Smart Network Tariffs: Managing Demand Peaks in Residential Electricity Distribution

Roman Hennig, PhD Researcher at TU Delft

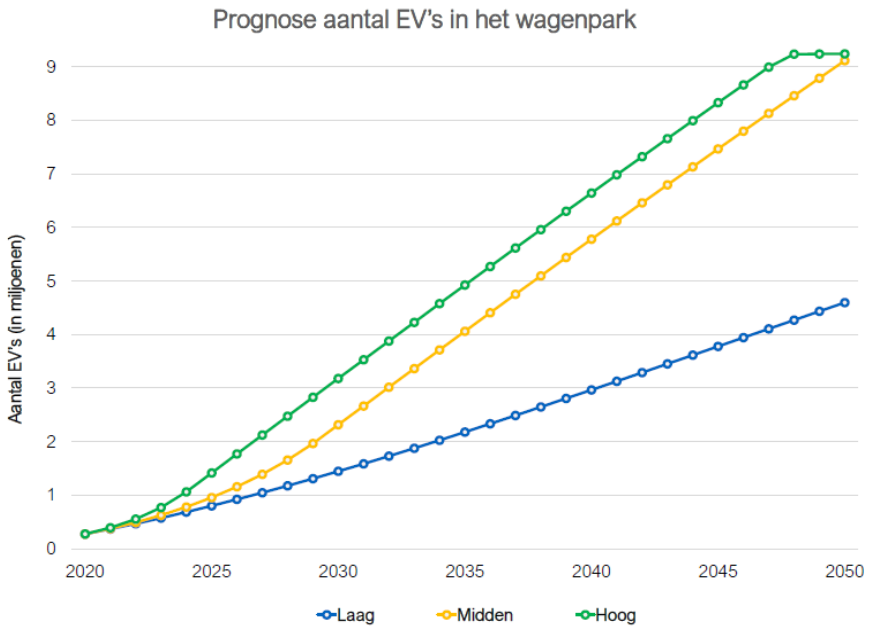
Supervisors:
Prof. Dr. ir. Laurens de Vries
Dr. Simon Tindemans

