years depending on loading, corrosion etc.



The PoF describes the chance that a component will experience a serious failure during the next year. The industry standard is to replace components when they reach a 0.4% chance of failure, although infrastructure serving hospitals or railways can have thresholds as low as 0.03%, while residential customers might live thresholds at 0.5%. The replacement criteria is defined by estimating the Consequence of Failure (CoF) – a monetary value describing the potential damage done by an individual asset failure.

Large failure-rate datasets train PoF models, which are typically defined for dozens of component types and use several explanatory variables to improve their accuracy. Common variables include oil chemistry, pollution and salinity, as well as loading and temperature information. By accounting for so many variables, an accurate estimate can be created of how failure rates will increase if reinvestment is delayed.

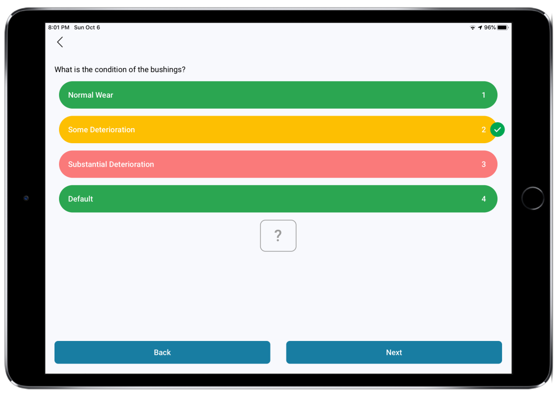
A corrosion map of Denmark, which most impacts assets on the west and south coasts



CNAIM standard ensures consistency

PoF and CoF calculations are well defined in the CNAIM standard[V]. First developed in the UK, adapting it to national conditions, e.g. with the use of the Danish ELFAS database, is now key. Beyond the common explanatory variables, CNAIM contains 175 well-defined questions about visual evidence of rust, oil leaks and metal fatigue to improve model accuracy. Mobile apps can assist here by making these questions fast and easy to answer, as well as enabling documentation of supplementary photographic evidence.

Mobile apps ensure fast, consistent and accurate data collection to improve PoF accuracy

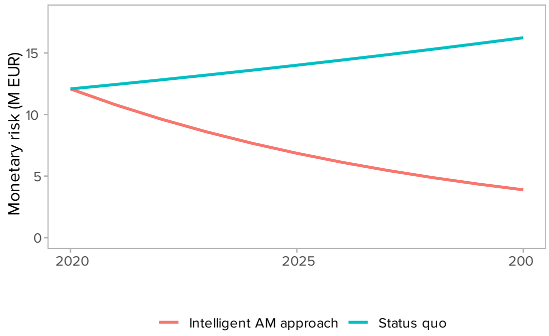


Show the Regulator How to Minimize Risk Costs Over Several Years

Inaction increases future costs

Risk matrices are an intuitive way to visualize how unforeseen outage costs will develop in the coming years. The monetary risk is calculated by multiplying PoF with CoF and can be understood as the yearly socio-economic cost of operating the infrastructure at its current state of health. As well as understanding risk on a per asset basis, regional analyses can also be performed.

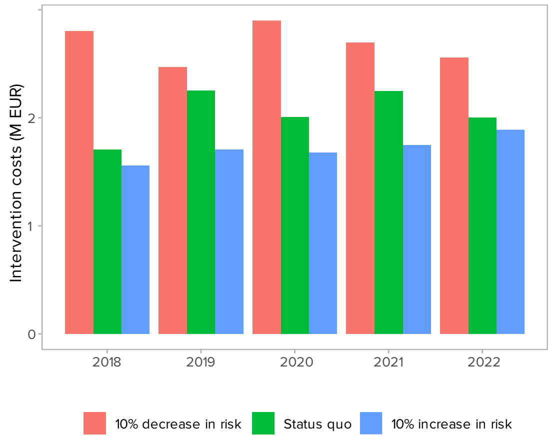
Risk will increase through the green transition if no intelligent interventions are performed



When should risk be reduced?

