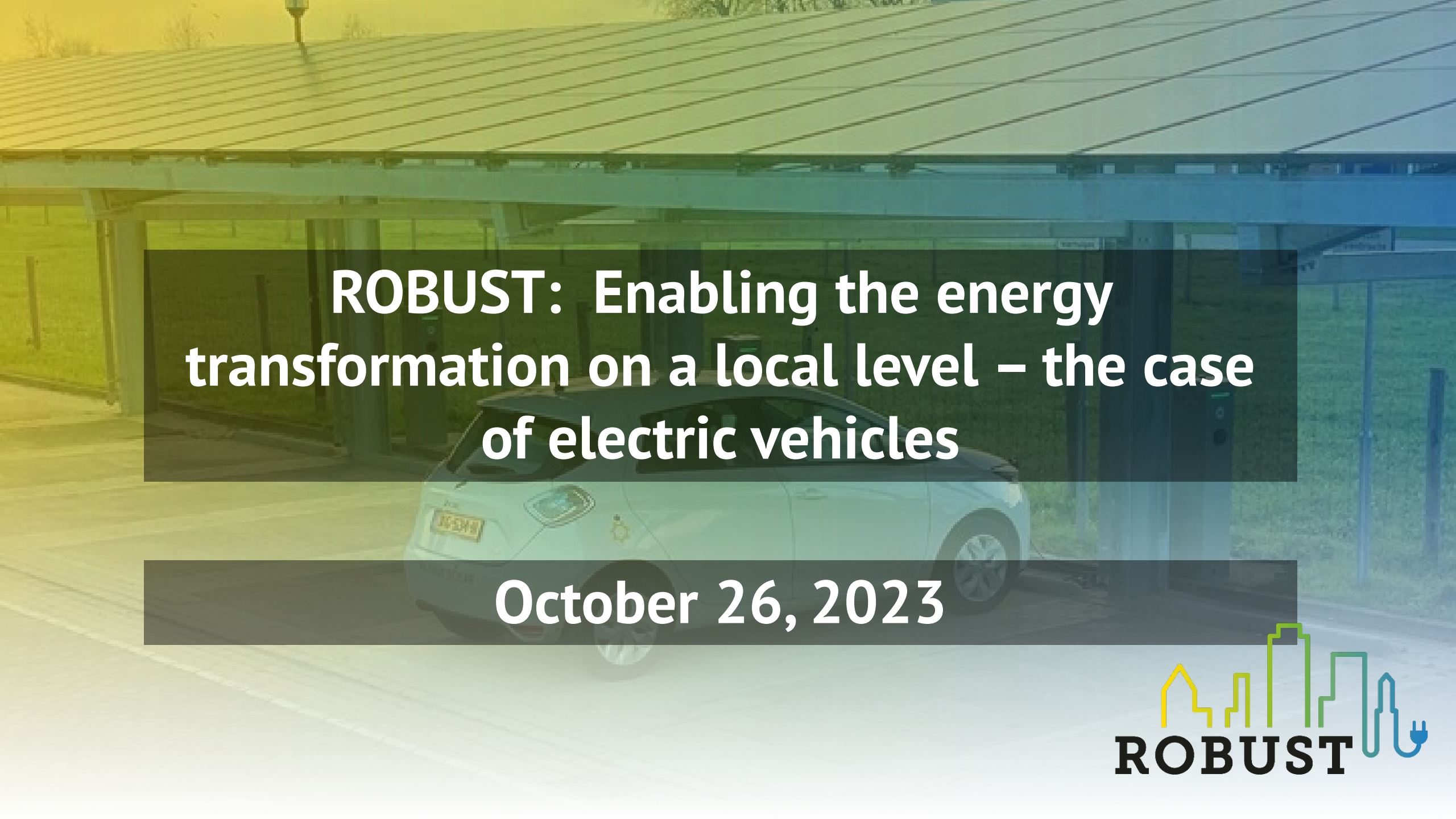


ROBUST: Enabling the energy transformation on a local level – the case of electric vehicles

October 26, 2023

ROBUST

Agenda

08:30 ***Enabling the energy transition on a local level: the case of electrical vehicles*** - Bart van der Ree

08:45 ***Data-Driven Modeling of Electric Vehicle Flexibility for Congestion Mitigation Services: A Multi-Objective Optimization Approach Balancing Cost and Emission Reduction*** - Nanda Kishor Panda

09:00 ***The role of legal research in transdisciplinary projects regarding the energy transition: harnessing flexibility for congestion management*** - Anoeska Buijze

09:15 ***Willingness to participate in vehicle-to-grid program: An exploration of battery electric vehicle users with various driving needs and charging preferences*** - Yang Hu

09:30 ***Identifying Barriers and Facilitating Factors for Smart Charging Behavior of Electric Vehicles. Insights from applying the COM-B framework*** - Janna de Graaf

09:45 ***Discussion***

ROBUST

RES targets ‘unrealistic’

Netbeheerders noemen RES-doelstellingen onrealistisch

02.07.2021 | Nieuws Jan de Wit

De netbeheerders hebben voor de dertig RES-regio's de impact op de infrastructuur van de regionale ambities doorgerekend. Uit de berekeningen blijkt dat er tot 2030 nog meer dan 130 stations moeten worden uitgebreid en er moeten bijna 60 nieuwe stations worden gerealiseerd. De voorgestelde hoeveelheid terawattuur (TWh) noemen ze 'onrealistisch'.

Er zijn in totaal bijna 250 stations die de verbinding vormen tussen het landelijke hoogspanningsnetwerk en het regionale middenspanningsnetwerk. Daarvan moet dus meer dan de helft worden uitgebreid en het aantal zal met ongeveer een kwart moeten toenemen. Zo blijkt uit een gezamenlijk statement van onder andere Netbeheer Nederland, TenneT, Liander en Stedin.

New solar/wind parks cannot be connected

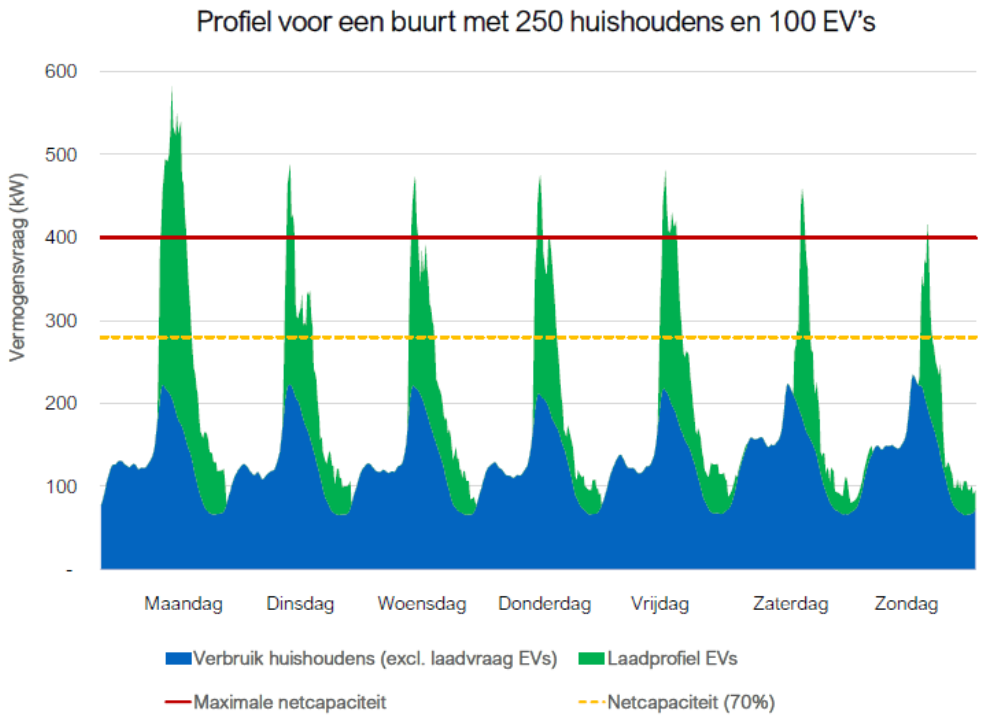
12 oktober 2021 13:12
Laatste update: 12 oktober 2021 13:15

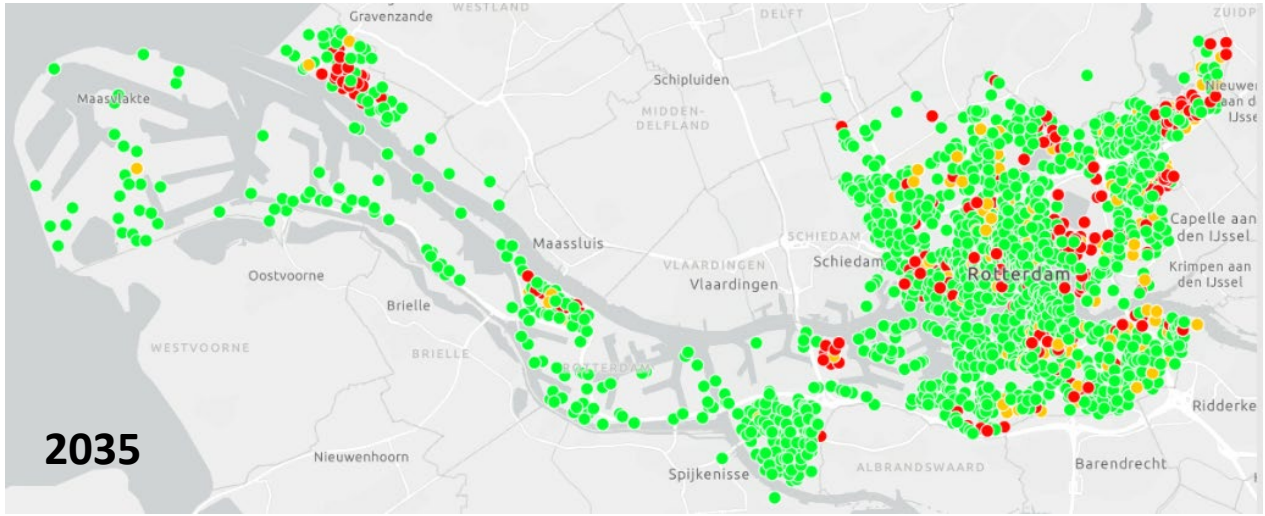
419 NUjij-reacties

Er is tijdelijk geen plaats voor nieuwe zonne- en windparken of grote

- How to avoid / reduce reinforcing the electricity grid to cope with increased supply and demand?
- Stakeholders: DSO, TSO, municipalities, aggregators, balance responsible parties