Enerday Dresden, May 5th 2023

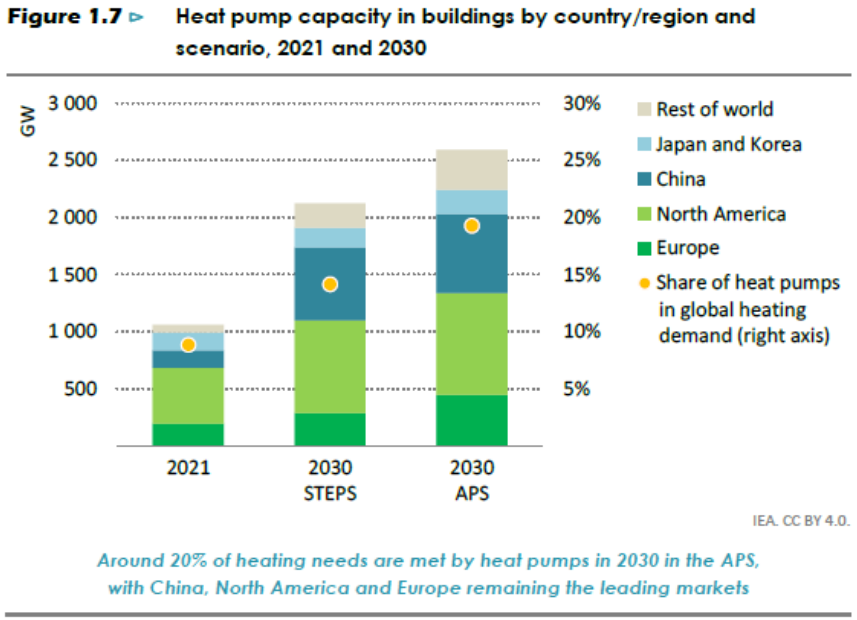
TU Delft

Part 1: Problem Description

Starting Point: strong increases in flexible loads in residential sector

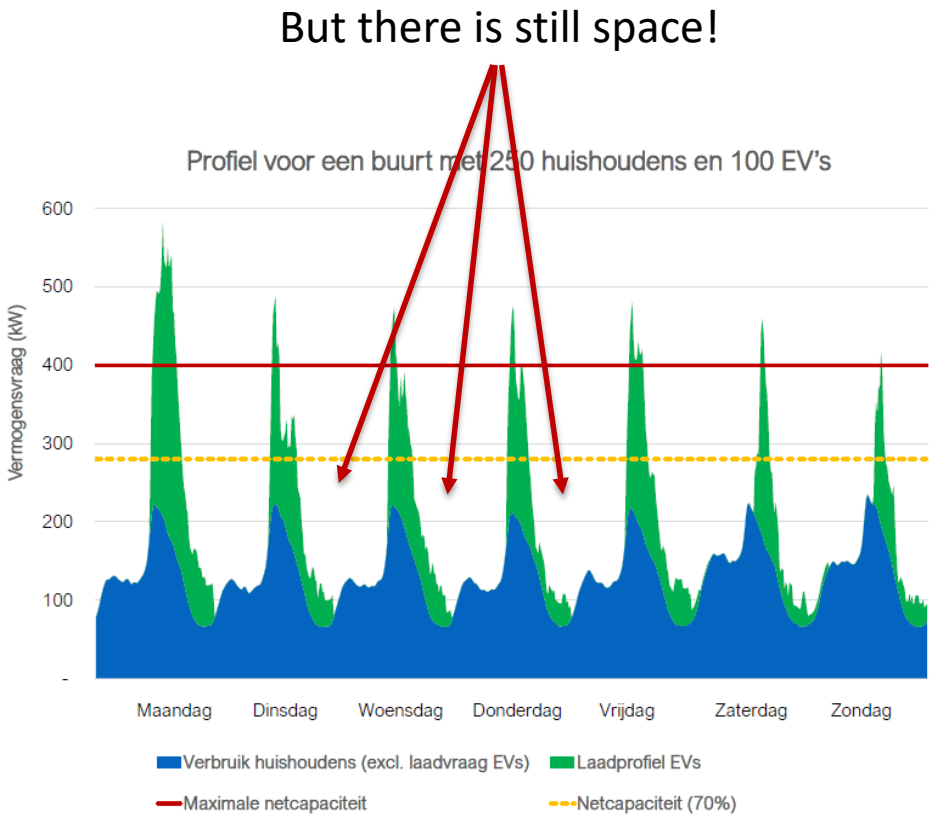


Source: ElaadNL Outlook 2021



Source: IEA Report, The Future of Heat Pumps

Problem: Increasing “Peakiness” of loads can lead to network congestion



Source: ElaadNL Outlook 2021

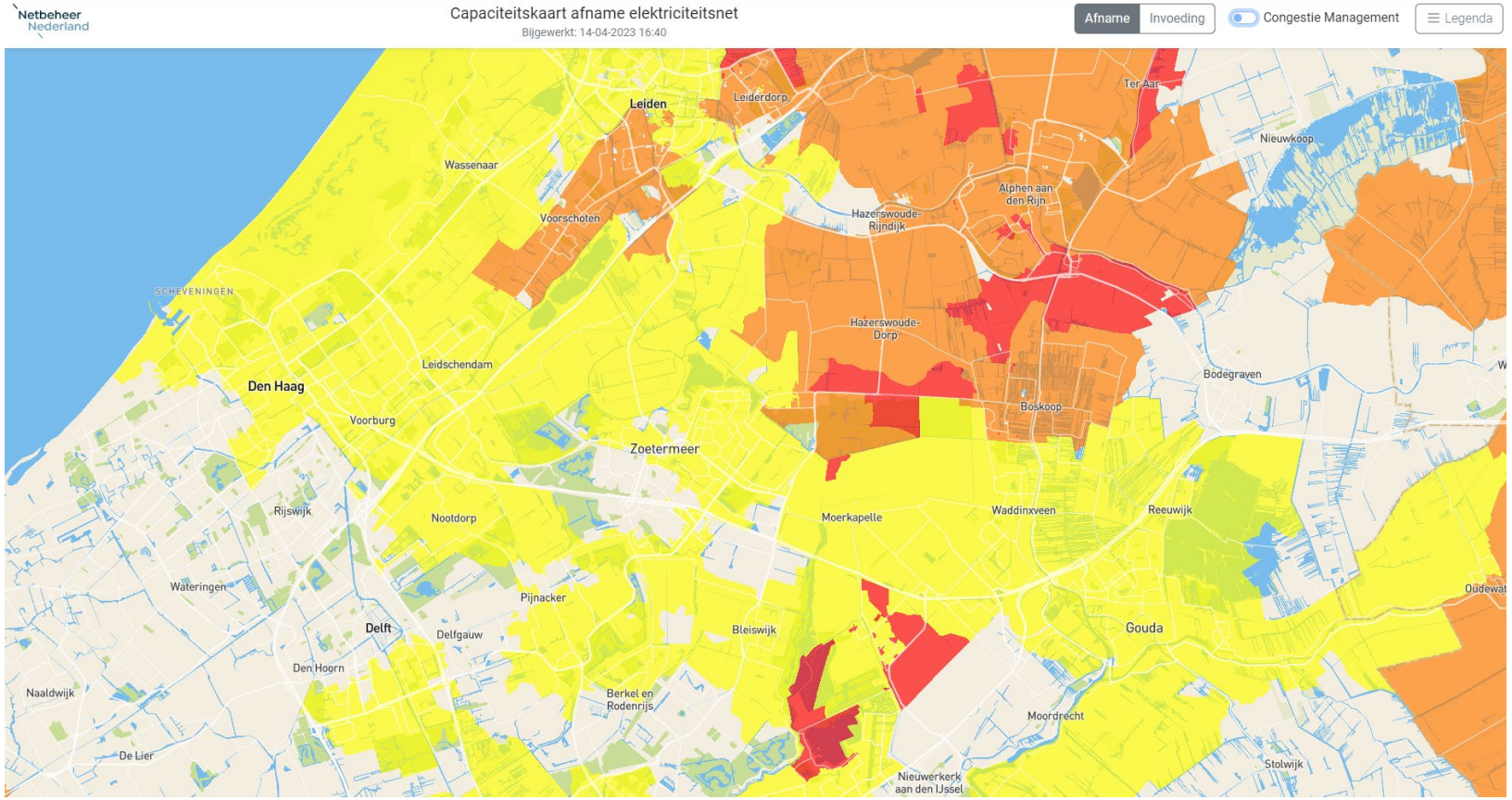
Flexibility could be used:
Often it’s not a question of feasibility, but *coordination*

