THE PERFECT STORM FOR MONOPOLY GRIDS: THE DUAL DISRUPTIVE IMPACT OF DISTRIBUTED GENERATION AND LOCAL COMPETITION

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ABSTRACT

This paper shares the insight that ***monopoly grids can expect their share of demand to decrease****. For the Netherlands,* ***a decrease of two-fifth appears possible*** *mainly due to self-generation and the rise of microgrids.* ***Microgrids will become economically competitive with monopoly grids for a sizable, minority share of total electricity demand****. Furthermore, adoption could be relatively rapid as* ***a majority of electricity consumers in a large survey in Denmark and The Netherlands indicate to prefer autonomy or a local grid versus the monopoly grid****. Two-fifths to three-fifths of the respondents prefers to switch away from the electricity grid to solar panels and batteries if the price is the same. A full 60% of all neighbourhoods could be self-sufficient with solar-PV, generator and batteries.*

INTRODUCTION

The **subject** addressed is the impact on grid companies when the monopoly position enjoyed by grid companies is withdrawn, while distributed and renewable generation and storage are becoming affordable as well as actively supported. Currently, most grid companies enjoy a regulated monopoly position with the aim to provide reliable access for all at affordable costs.

The European Commission envisions more choice and competition and proposes a first step by allowing and supporting competition within the local monopoly of DSO grids. The Winter Package, proposes that local energy communities are able to 'own, create or lease community networks'. In addition, competitive pressure from new entrants emerge while monopoly grid are required to uphold legacy grids and ensure universal access to energy. Facing this possible perfect storm of regulatory and economic disruptions, the main question from both the energy community and DSO perspective becomes: how sizable could the application of microgrids and energy communities become within the monopoly grid?

The **problem** is grid planning and making investment decisions while facing an increasingly uncertain future. The energy transition and climate goals require large-scale investment in electrical infrastructure, however the infrastructure capacity factors and economic life-time are increasingly difficult to assess. One of the potential largest uncertainties is the combination of local generation and storage with the regulatory possibilities to go (partly) off-grid or enter an energy community grid / microgrid. The underlying economic logic of the current grid could be severely tested as peak-loads are increasing, while transported volumes are dropping and the base on which to socialize grid costs is shrinking. Pushing up capacity charges, as the Swedes are doing, could solve the peak-load costs but speed up the rate by which users and communities are going off-grid.

RESEARH QUESTION

The research questions involved are: **what driving forces could create disruption for monolopy grids**? **How do consumers view local grids, self-production and decentral production**? **How large could the impact be for the monopoly grid**? The goal of this paper is to start to outline answers to these questions.

METHOD

The **method** of addressing this problem is through understanding the key drivers that impact the monopoly grid share of demand. This paper identified and estimates these drivers through a number of steps: (1) theoretical approach using a Fermi-estimation, (2) qualitative survey of a thousand Dutch and thousand Danish households, (3) economic analysis of microgrids on the level of Dutch neighbourhoods, (4) quantification of microgrid and off-grid shares using a MonteCarlo analysis using the Dutch MV and LV grids and connections. The **scope** is the demand in the MV and LV grids, excluding the high-voltage grids and demand exceeding 50 MW.

The **survey** is a questionnaire to obtain relevant data on a number of important variables. The reason is that a number of variables do not have any meaningful data or are difficult to estimate, for example consumer preferences regarding microgrids.

The survey is a representative sample of a 1.000 Dutch and 1.000 Danish people. The people are the people in charge of energy matters of the household. The survey has been performed in December and January 2018 with 1145 people surveyed in the Netherlands and 1100 in Denmark. The survey organisations who have executed the survey are Motivaction in the Netherlands and Analyse Denmark in Denmark. This paper presents the relevant survey questions to assist in determining the MonteCarlo analysis.

The **Fermi-estimation** is an order estimation to do a dimensional analysis to come to an answer to the stated problem. In other words, it constitutes an approximate calculation to reach a justified estimate. It uses little data, but is useful in identifying the important variables and establish variance and lower and upper bounds of variables. These variables will subsequently be applied and refined in a MonteCarlo analysis.

The **economic analysis of microgrid** quantifies the potential economic competitiveness of microgrids on neighbourhood level for the 13.000 neighbourhoods in The Netherlands. It builds upon the approach of the report 'Economics of Grid Defection' by Homer Energy and Rocky Mountaints Institute [1]. The report analysis the economics of grid-defection for an individual house or small company. The method is to us a solar-PV, generator and battery storage configuration. This paper uses the same approach but extends it by aggregating the calculations to neighbourhood level and adding the required grid cabling and convertors. This results in an estimate of the economic competitiveness of a new microgrid for each neighbourhood in The Netherlands.