Will the electric car (EV) be the problem…

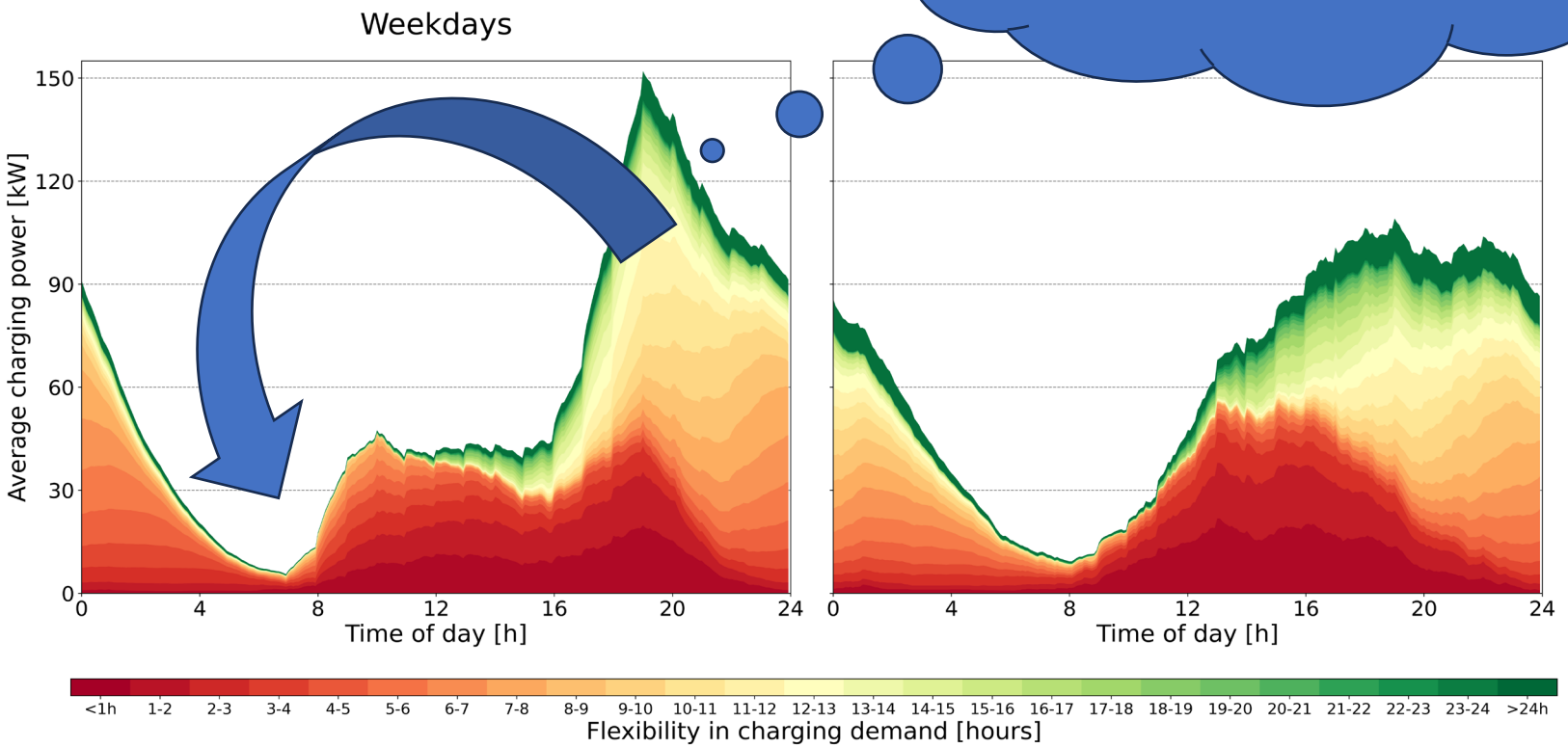


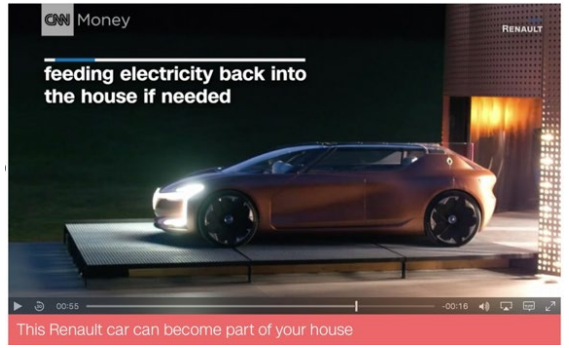


	2025	2030	2035
Rotterdam	111 (5 %)	164 (7 %)	211 (9 %)
Den Haag	239 (14%)	289 (17 %)	390 (23 %)
Utrecht	99 (10 %)	200 (19 %)	318 (31%)
Stedin (excl. Enduris)	1.436 (8 %)	2.455 (13 %)	3.635 (20 %)

...or a solution?

Smart and V2G charging:
shift demand to moments with lower grid load





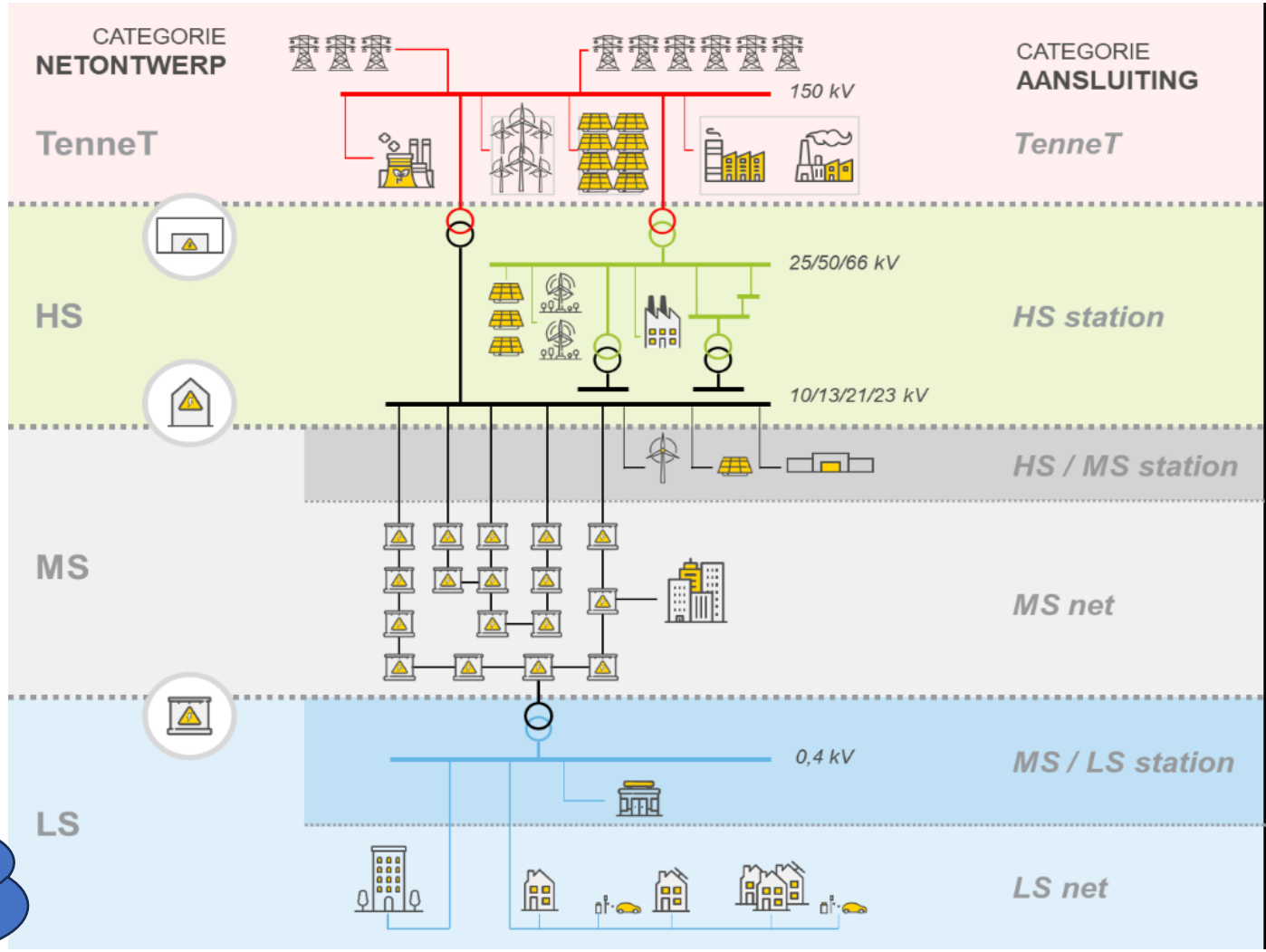
STEDIN.NET | VOOR DE NIEUWE ENERGIEGENERATIE

Virtual coupling of EV's and Vehicle-to-Grid discharging (V2G) represent a huge potential for grid flexibility

	# EV's	EV-FLEX potentie *		
	NL	NL	MS-ring	MS/LS trafo
2025	953.967	2 GW	0,6 MW	30 kW
2030	2.313.893	5 GW	1,6 MW	80 kW
2040	5.778.141	12 GW	4 MW	200 kW
2050	9.112.808	20 GW	6 MW	300 kW

** FLEX potentie gebaseerd op 20% van de EV's*

Comparable to fossil power plants NL

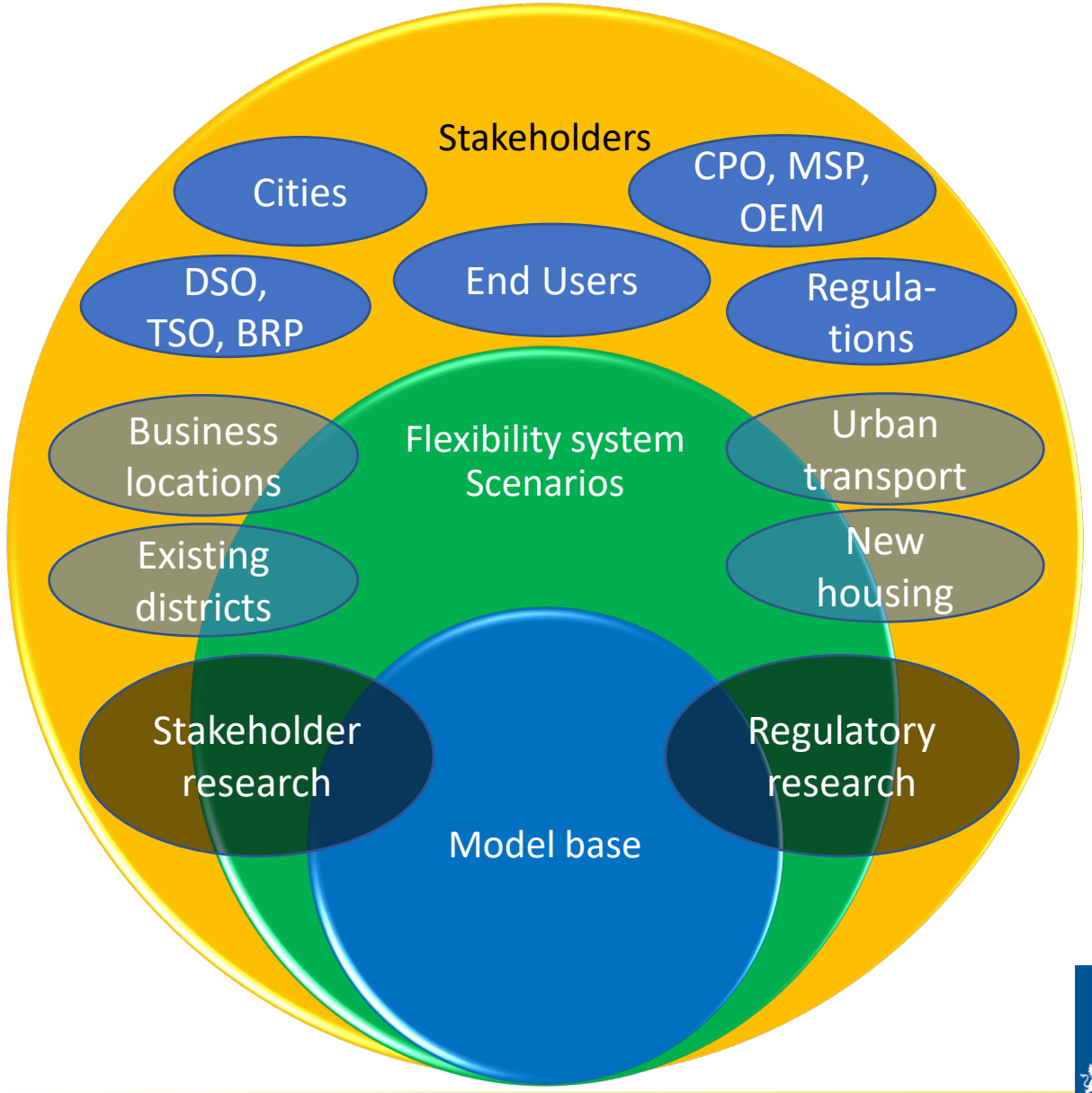


The Utrecht Bidirectional Ecosystem

- **700 V2G EV chargers**
- **250 shared EVs smart charging**
- **25 V2G shared EVs**
- **2 Stationary batteries**

- New housing districts
- Existing districts
- Energy producing high-rise housing
- V2G charging plazas
- Smart e-bus charging

ROBUST multidisciplinary research



ROBUST

Universiteit Utrecht

UTRECHT SUSTAINABILITY INSTITUTE

TU Delft

HOGESCHOOL UTRECHT

WE DRIVE SOLAR

STEDIN.NET

Enervalis

edmij

Elaad nl

Gemeente Utrecht

GEMEENTE Arnhem

Rijksdienst voor Ondernemend Nederland

TKI URBAN ENERGY
Topsector Energy

Outline ROBUST

Open flexibility system

- City-wide network
- Utrecht & Arnhem / Amsterdam

Multidisciplinary

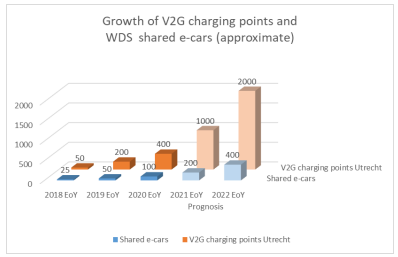
- Modelling / simulations
- Legal / regulatory
- Social / end user Research
- Pilots