Objective and Toolbox

- Objective:
  - Find coordination mechanism that removes network congestion at low cost (a.k.a.: congestion management)
- “Toolbox”:
  - Smart network tariffs
  - Redispatch (local markets for flexibility)
  - Demand response programs (direct control)

Forthcoming paper: Hennig et al., “Congestion Management Options in Electricity Distribution Grids”, preprint submitted to Utilities Policy

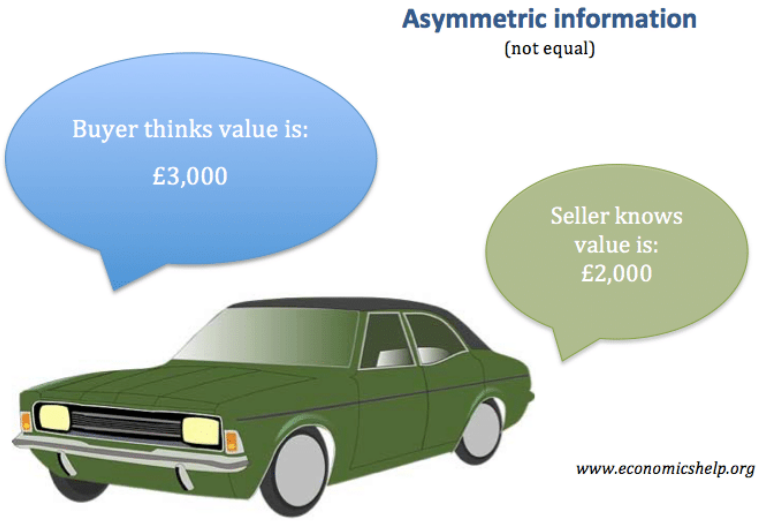
Dilemmas in Network Congestion: Discrimination



Source: capaciteitskaart.netbeheernederland.nl

Dilemmas in Network Congestion: Information Asymmetry

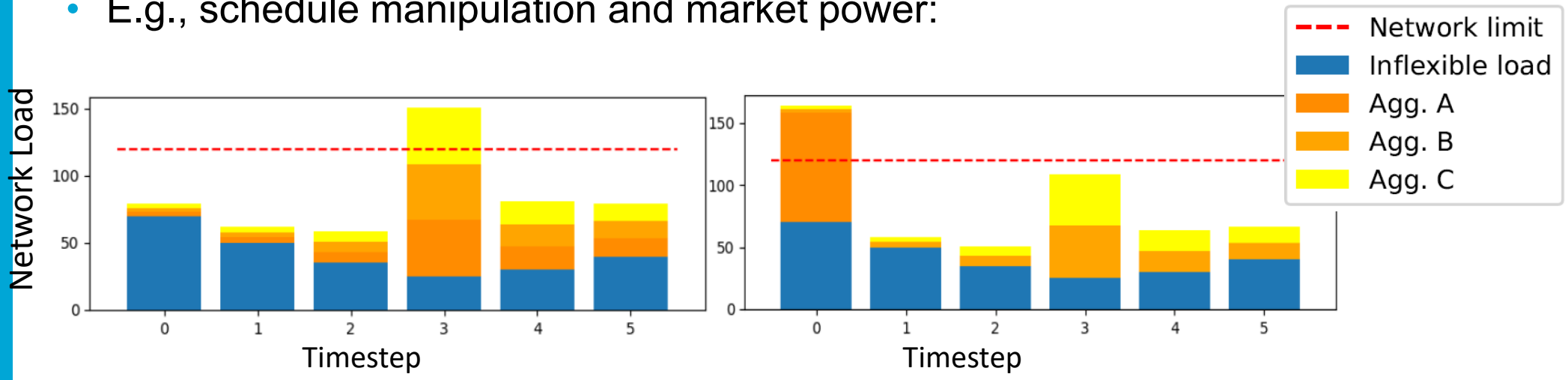
- Network operator does not know:
  - When users are planning to use the network
  - How much they value using the network