The **MonteCarlo analysis** uses a probabilistic interpretation of the problem, drawing samplings from probability distributions for each variable. In other words, it recognises and describes the variation of values that each variable might have, and formulates this into a distribution of each variable. The MonteCarlo analysis then simulates expected outcomes by drawing samples from these distributions. This is opposite of deterministic methods and has the advantage to provide a range and distribution of the expected outcome, in this case the share and size of transported electricity on monopoly grids compared to total electricity demand. The variables and distribution applied are clearly stated so as to facilitate replication and discussion.

The MonteCarlo analysis applies the variables that emerge from the Fermi-estimation. Each variable is assigned a distribution ranging from Bayesian, Gamma, triangle, square. These are mainly determined by sorting the variable and a simple statistical analysis, or from the survey; however in some cases the authors best estimate is taken for setting the distribution shape, as little data is available on a number of variables. The analysis itself is a 10.000 times sampling of the variable distributions to derive the outcome: the size of the grid connections that could migrate away from the monopoly grid.

RESULTS

The results are presented in four parts: the survey outcomes, the Fermi-estimation, the economic microgrid analysis and then the MonteCarlo analysis.

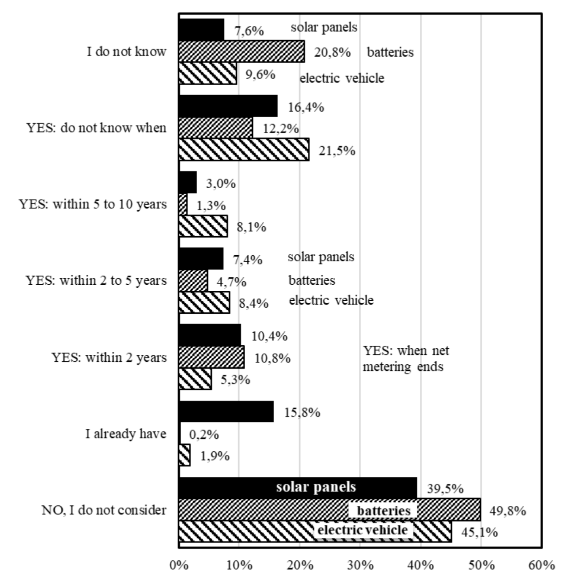
Survey of the Dutch and Danish population

The survey results presented here inform the Fermi and MonteCarlo analysis. The survey examines the following topics: satisfaction with current grid company, the expected usage of solar-PV, electric vehicles use and charging behaviour, battery installation, the attitudes towards local grids for heat and electricity, the willingness to spend additional money on local grids, preferences for the means of cooperation within a local grid, the preferred scale of a microgrid, investment levels in energy installations for the home, and practically, space available in the home for energy storage. The main results related to the Fermi and MonteCarlo analysis are shared in this paper. In an upcoming paper the full results will be published.

Looking at solar panels and batteries, the Danish survey indicates that 16% of respondents is considering to install solar panels and 14% is considering installing batteries, with the share answering '*I do not know'* being 10% for solar and 17% for batteries. For the Netherlands, the numbers are different: 53% answers to consider installing solar panels and 29% considers installing batteries, with the share indicating *'I do not know'* at 8% and 21% respectively. For the Netherlands, this is a full 20% higher than a survey performed two years earlier by authors [2].

How about electric vehicles? In the Netherlands, 45% answer that they are considering driving an electrical vehicle, with 10% not yet knowing. Strikingly, the 45% is 11% higher, compared to the survey done two years ago. Below the results are presented for solar-PV, batteries and electric vehicles for the Netherlands.

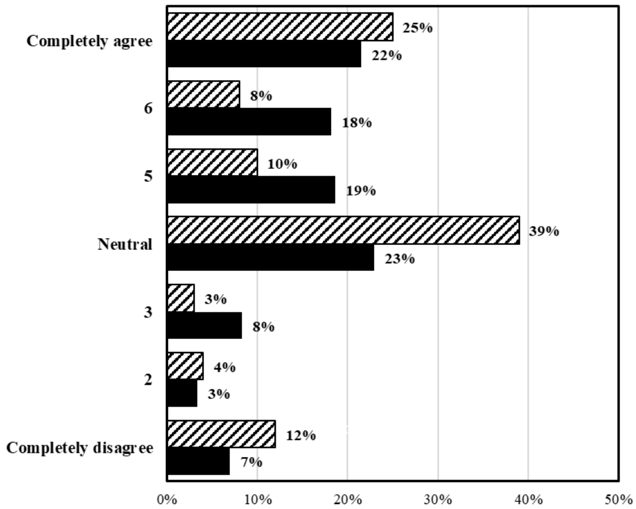
Figure 1: solar PV, batteries and electric vehicle expected adoption