Sources of flexibility

- **Electric cars (V2G)**
- Stationary batteries
- Heat pumps
- Electric buses
- Open to other sources

Project running time

- April 2021 – September 2025



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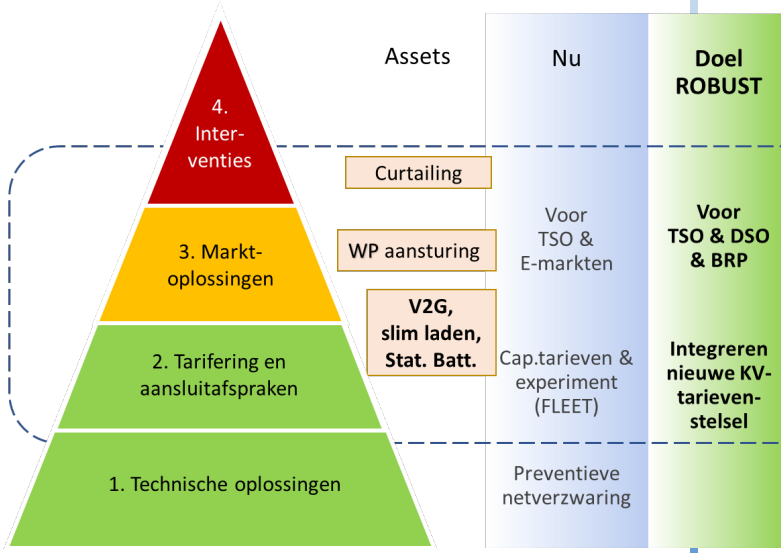
Proof of principle: urban flexibility system

- Large scale experiment and analysis
  - Delayed / interrupted EV charging
  - V2G charging
  - Flexible grid tarriffs
  - Test - GOPACS grid congestion
  - Test - EQUIGY grid balancing (SCALE project)
- Regulatory, social, end-user research
- Synthesis to integral urban flexibility system
- Perspective for action for problem owners



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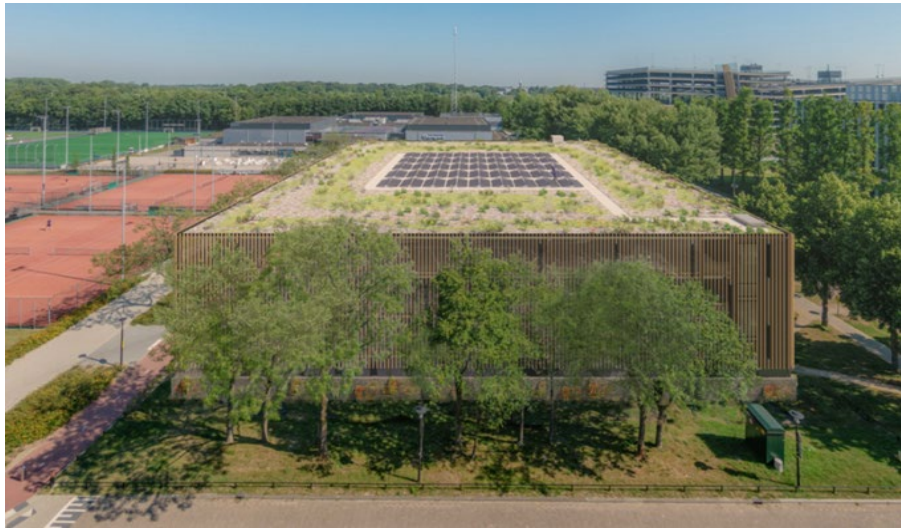
Research locations

- New housing districts (all-electric, shared V2G e-cars)
- Working locations (Utrecht Science Park, Triodos Bank)
- Urban mobility (Qbuzz plaza)



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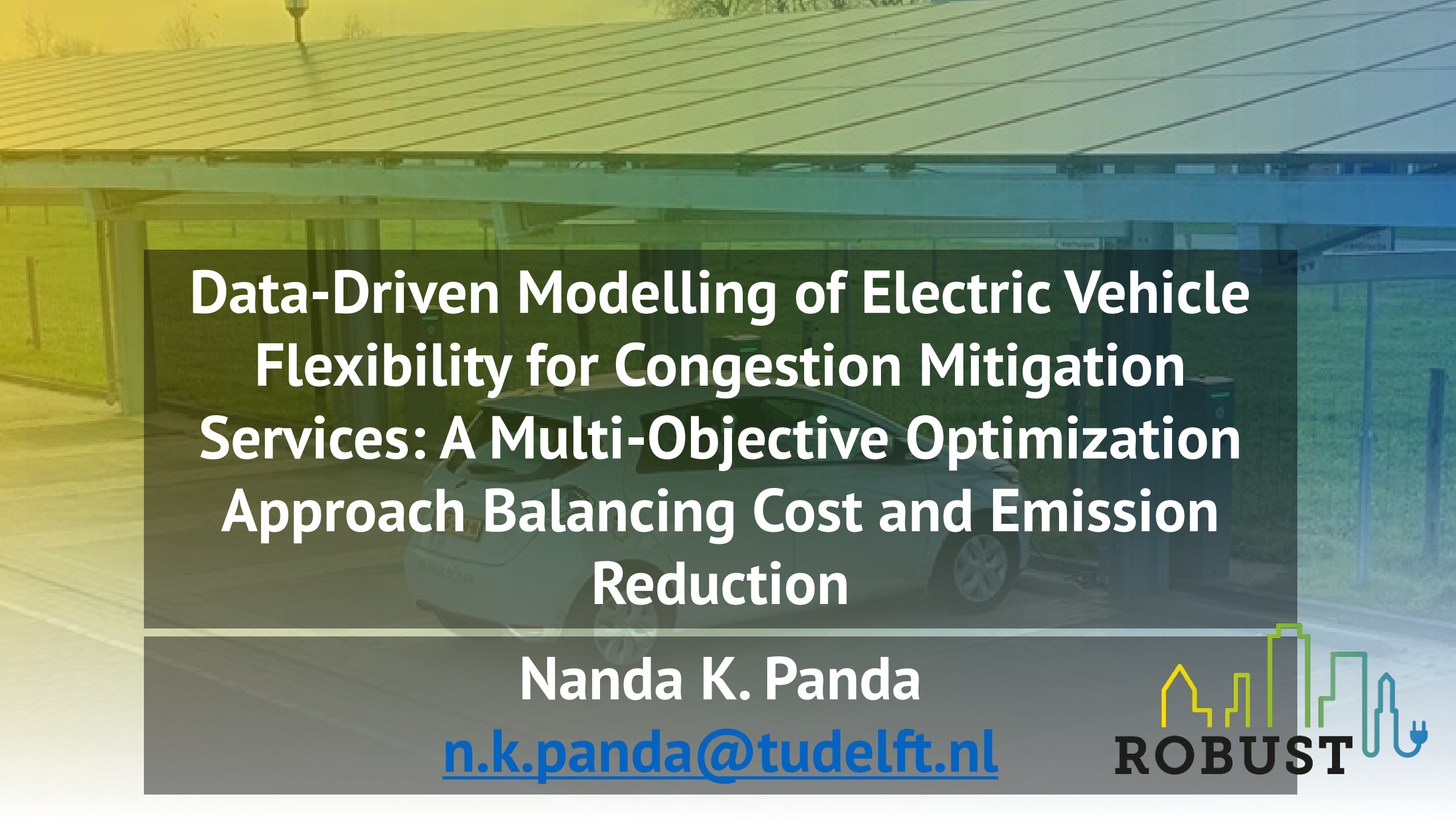

Data-Driven Modelling of Electric Vehicle Flexibility for Congestion Mitigation Services: A Multi-Objective Optimization Approach Balancing Cost and Emission Reduction

Nanda K. Panda
n.k.panda@tudelft.nl

ROBUST

1. Electric Vehicles Challenges and Opportunities

ROBUST

2. Flexibility in Practise

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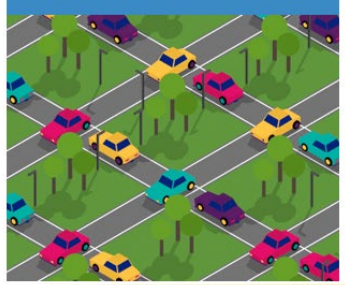
3. Flexibility Products for Congestion Management



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4. Takeaways

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1.

Electric Vehicles Challenges and Opportunities

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EVs – The Challenges

Standard household (3 x 25 A ~ 17.2 kW)

Normal household wall charger (AC 1 ph ~ 7.4 kW)

>40%

DC fast chargers (up to 150 kW)

- Voltage problems
- Network congestion
- Power quality issues
- Slow reinforcement of network infrastructures

SOURCE:
https://alternative-fuels-observatory.ec.europa.eu/general-information/recharging-systems
https://www.stedin.net/aansluiting

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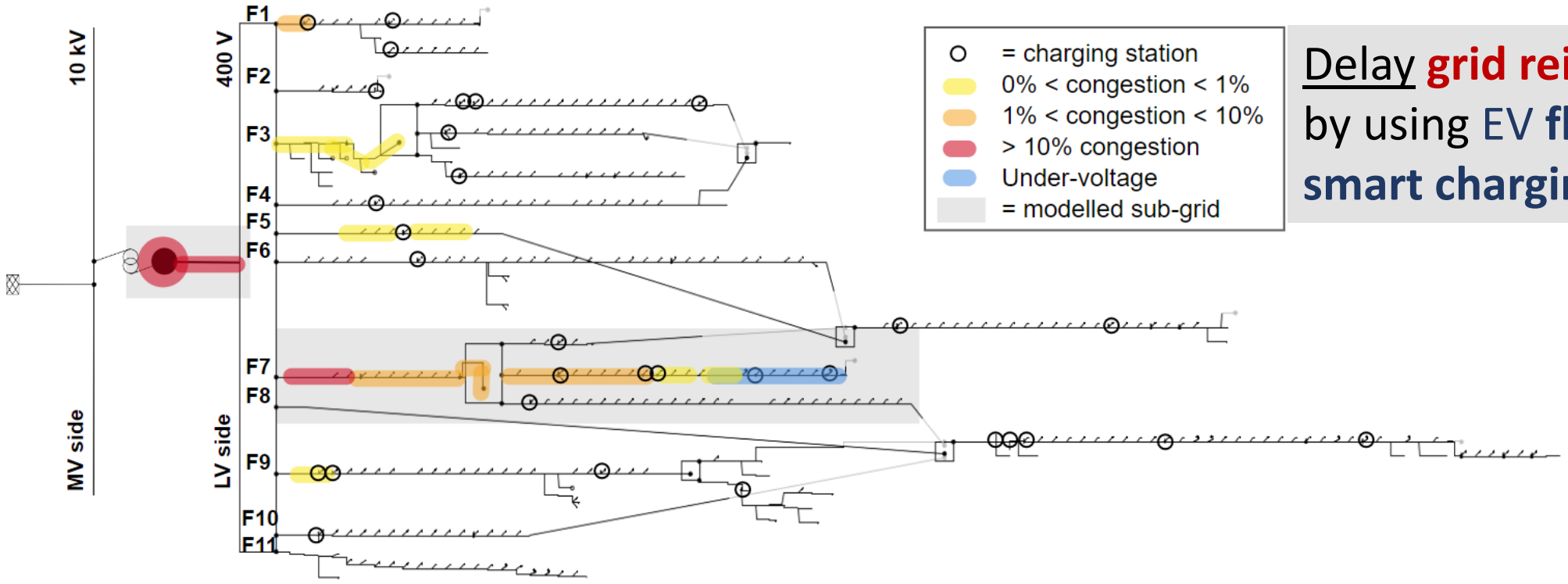
EVs – The Challenges

Degree of ***voltage*** *and* ***congestion problems*** *in a typical Dutch LV grid with* ***uncontrolled charging*** *towards 2050.*



Delay **grid reinforcement** by using EV **flexibility** and **smart charging**

SOURCE:
https://repository.tudelft.nl/islandora/object/uuid%3A8c2b5e78-836a-497e-805a-932b9231e313