Part 2: Possible Solutions

Possible Solution:
Local Flexibility Market for Redispatch

- In congested areas, customers (or aggregators) are paid to reduce consumption by the network operator
- Problem: information asymmetry may lead to undesirable strategic behaviour of profit-oriented market actors
- E.g., schedule manipulation and market power:



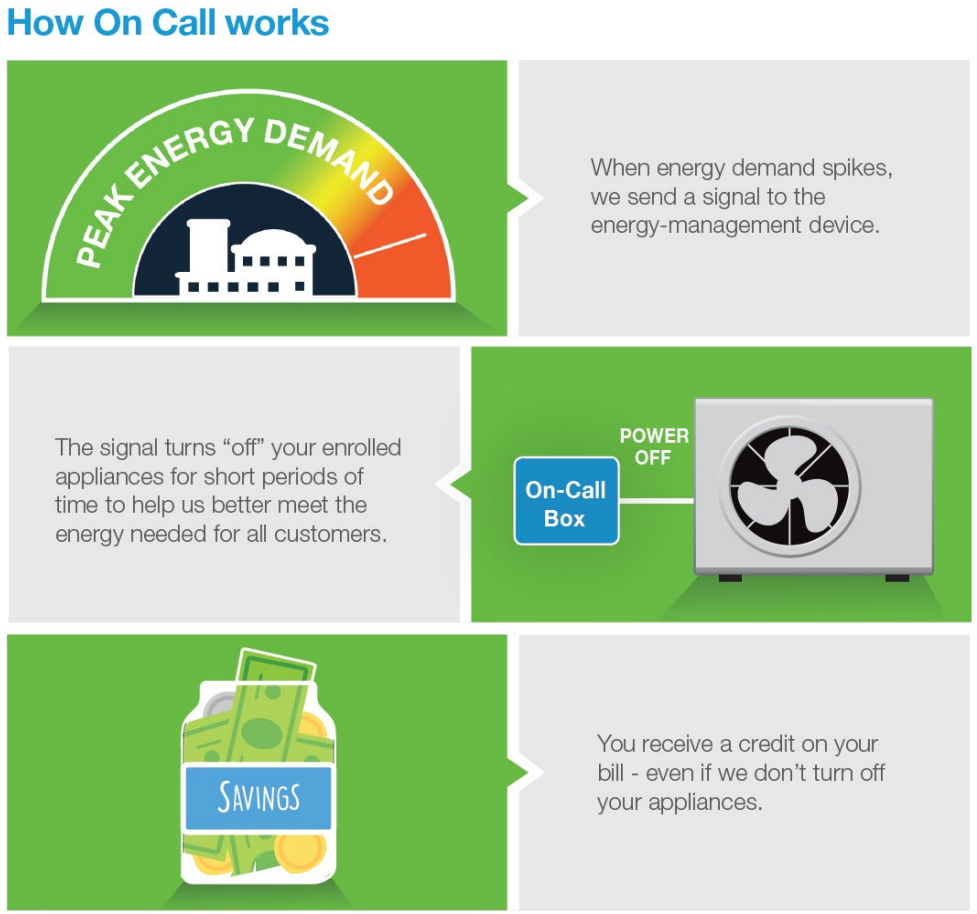
Intended situation: competitive market

Undesirable situation: vulnerable to Market power abuse

Source: [Hennig et al., Market failures in local flexibility markets, EEM 2022]