When asked about preferred charging behaviours of an electric vehicle, a full 47% indicates to want to *'start charging when I get home and I want the battery to be (almost) full as quick as possible'*. A further 34% indicates the charging timing is flexible and the own home can use the battery. The remaining 19% indicates that charging is flexible, and the local cooperation or energy company can use the battery.

The Danish respondents answer that 43% would switch from the electricity grid to solar panels and batteries if the price was the same. In the Dutch survey this share is even higher at 58%. In both countries a quarter of respondents *'Completely Agrees'*, the strongest statement indicating a high preference (see figure 2).

Figure 2: 'I would switch from the electricity grid to solar panels and batteries if the price was the same'

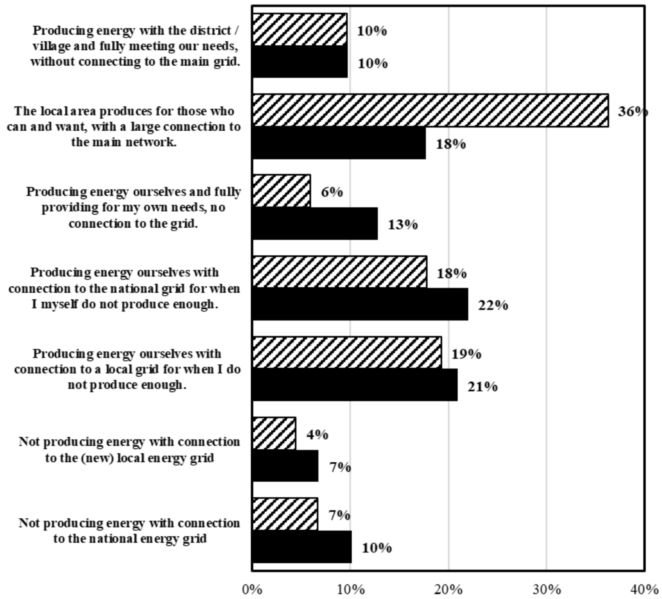


To the question to what people prefer for a new heat and electricity grid, given the same reliability and costs, 39% of the respondents in Denmark indicates to prefer a local grid or no grid. In the Netherlands, 50% prefers a local grid or no grid versus the national grid (see figure 3). In both countries, more than three-quarter of respondents prefers self- or local energy production versus no self-generation.

In both countries, the majority of respondents prefer a microgrid on the scale of the district/village or smaller. Slightly over a third prefers a scale of city, municipality or province (see figure 4). *This constitutes the reason to choose the neighbourhood as level of analysis of microgrid economics.*

In the Netherlands, 39% of respondents have no room for energy storage, 18% has space for batteries, 16% has space for batteries and heat storage in water, 27% indicates that there is space for batteries, heat storage and a micro-generator.

Figure 3: 'Suppose a new heat and electricity grid is installed, with the same reliability and costs [...], what do you prefer (choose two)'



The preferred party of a local energy network is the municipality in The Netherlands (30% of respondents) and energy company in Denmark (33%). The network operator or grid company is the desired party in 18% of responses in The Netherlands and only 7% in Denmark.

Next, the results from the survey are used to obtain justified approximations in the Fermi-estimation.

Fermi-estimation

The Fermi-estimation aims to use the least number of variables to come to a justified order estimation of the size of the electricity demand that might leave the monopoly MV and LV grid. The problem is stated as: '**how much grid demand (load) might leave the monopoly grids in the Netherlands?'** For the order estimation of this question the following variables are identified and approximated:

1. There are approximately 17,3 million people in the Netherlands [3].
2. Household size is on average 2,2 persons [3].
3. The number of connections is 1,04 per household [4].
4. The yearly average use per connection is 10 667 kWh which includes small business. *The 'standard yearly use', and industry definition, is 4 417 kWh.*
5. Current electricity end-usage totals about 87.000 GWh in the LV and MV grids in The Netherlands.
6. Demand is expected to increase by 49% (i.e. electric vehicles and electric heating and cooling plus

additional appliances and computational devices).