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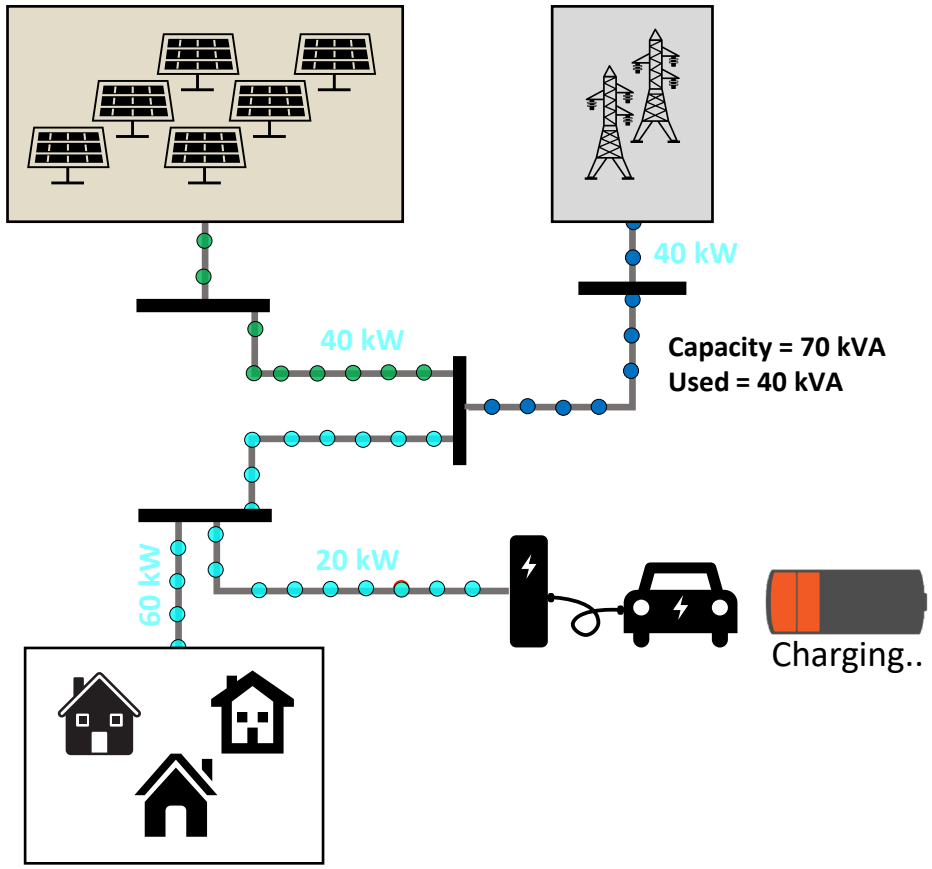
Congestion and Flexibility in Power Networks



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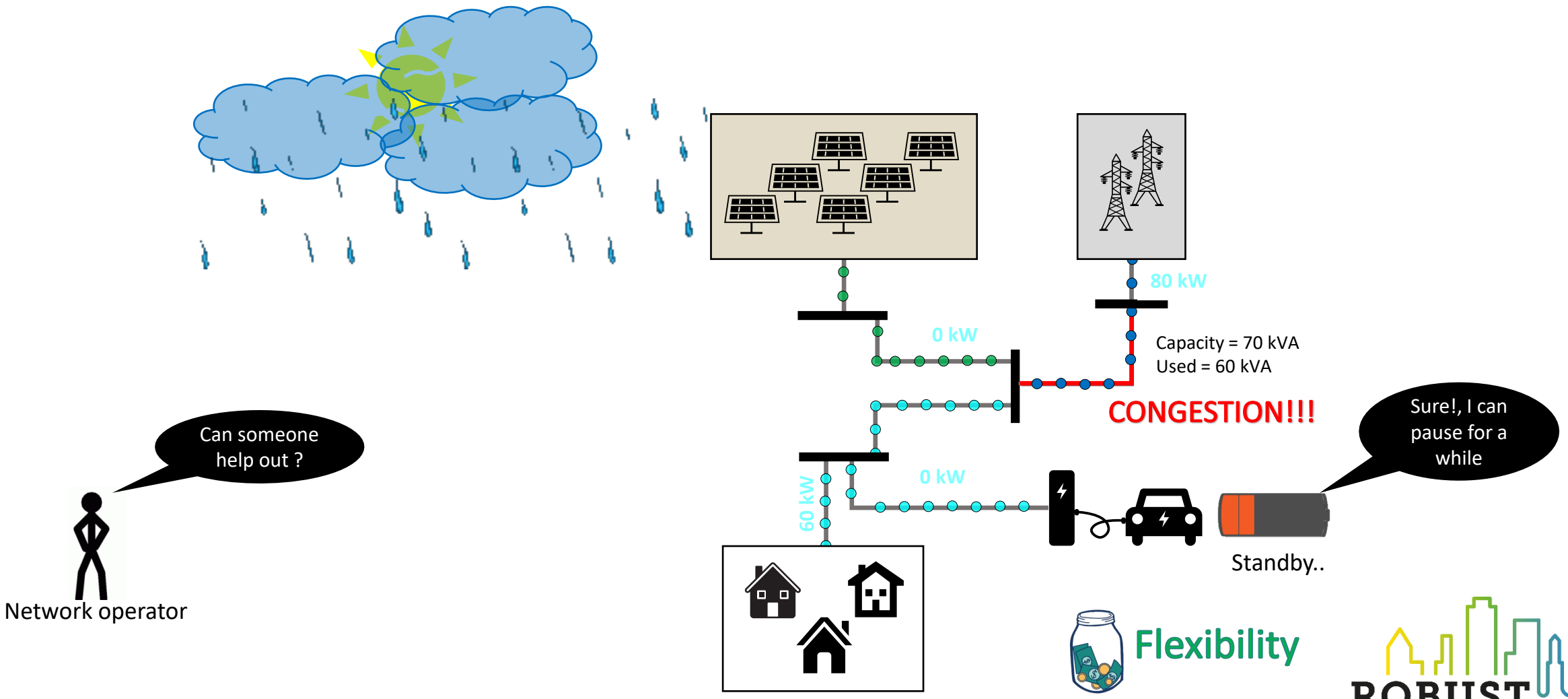
Congestion and Flexibility in Power Networks



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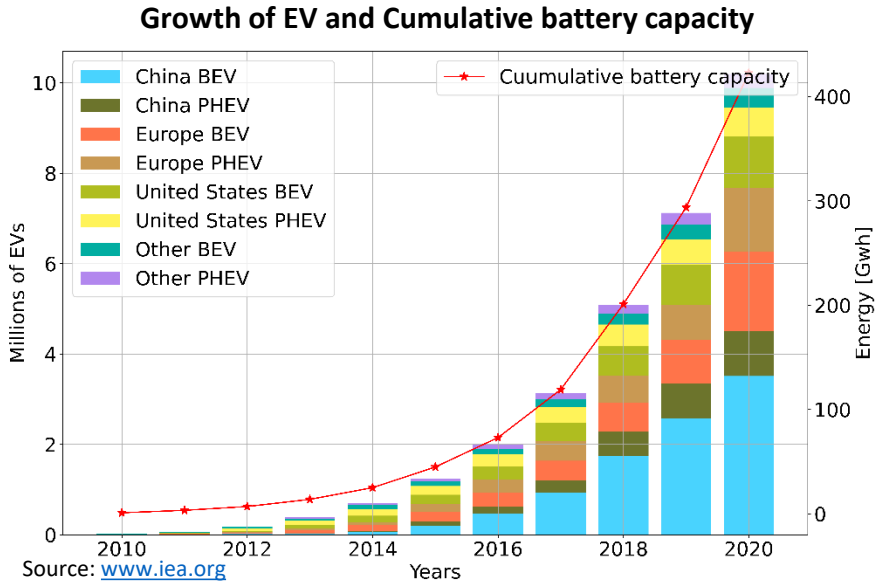
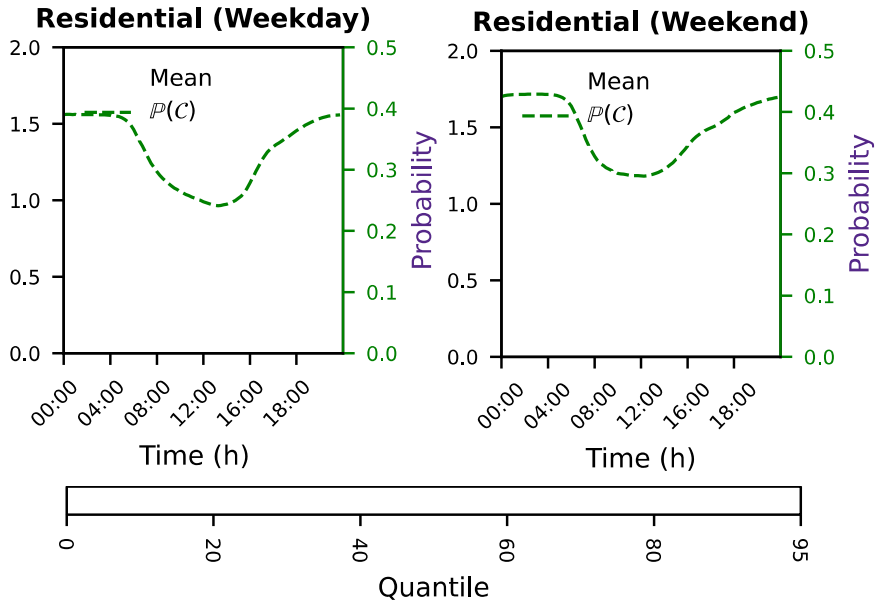
EVs – The Opportunities

- All EVs do not charge at the same time
- Time-to-charge is less than time-connected to chargers
- Huge **aggregate** battery capacity

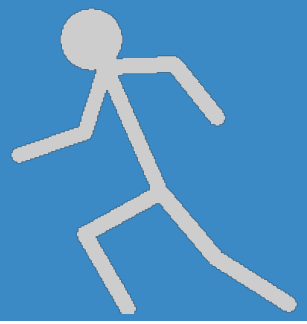
EV Battery flexibility
- Shifting charging
- Storing energy
- Bi-directional





2.

Flexibility in Practise



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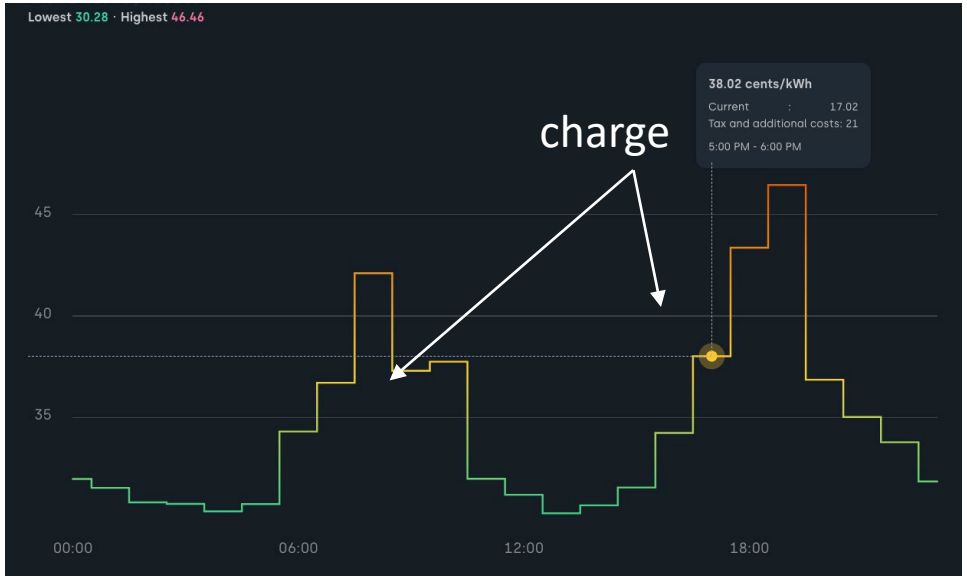
Using Flexibility

Implicit flexibility



Explicit flexibility

- EV fleets as active customers
- Charging point operators (CPO) as aggregators
- Distribution system operators (DSOs)

Source: https://www.usef.energy/app/uploads/2021/05/USEF-The-Framework-Explained-update-2021.pdf