Possible Solution:
Demand Response Programs

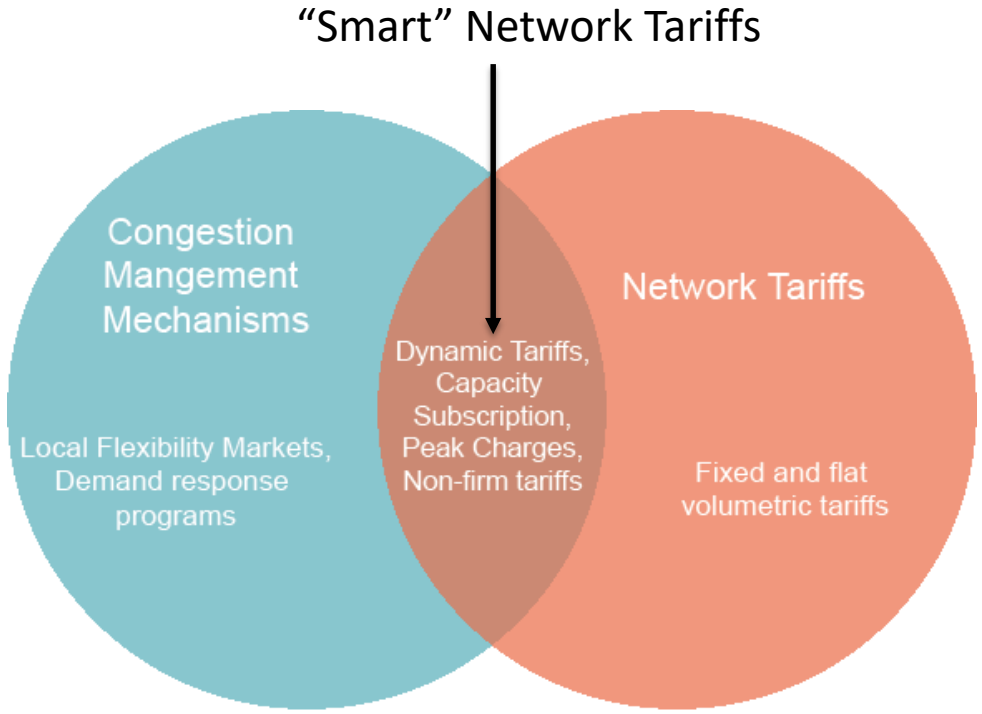
- Utility company gives direct credit in exchange for the option to curtail loads
- E.g.: “On-Call” program by Florida’s public utility:
- Problems (in unbundled power systems like the European):
  - interferes with portfolio of energy provider
  - Difficult to use flexibility for other purposes (e.g. TSO services)
  - Network operator may curtail when it is very inconvenient for user (information asymmetry)



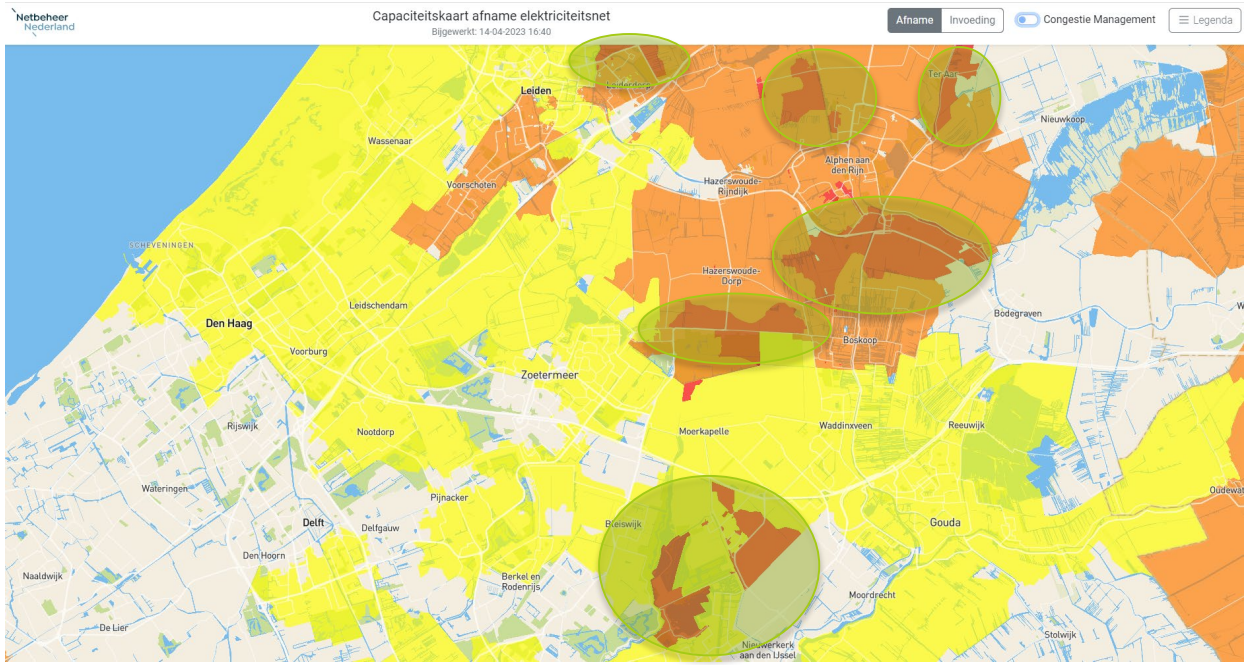
Source: https://www.fpl.com/save/pdf/oncall.pdf

Network Tariffs and Congestion Management

- LFMs and DR programs are added on top of network tariff
- Network tariffs are charged by the operator for building and maintaining the network.
- In addition to cost-recovery, they could also be used to incentivize smart network usage.
- “Smart” tariffs integrate congestion management to a varying degree



Possible Solution: Dynamic Tariffs (Local)



- Prices increases only for congested areas
- Increasing prices are intended to prevent network overload