Historically, factors that impacted risk were limited to variables that serve as the PoF and CoF inputs. Today, this is a short-sighted approach, as electrification and climate change introduce fast change dynamics that are increase risk at an accelerating rate. PoF scenarios stretching 10 and 20 years into the future can be used to create monetary risk assessments that can be optimized with linear programming, according to the intervention costs. Assuming a fixed quality of service (QoS) goal, intervention costs will outweigh the reduction in monetary risk in some areas and for some assets. In other areas, intervention will be an attractive decision. Decisions change year-by-year and creating a long-term forecast ensures the lowest cost to society.

Sensitivity analyses of intervention costs show they are non-linear with respect to time and QoS



Foolproof plans with regulator support

Given fixed QoS goals and operational constraints, the mathematics dictate that only one multi-year reinvestment and maintenance plan is optimal. The multi-year optimization that creates this optimal result can be seen as a multi-step Cost-Benefit Analysis (CBA). As regulators move to condition-based regulatory frameworks, utilities submit their risk matrix to the regulator, as well as individual CBAs that support utility plans. If the regulator cuts revenue, then this will directly impact risk, which increases future costs and decreases QoS.

Condition-based risk assessments ultimately ensure best practice at a utility and allow them to identify which regions and asset classes should have interventions.

A risk matrix that shows a DSOs 10kV and 60kV cables in M DKK. Consequences of failure increase per unit on the vertical axis. The health indicators, which is part of PoF, increases moving from left to right.

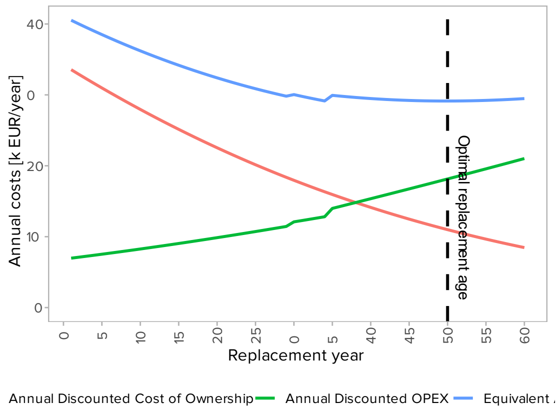
Consequences of Failure	Health Indicator HI1	HI2	HI3	HI4	HI5	Sum
C1	4.6	7.5	3.0	2.2	2.3	19.7
C2	10.1	16.1	6.1	5.6	4.8	42.7
C	15.6	25.1	9.6	7.8	7.6	65.7
C4	1.4	2.1	0.7	0.7	0.7	5.6
Sum	31.7	50.8	19.5	16.3	15.5	133.8

Replace, Upgrade or Wait: Creating Long-term Investment Forecasts

Optimize asset reinvestment timing

Textbook economics describe the basic reinvestment recipe for capital-heavy industries like utilities, where the perpetual equivalent annual cost (EAC) sums the increasing maintenance costs and decreasing purchase costs to determine the Life Cycle Cost (LCC). Replacement should be performed when the EAC is lowest, although the timing of maintenance and upgrades like oil regeneration and forced cooling complicate this calculation. Here, linear optimization of EAC models can be used to compare all alternatives and select the optimal timing.

An asset's optimal replacement age is usually different from its technical lifetime



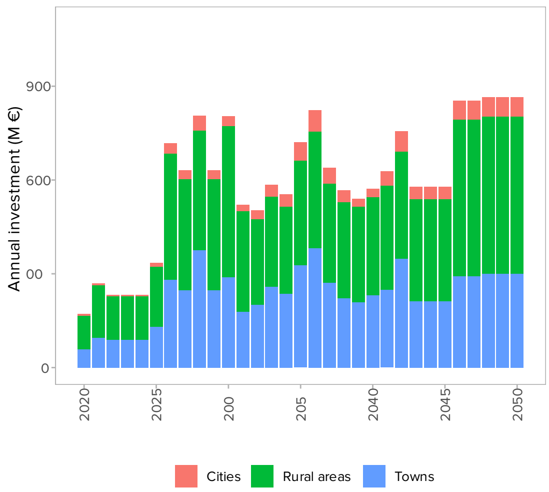
A priority list of reinvestments is cost efficient

By combining Life Cycle Cost (LCC) analysis with probabilistic First-In, First-Out (FIFO) simulations, it is possible to make precise reinvestment forecasts that achieve quality of service (QoS) levels as targeted by company leadership or the regulator. This approach allows utilities to become 25% more cost efficient by creating optimal DR, reinvestment, maintenance and upgrade plans for every asset a utility owns. When reinvestment is the best option, choosing the right time and a capacity that will match 2030 and 2040 needs becomes key.