7. Self-generation (i.e. behind the meter) is expected to amount to 65% of all connections, amounting to 5,3 million connections. Current local production amounts to 6% of connections [[5]
8. Self-generation is estimated to be 6 500 kWh on average, reaching 37.000 TWh (about half of all building rooftop PV-potential, not taking into account other sources).
9. Self-usage or self-consumption, without storage is taken to amount to 37% [6].
10. Storage behind the meter will approximate be 37% of all connections (survey outcome).
11. Storage size will average 6 kWh (based on 1,0 kWh per kW peak-PV-power [1] [6]
12. Self-usage will rise to 57%, an increase or 20%.
13. Non-use and non-trading share will amount to around 12% of local production (as no demand and storage capacity is available).
14. Demand in local grids will then amount to 111.000 GWh.
15. Local-generation within the MV grid-station area will be 21% of demand [microgrid neighbourhood analysis].
16. Local grid usage of local generation (within the MV-station) is guesstimated to 70% of demand, amounting to about 20.000 GWh. Implying high-transmission grids will transport 90.000 GWh.
17. New local grids, amongst which local energy communities and microgrids, are estimated to be cost-effective for 19% of total households and is estimated to be applied in areas where self-sufficiency and independency is judged as important, being 9% of the respondents in the survey (which also indicate a willingness to pay more), amounting to about 28% of total local grid demand, amounting to 37.000 GWh, Existing monopoly grids will transport the remainder 76.000 GWh.
18. The outcome of this estimation is that monopoly grids provide around 57% of transmission of total demand, with 27% being self-produced and consumed and 28% of the remaining demand will go through new grids. *Re-iterating, these are order estimates which are simplified, but justified where possible.*

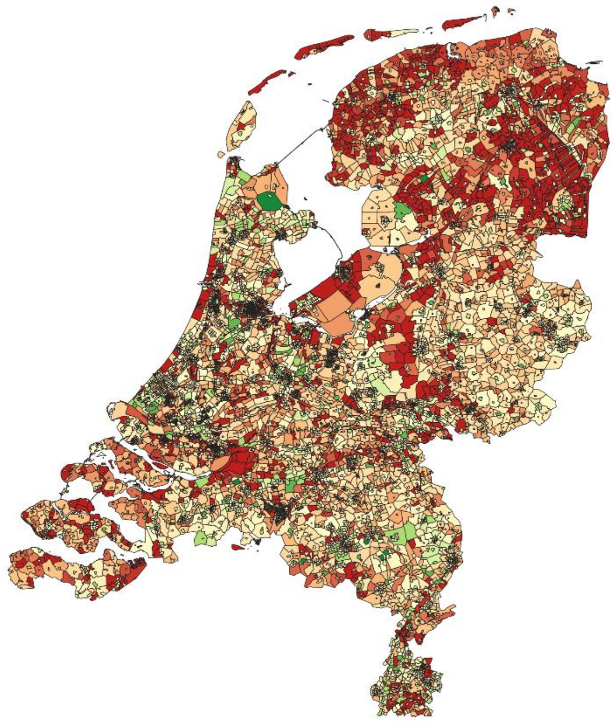
A number of variables are uncertain or almost no data is available: demand development, self-consumption share, local generation and competitiveness of microgrids. Especially the last step of microgrid competitiveness contains a high degree of uncertainty. In order to better estimate these four variables, a local analysis is performed on neighbourhood level for the Netherlands.

Economic analysis of microgrid neighbourhoods

The economic analysis simulates a local microgrid that provides each neighbourhood with electricity and where possible autonomy using renewable energy sources. When simulated, it calculates the expected costs of each microgrid for each neighbourhood. These costs are compared to the current consumer electricity cost. For each neighbourhood the Fermi-estimate steps are applied, and the economic of the microgrid is expanded in the following manner: the solar insolation is determined, and the available/optimal solar-PV installed is applied, then a generator is added for (25% of solar-PV capacity on average) as well as battery storage (3 kWh for each kW of solar) and convertors. The approach takes the same input for the investment figures (year 2020) as in the RMI, 2014 study [1].

Next, the length of the new local grid is determined based on the current grid length and population density. For each neighbourhood the investment, capital costs and operational costs are estimated for the complete microgrid. Average investment for the grid is 190.000 EUR per kilometre, with a maximum of 356.000 EUR per kilometre in some neighbourhoods. Capital costs are taken to be 6% of investment for panels, generator, convertors, etc and 7,5% for the new cables and transformers. Within the operational costs are operation, maintenance and losses. The consumer cost is taken as 0,16 EUR/kWh.