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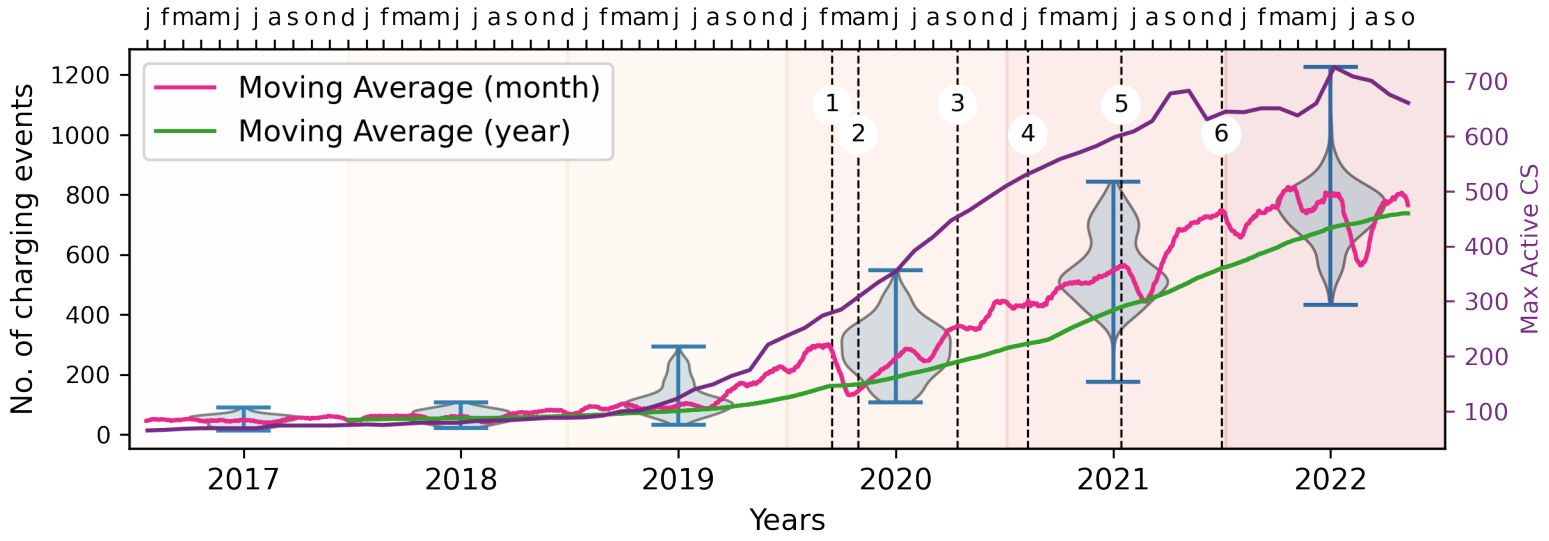
Flexibility from EV Fleets – A Dutch Case Study

- More than 0.5 Million real EV charging transactions
- More than 700 charging stations



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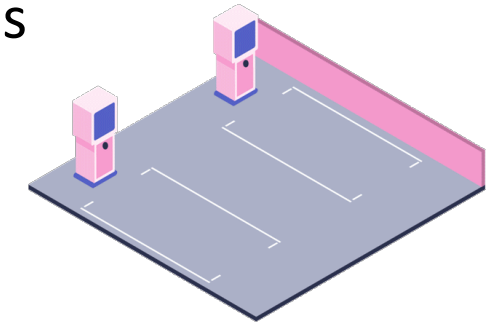
Flexibility from EV Fleets – A Dutch Case Study

- More than 0.5 Million real EV charging transactions
- More than 700 charging stations

- One of the largest cities with more than 500 bi-directional charging points

- Smart charging enabled charging stations



We investigate the potential of EV fleets in offering flexibility products for congestion management

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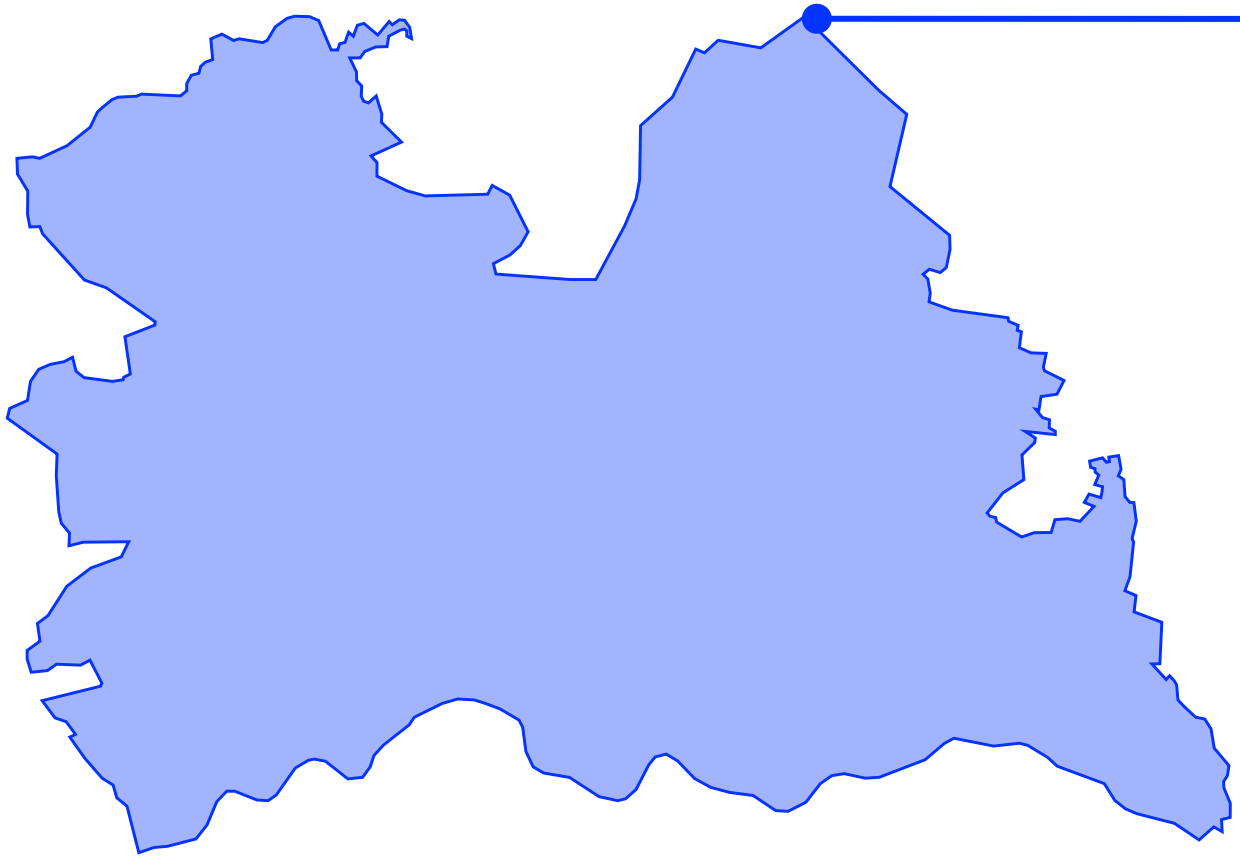
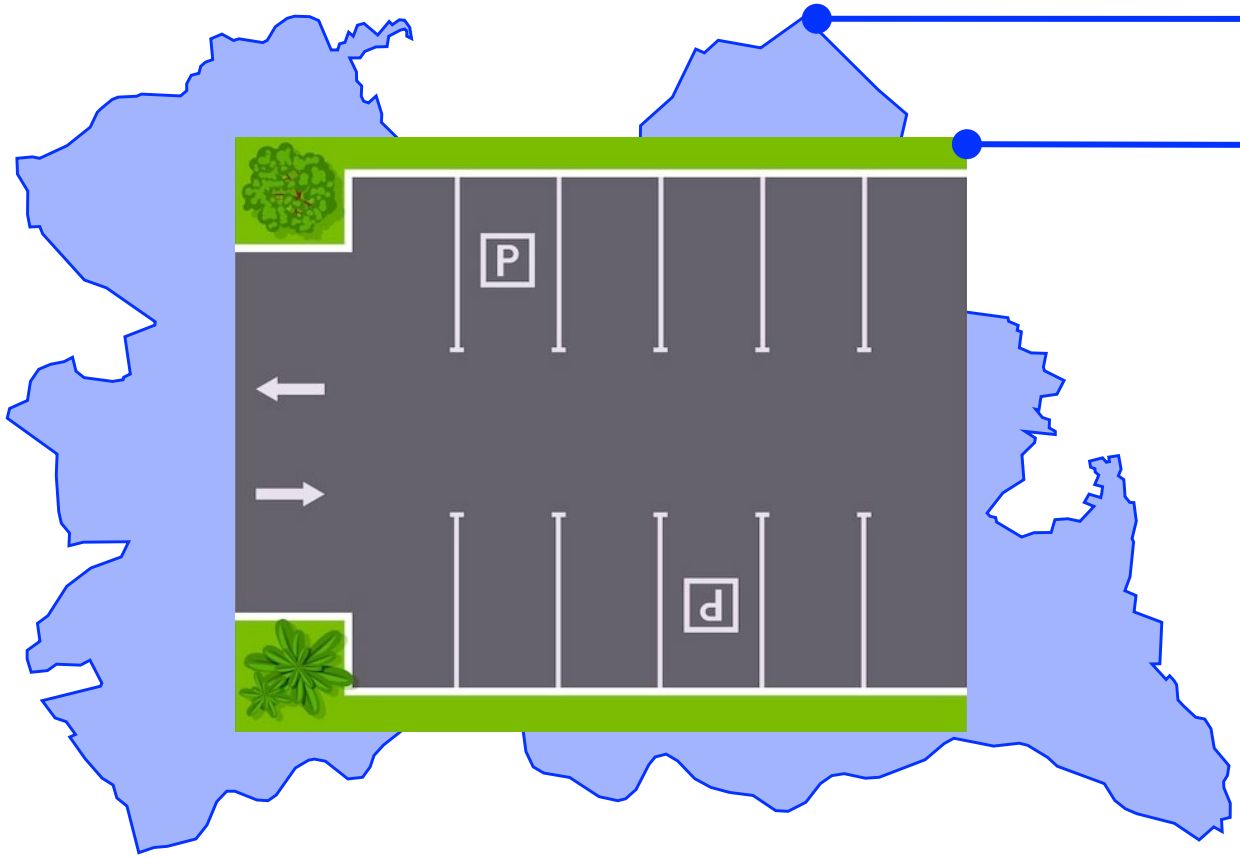
Charging Topology

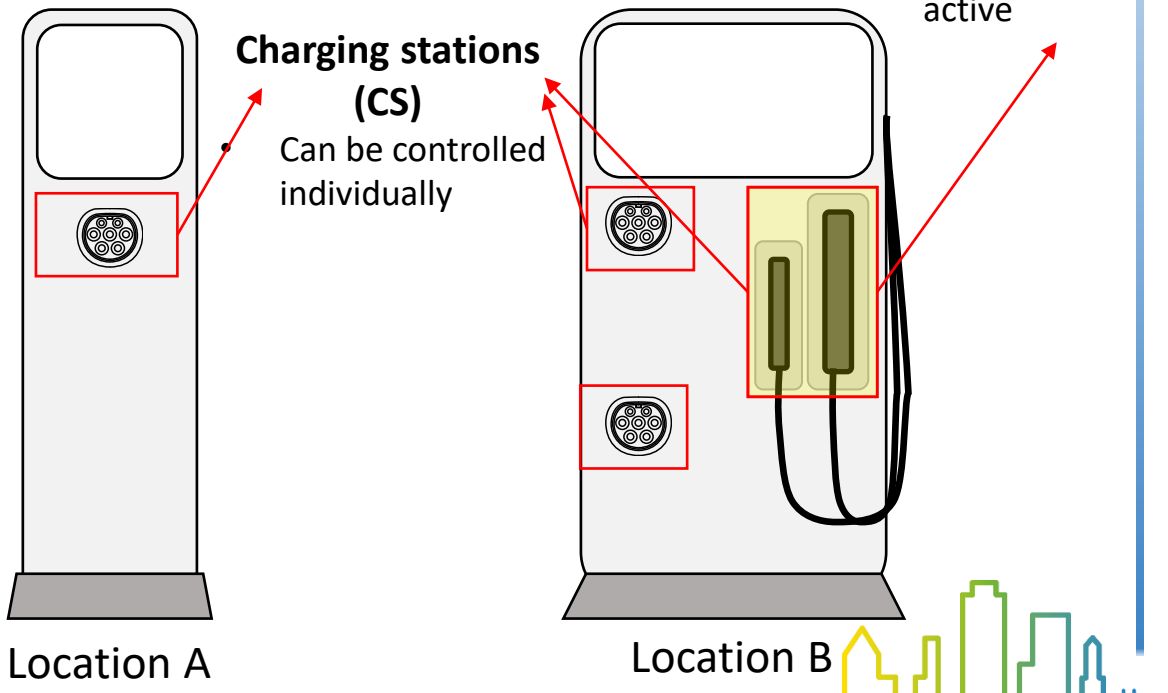
Country

Charging Topology



Charging Topology





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Categorising Charging Stations