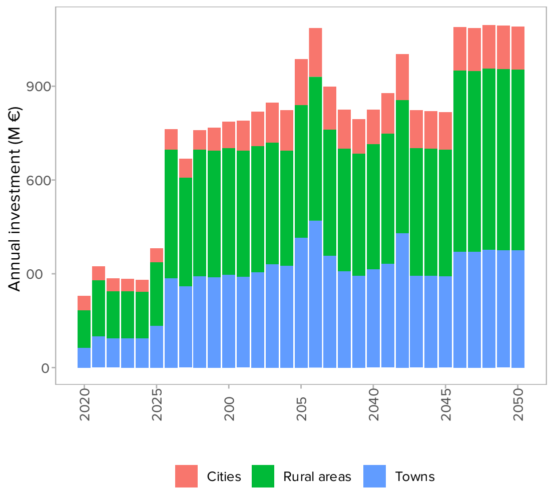
The green transition will be expensive

Once optimal plans are made, the cost of the green transition can be determined. Danish Energy estimates that 2020-2030 distribution grid investment will increase from 29 billion DKK to 32 or 48 billion DKK with and without intelligent asset management respectively[vi]. However, national goals for EV and HP penetration show that capacity issues will affect some areas more than others. For those facing higher investment needs, making the 25% leap in efficiency becomes essential, so that the affected customers and board members can be assured that a utility is delivering value.

Reinvestment forecast for Denmark without the green transition



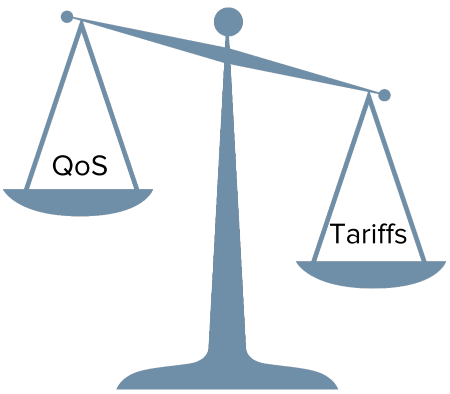
Investment forecast with the green transition, showing challenges in cities and towns



Asset Management Supports Your Quality of Service and Revenue Goals

Strike the right service quality - tariff balance

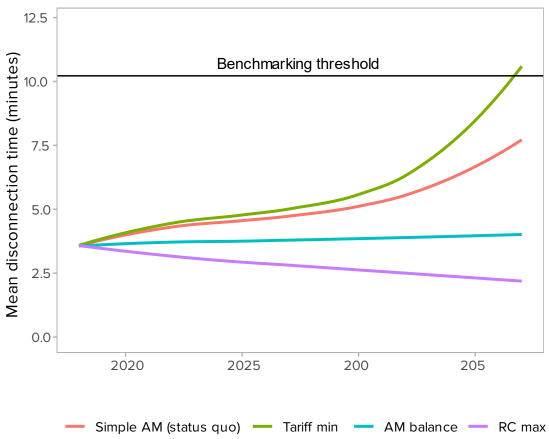
Utilities have a surprising degree of freedom when deciding if they will pursue a strategy of high quality of service (QoS) or a strategy of low tariffs for customers. This is reflected in the massive variation in tariffs that residential customers face in Denmark, ranging from 20 to 51 øre/kWh.



Growing or shrinking revenue caps deliberately

If a utility increases its investments in order to improve QoS, depreciation goes up, which in turn increases the utility's cost and return on investment contributions to their revenue cap. Although costs go up, benchmarking efficiency demands don't go up by the same amount (and additionally get reset every five years), causing revenue caps to increase significantly, giving utilities greater financial headroom throughout the green transition.