Figure 5: microgrid cost comparison for neighbourhoods in The Netherlands



The resulting cost comparison indicates that in 7% of the neighbourhoods the microgrid is expected to be cost competitive, these neighbourhoods cover 20% of the population and 21% of the total electricity demand (see figure 5). This input is applied in the MonteCarlo analysis. A full 60% of all neighbourhoods could be self-sufficient with solar-PV, generator and batteries. Potential additional economic benefits which are not taken into account to remain on the conservative side: grid balancing, co-generation of heat, cooperation with surrounding neighbourhoods, increase in consumer prices in the future.

MonteCarlo simulation

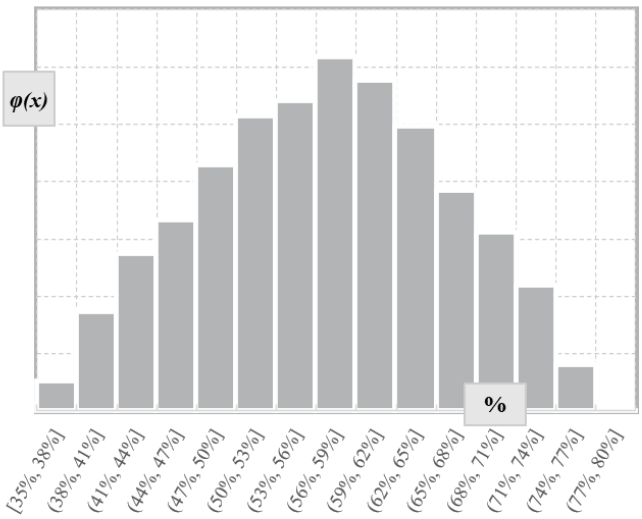
The MonteCarlo simulation aims to use the minimum number of variables to meaningfully explore the extend to which the use of monopoly grids could change. The population, households and grid connections are taken as given [3]. The variables and distribution as given below are applied in the MonteCarlo simulation.

Table 1: MonteCarlo input variables

	ELECTRICITY USE	DEMAND	SELF-GENERATION	SELF-GENERATION	SELF-CONSUMPTION	STORAGE SHARE	STORAGE SIZE	SELF-CONSUMPTION RISE	NON-USE SHARE	LOCAL GENERATION	LOCAL USAGE	NEW LOCAL GRIDS COST-EFFECTIVE	NEW LOCAL GRIDS INDEPENDANCE
unit	yearly average	increase	share	kWh		share	kWh	%	%	% of demand	% of generation	share	share
DISTRIBUTION	Bayesian	Triangle	Triangle	Triangle	Bayesian	Triangle	Square	Square	Triangle	Triangle	Triangle	Triangle	Triangle
LOW		28%	50%	4 900		25%	4	13%	4%	11%	60%	6%	4%
MEAN	10 667	49%	65%	6 581	37%	37%	6	20%	12%	18%	70%	19%	9%
HIGH		90%	85%	8 392		48%	8	26%	16%	33%	90%	39%	16%
STANDARD DEV	1 067				4%								
c		34%	43%	48%		53%			69%	32%	33%	39%	42%

The results from 10.000 simulations indicate that monopoly grids might transport about three-fifth of total demand in MV- and LV-grids in The Netherlands in the future. Important to mention, this is the mean figure, and the distribution around this figure is large running from 36% to 78% (see figure 6).

Figure 6: monopoly share of total demand



he main variables influencing the simulation outcome are demand increase, self-generation and consumption, application of microgrids. Most uncertainty is within the local competitiveness of the microgrids.

CONCLUSIONS

The main conclusion is that **microgrids will be economically competitive with monopoly grids in a sizable, minority of neighbourhoods. In The Netherlands, estimated at one-fifth of total demand**. Furthermore, one-third to one-half of the surveyed people prefer a local grid or no grid at all versus the national grid. Two-fifths to three-fifths of the respondents prefers to defect from the electricity grid towards solar panels and batteries if the price was the same. A full 60% of all neighbourhoods could be self-sufficient with solar-PV, generator and batteries. The battery electric vehicle might not provide the flexibility and storage as expected since survey results indicate that half of all drivers want to charge immediately to almost full capacity without flexibility. The share of demand that monopoly grids will transport is highly uncertain, but is almost certainly set to decline. Still, the amount of electricity will not decline to the same degree due to the strong increase in electricity consumption. The main driving forces are local generation and cost-effective microgrids. The EU's Winter Package would speed up the adoption of microgrids as legal steps to reduce the uptake would be harder to implement. The conditions for a perfect storm are present but how large the downpour could be remains uncertain.

Acknowledgments

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