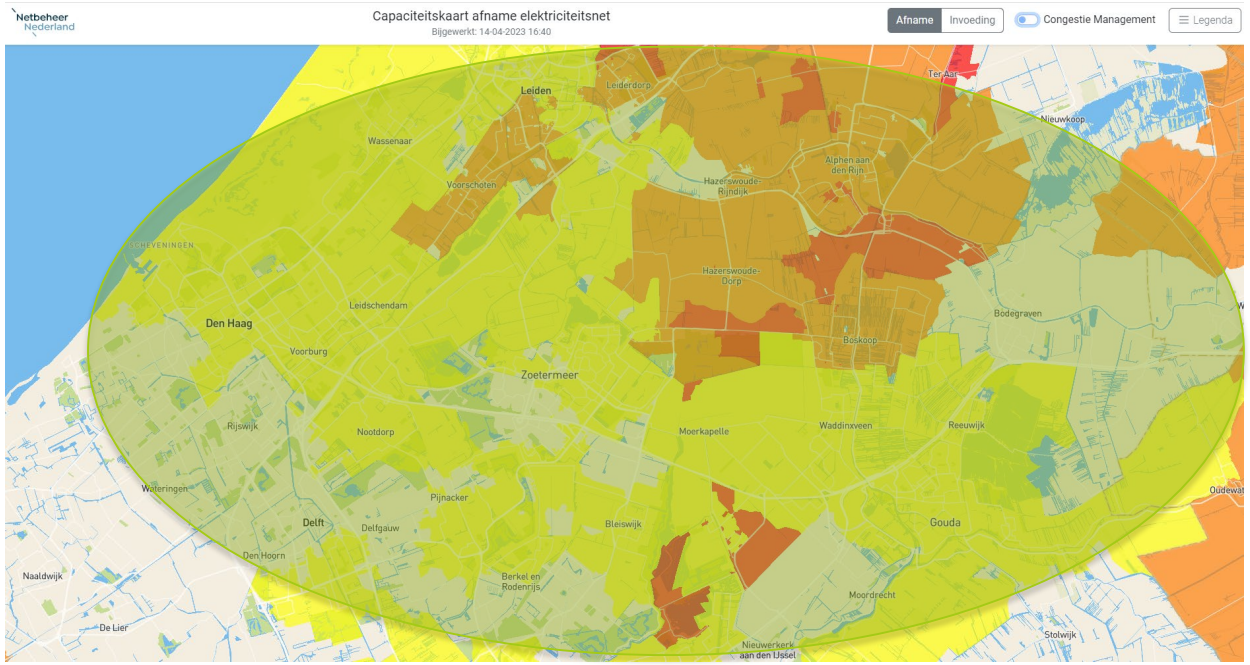
Benefit:

- Reveals network valuation of users
- Targets congested areas explicitly

Problems:

- Spatial price discrimination
- Regressive
- No guarantee on congestion removal

Possible Solution:
Dynamic Tariffs (Network-wide)



- Prices increase for everyone when congestion appears in isolated areas
- Increasing prices are intended to prevent network overload

Benefit:

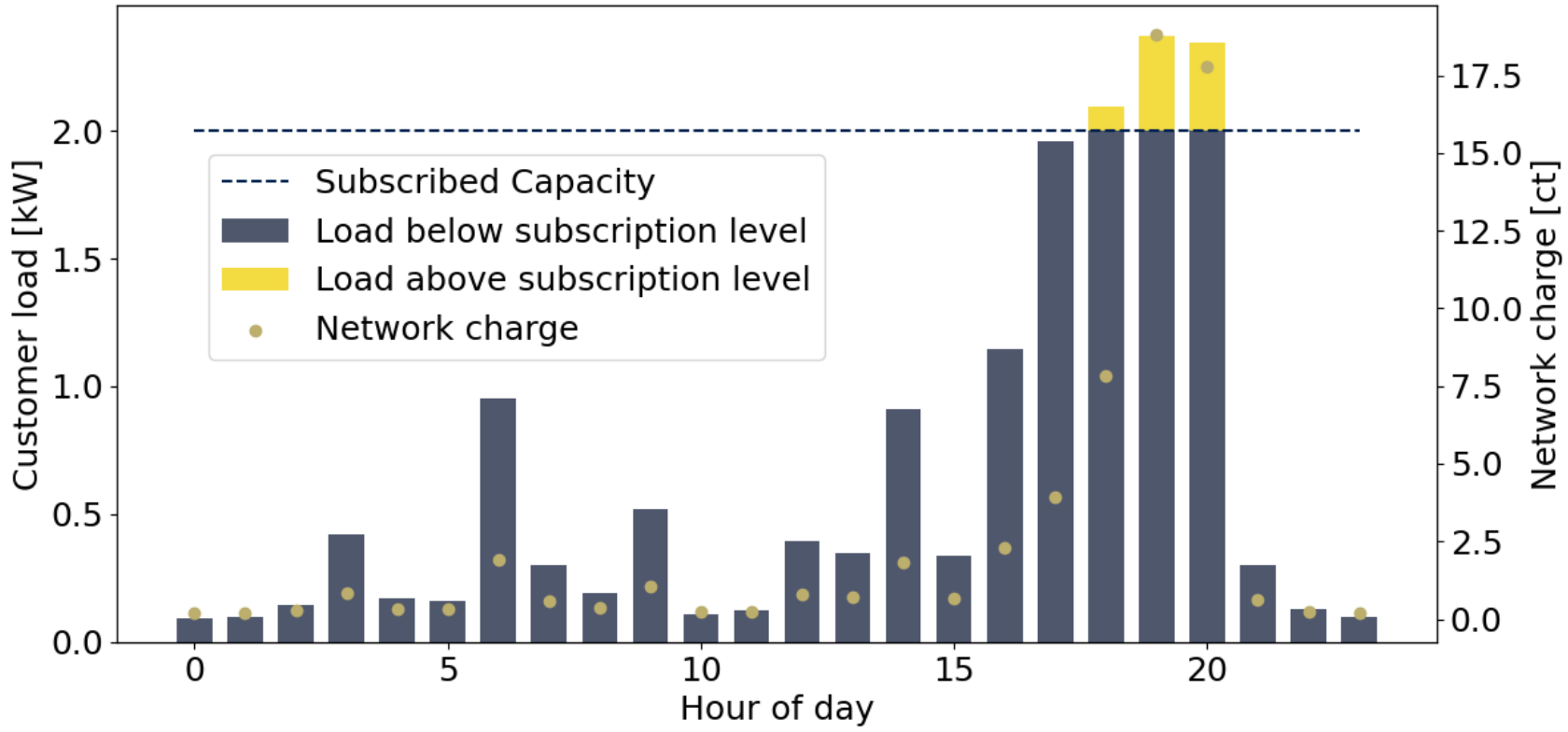
- Reveals network valuation of users
- No spatial price discrimination