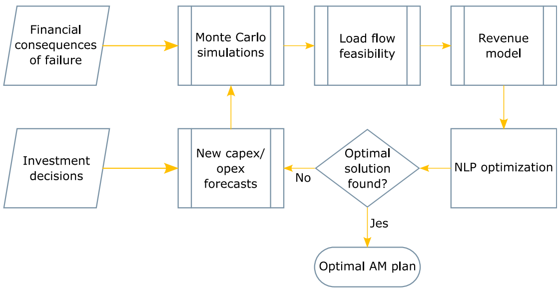
Quality of service is directly correlated to several variables including grid age and loading



Implementing strategic decisions

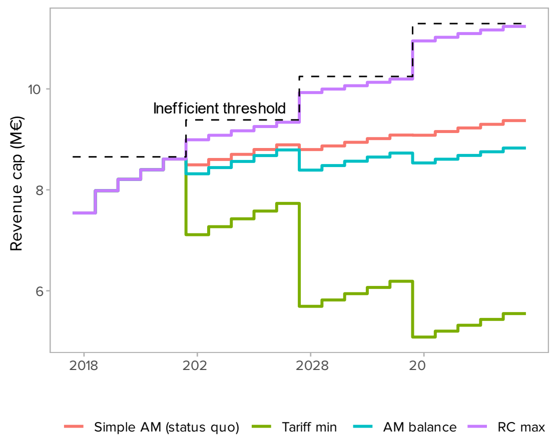
Once the strategic trade-off between QoS and tariffs/revenue cap has been decided, or, alternatively, a minimum QoS has been set, non-linear optimization runs through load flow feasibility studies and the regulator's revenue cap and benchmarking models to create new AM plans. Each iteration of the optimization starts with tweaked Capex and Opex forecasts until an optimal solution is found. Cheap cloud computing has created a paradigm shift in the ability to create these decisions based on previously inconceivable amounts of data.

Non-linear optimization lies behind the perfect reinvestment, upgrade and service plan



Ultimately, intelligent asset management has several uses. It can be used at board level to show what the green transition will cost and how it impacts utility revenue caps, and it can be used operationally to cut costs by up to 25%, increase efficiency by 25%, or increase revenue by up to 20% over a 15-year horizon.

Revenue caps are tied to investment and can increase or decrease depending on strategy



What Our Customers Say

Make the Right Assumptions about Demand Response

Utiligize was instrumental in modelling, activating and verifying Demand Response in the EcoGrid 2.0 experiment, where we proved that, even without EVs, DR can move 10% of consumption over several hours.

Jørgen S. Christensen
CTO, Danish Energy

Component-specific Lifetime Estimates

Understanding the impact of electrification on our HV transformers' life expectancy was a key factor in the upgrade strategy for Banedanmark's train power supply. By using probability of failure, we could determine which transformers needed replacement and which could have their lifetime extended, bringing down cost significantly.

Frederik Bindner
AM Discipline Lead, Banedanmark

Investment Forecasts that Support Your Goals

Utiligize's investment forecasts give us clarity about when and which components we should change, and what electrification costs - with and without DR.

Erik Kongsgaard Rasmussen
Head of Power, Dinel

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[i] Forecasting distribution grid flows using smart meter data, Jules Truong, 2019, www.utiligize.com/Jules_Truong_MSc.pdf
[ii] EcoGrid 2.0 Main Results and Findings, Dansk Energi, 2019, http://www.ecogrid.dk/#new-downloads
[iii] Electric Vehicle Charging Implications for Utility Ratemaking in Colorado, NREL, 2019, https://www.nrel.gov/docs/fy19osti/73303.pdf
[iv] Technical and Economic Impact of Residential BESS on Distribution Systems Under Alternative Tariff Regimes, Philip Douglass, 2019, https://www.cired-repository.org/bitstream/handle/20.500.12455/209/CIRED%202019%20-%20942.pdf?sequence=1&isAllowed=y
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