Charging Stations (CS)

Based on usage

Mostly used by shared Evs (> 50 %)

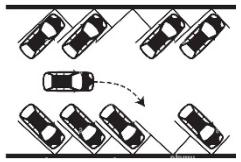
Shared

Mostly not used by shared EVs

Based on location of charging station

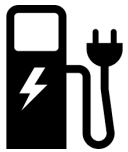
- •Public garages
- •Other public locations
- •Public parking lots

Commercial



- •On-street
- •Underground parking lots
- •Private garages
- •Private parking lots

Residential



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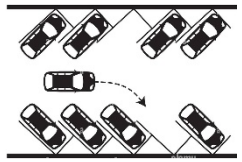
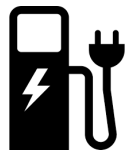
Charging Stations Usage Pattern

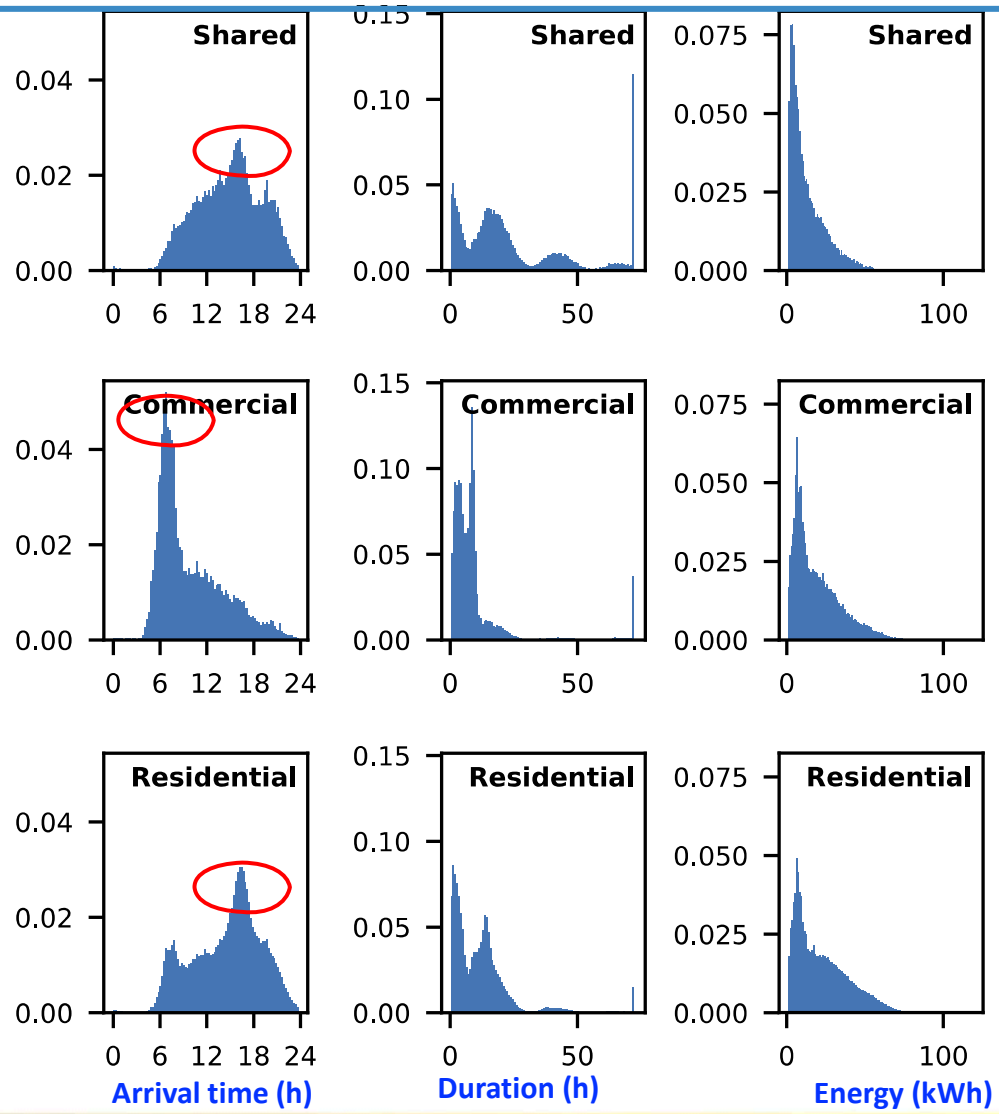
Shared



Commercial



Residential



- Different peak times
- Homogenous fleet for shared category
- Different patterns for weekday and weekends

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Charging Schemes (1)

Unoptimized charging (‘dumb’)

Charge with max power as soon the EV is connected

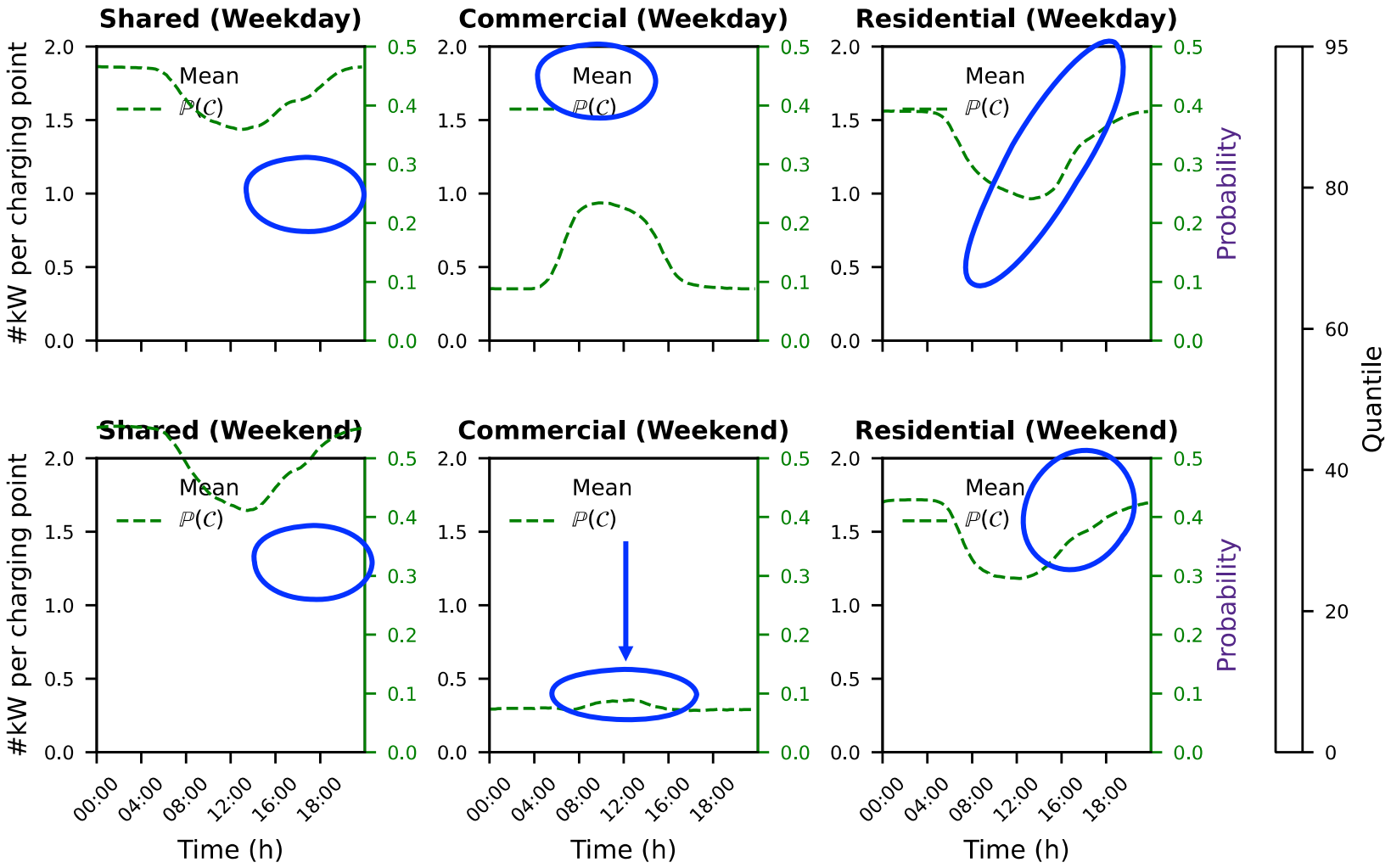
Charging Schemes (1)

Unoptimized charging ('dumb')

Charge with max power as soon the EV is connected

ROBUST

Unoptimised Charging



Significant loads peaks

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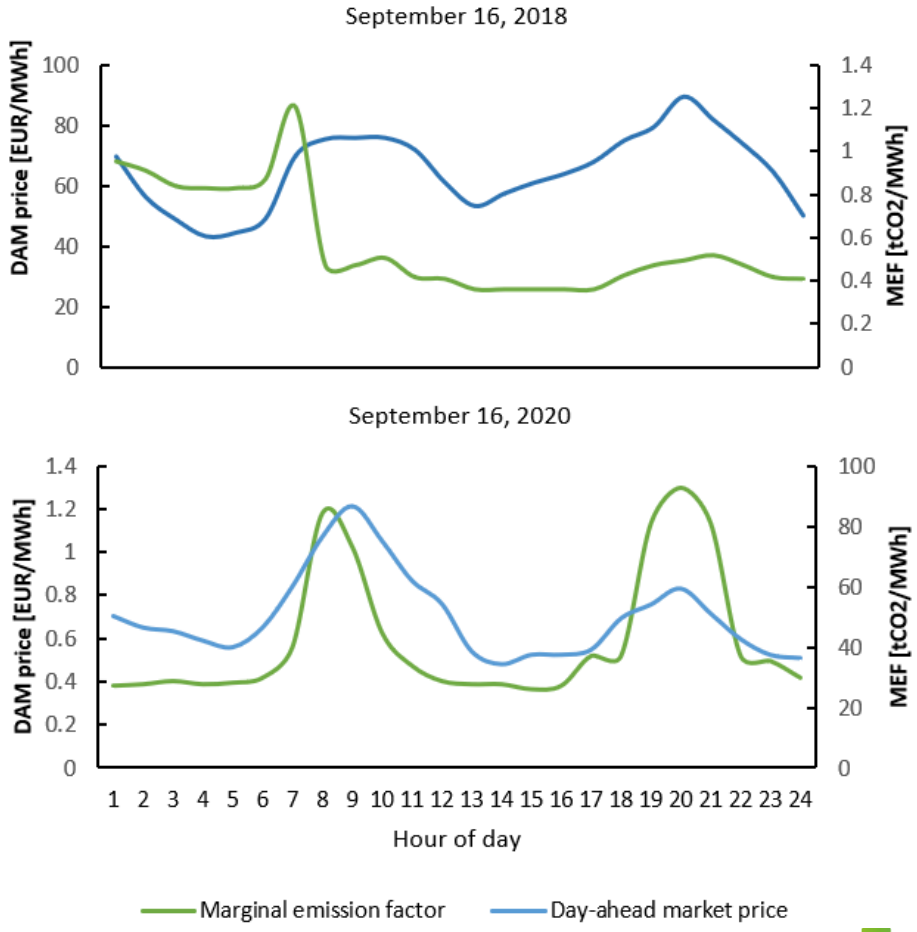
Charging Schemes (2)

Cost or Emission optimised charging

- Schedule charging according to day-ahead-prices (€/ kWh)
- Schedule charging according to marginal emission factor (MEF)



MEF: Amount of emission (kg CO_2/ kWh) that would come online if new load were added

Source:
Alikhani, P.; Brinkel, N.; Schram, W.; Lampropoulos, I. and van Sark, W. (2023). **Marginal Emission Factors in Power Systems: The Case of the Netherlands**. In *Proceedings of the 12th International Conference on Smart Cities and Green ICT Systems* DOI: 10.5220/0011855700003491

ROBUST

3.