Problems:

- Inefficient price increases
- Regressive
- No guarantee on congestion removal

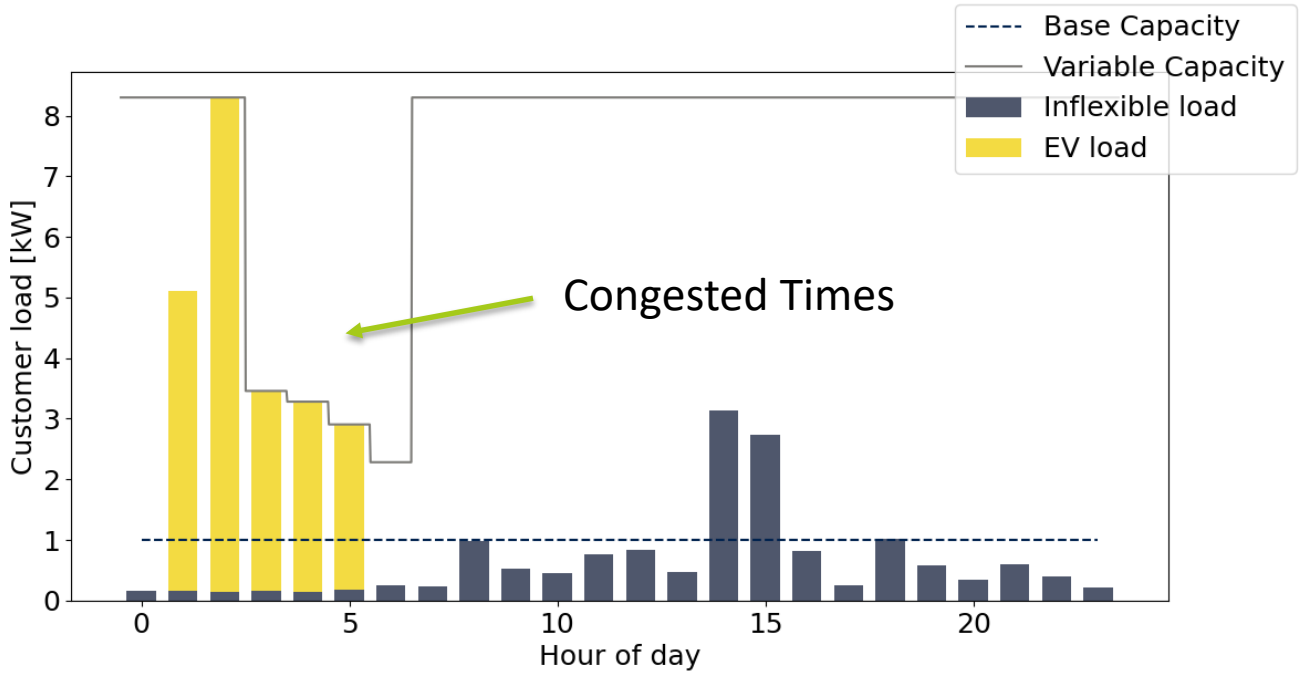
Possible Solutions:
Capacity Subscription Tariff