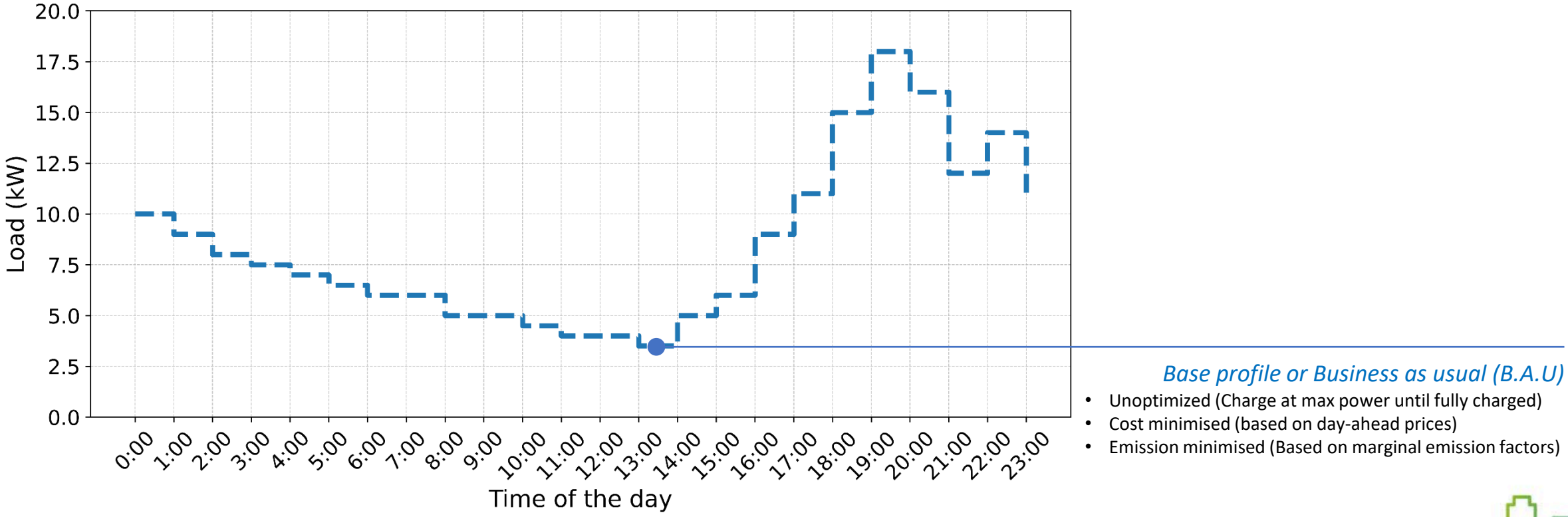
Flexibility Products for Congestion Management

ROBUST

Flexibility Products

Two flexibility products for congestion management

- New ‘ACM’ regulations 2022 on congestion managements
- Re-dispatch down
- Capacity limitation



Base profile or Business as usual (B.A.U)

- Unoptimized (Charge at max power until fully charged)
- Cost minimised (based on day-ahead prices)
- Emission minimised (Based on marginal emission factors)

ROBUST

Flexibility Products

Two flexibility products for congestion management

- New ‘ACM’ regulations 2022 on congestion managements
- Re-dispatch down
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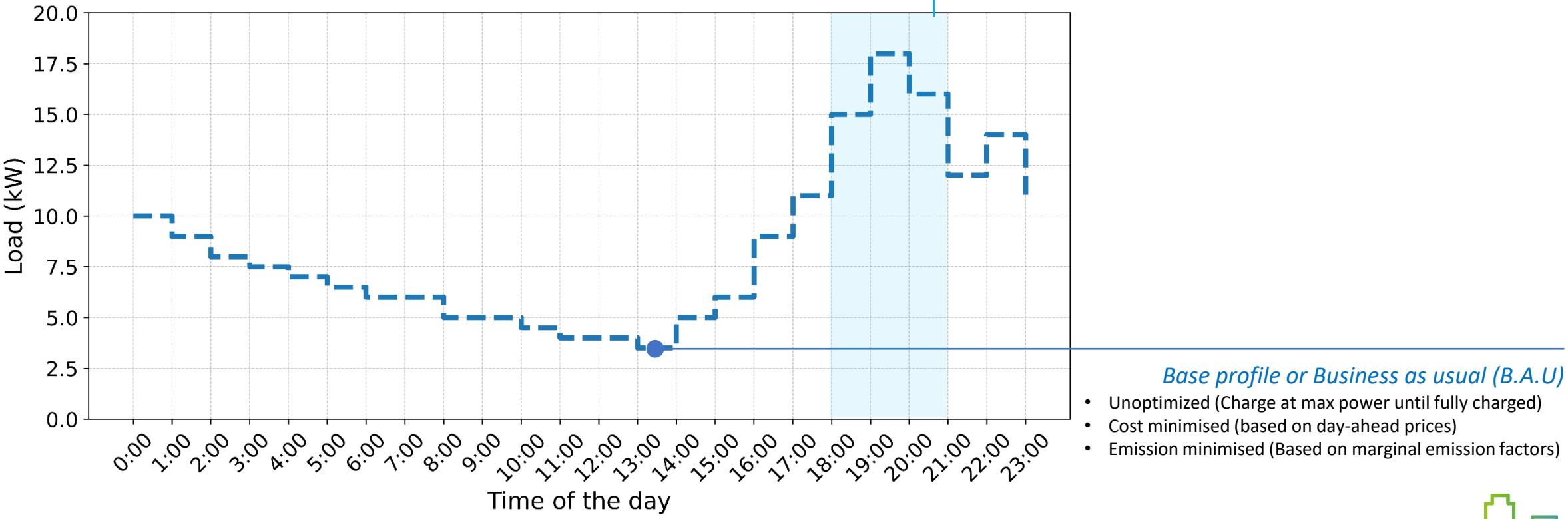
Flexibility request window

- Time-window where the flexibility product is requested
- For e.g., evening peaks (18:00-21:00)



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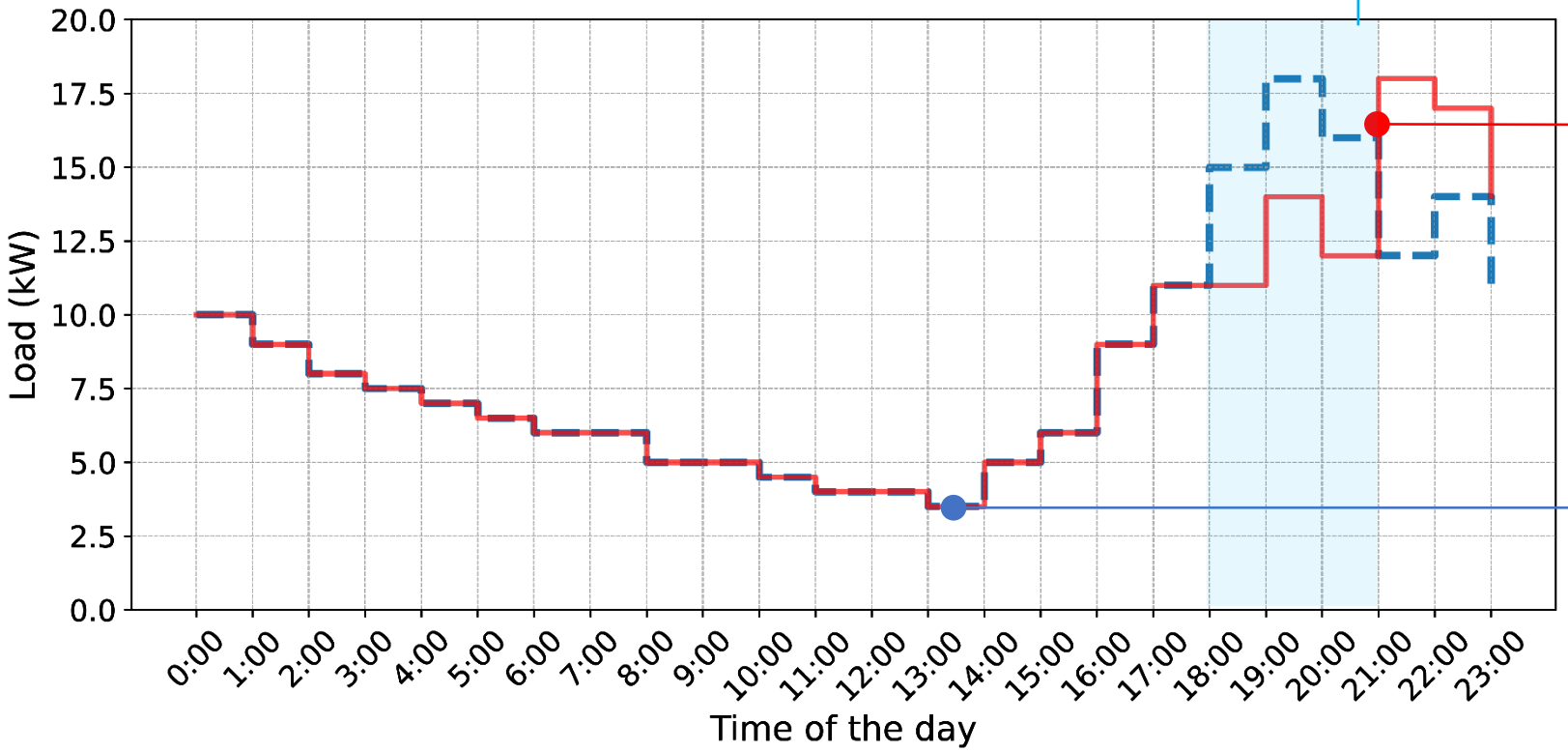

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Re-dispatch down

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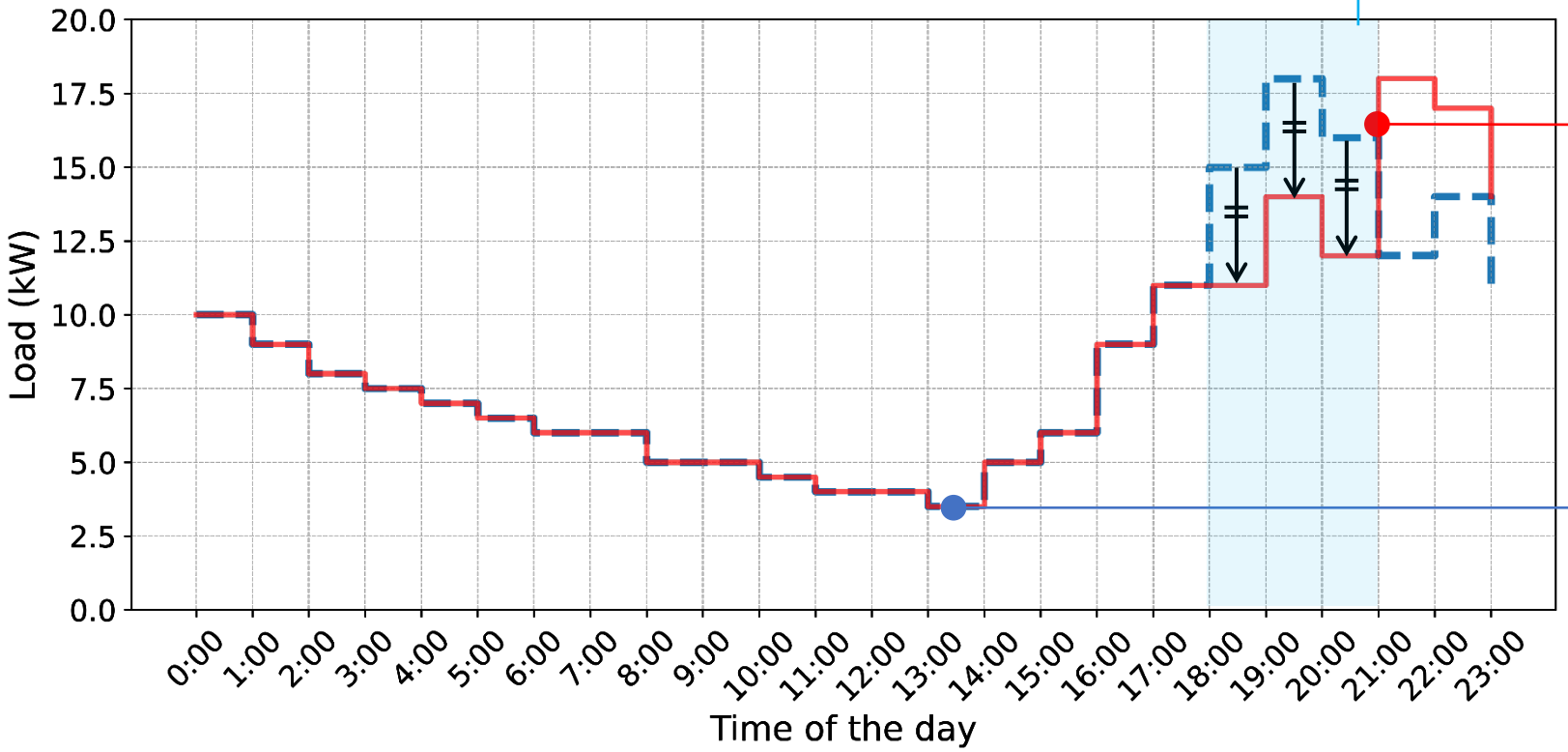