- Users sign up for a chosen amount of network capacity. Within this capacity they can use the network at a low charge. Above: higher charge



Under Development: 2-part variable Capacity Subscription

- Users sign up for a 2-part subscription:
  - A “Base” subscription that has a higher price and gives guaranteed capacity
  - A “variable” added subscription at lower price per kW of capacity, but this can be curtailed during network congestion by the network operator
- Benefits: Better reveals users’ network valuation, more available network capacity when there is no congestion



Assessment of Network Tariffs

- Network tariffs are expected to fulfil a range of objectives:
  Cost-recovery, cost-reflectiveness, non-discrimination, efficiency, simplicity
- Whether they fulfil these objectives can be assessed by defining indicators and measuring them in simulations or real-world case studies

Hennig et al., "What is a good distribution network tariff?—Developing indicators for performance assessment", https://www.sciencedirect.com/science/article/pii/S0306261922005554

Tariff	Cost-refl. low EV	Cost-refl. high EV	Efficiency high EV	Simplicity
Fixed	- -	- -	- -	+ +
Vol. Day-Night	+ +	-	- -	+
Capacity Subscription	+	+ +	+ +	-
Mixed Capacity-ToU Vol.	+ /+ +	+	+	- -

Table 4: Comparative assessment of the performance of the four tariffs relative to each other.

Summary and Conclusion

- The increasing “peakiness” of loads that comes with electrification of personal transport (EVs) and heating (heat pumps) leads to network congestion.
- There is no perfect solution to this problem, need to compromise.
- “Smart” network tariffs are a good option in the European context.
- We think a capacity subscription tariff is a good solution. It can be further improved by dividing the subscribed capacity in “base” (guaranteed) capacity and variable capacity.
- Network tariffs have to fulfil are range of objectives, which can be conflicting. Thus, a careful assessment is necessary.


Questions,
Comments?
TU Delft

Backup Slides

Comparison of Solutions

Table 1: The dilemmas of network congestion in different methods

	Discrimination	Info. asymmetry	Complexity
Dynamic network prices	Translated to explicit price-based discrimination.	Removed: network users are forced to reveal network valuation in near real-time.	Complex: price variations may lead to bill shock. Flexible users with SEMS may be able to react better.
LFMs for congestion	Effectively removed: users can be made indifferent between congested and non-congested areas through LFM payments.	Misrepresentation of information can inflate prices and worsen the congestion problem.	Simple for non-flexible users. Implementation complexity can be handled by DSOs, aggregators and SEMS.
Capacity subscriptions	Removed: in standard version, the subscription contract is equal everywhere.	Partially removed: network capacity valuation revealed in long-term contract, no short-term adjustments.	Relatively simple: predictable, but requires to educate users about the capacity subscription concept.

Assessment Framework

- Our contribution:
  - Framework with performance indicators for regulatory objectives.
- Possible indicators (examples):
  - Cost contribution / network charge – per user
  - Total cost / revenues for network operator
  - Network overload events
  - Simplicity (for EV/Heat pump owners and “non” owners)

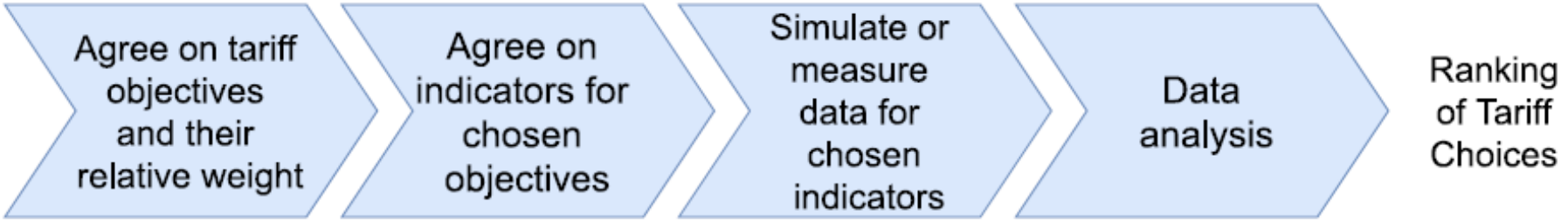


Fig. 1. Assessment process for network tariffs.

Tariffs and Congestion Management Design Variables (examples)

Design Variable	Regular Connection (fixed)	Non-firm connections	"Pay-to-Reduce" Markets	Dynamic Tariff
Offer vs. buy-back network access	Offer	Offer	Buy-back	Offer
Time-frame for mechanism	Yearly	Yearly contract Day-ahead/real-time activation	Day-ahead/real-time	Day-ahead/real-time
Firm vs. non-firm access	Firm	Non-firm	Firm	Firm
Traded product	Network Capacity	Network Capacity	Load reduction (to baseline or current consumption)	Energy

Simple, but not adaptable

Adaptable, but vulnerable to strategic behaviour