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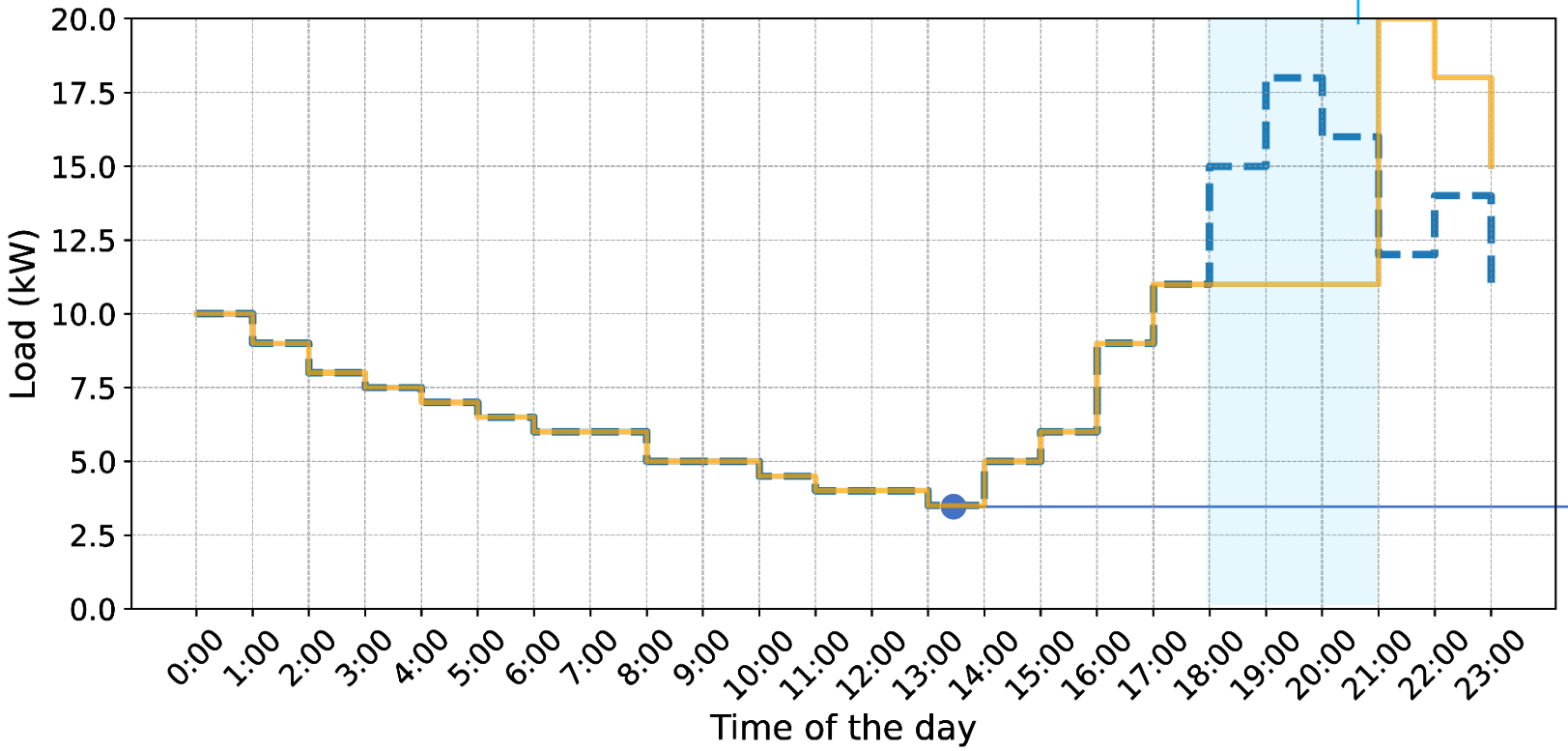
- Time-window where the flexibility product is requested
- For e.g., evening peaks (18:00-21:00)



Base profile or Business as usual (B.A.U)

- Unoptimized (Charge at max power until fully charged)
- Cost minimised (based on day-ahead prices)
- Emission minimised (Based on marginal emission factors)

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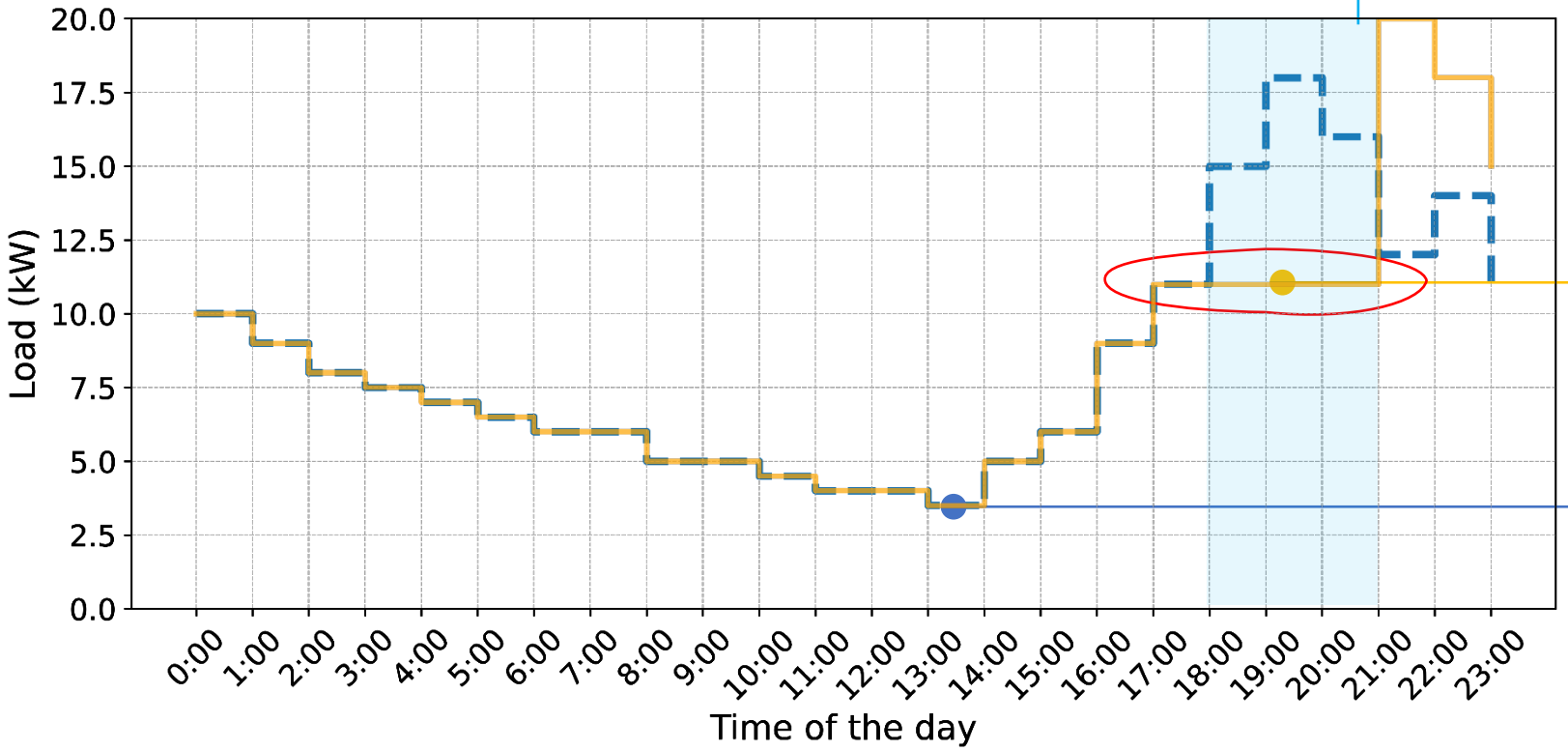
Flexibility Products

Two flexibility products for congestion management

- New ‘ACM’ regulations 2022 on congestion managements
- Re-dispatch down
- Capacity limitation



Flexibility request window

- Time-window where the flexibility product is requested
- For e.g., evening peaks (18:00-21:00)

Capacity limitation

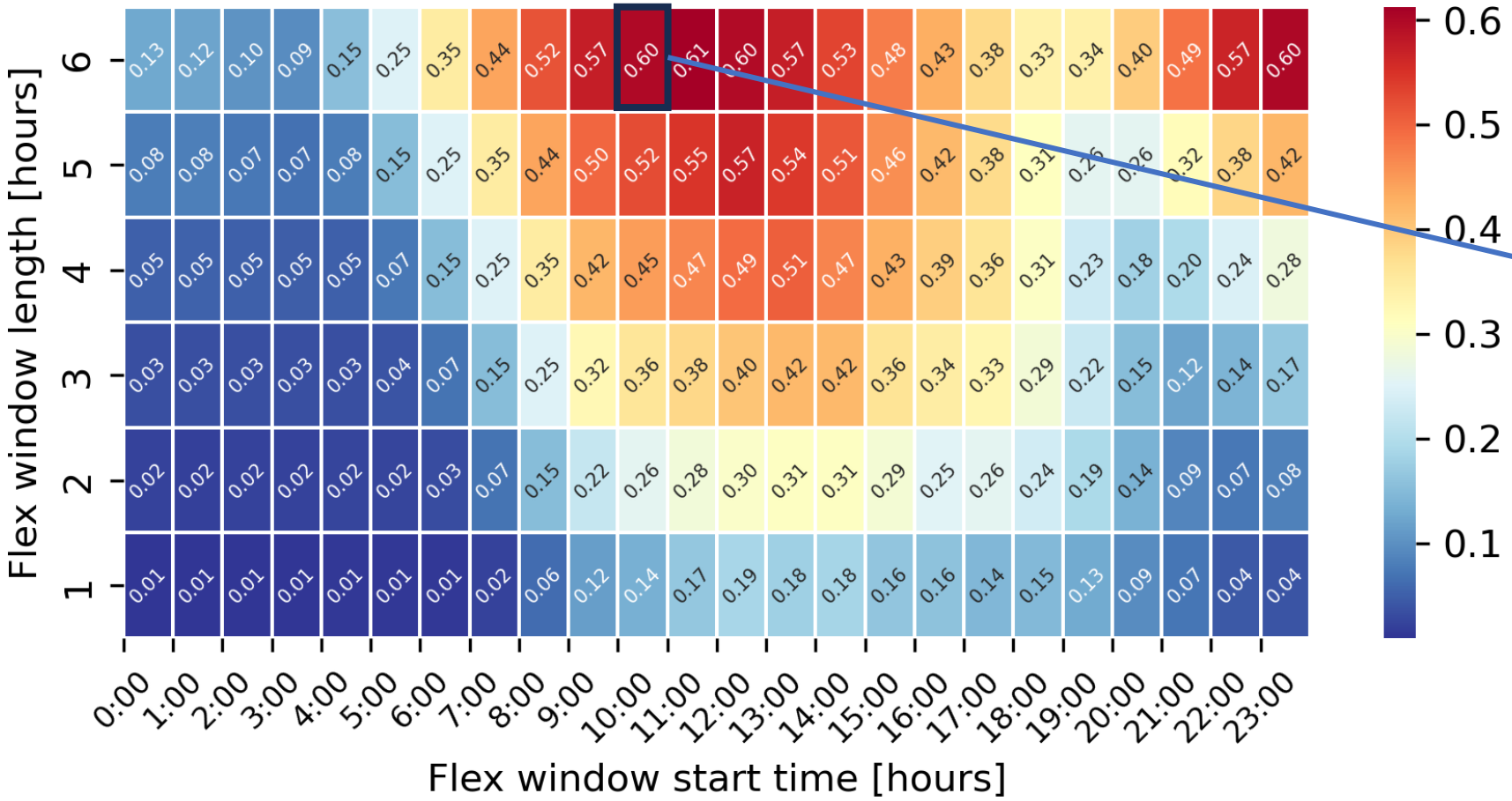
- Minimize consumption for all time-steps in the window

Base profile or Business as usual (B.A.U)

- Unoptimized (Charge at max power until fully charged)
- Cost minimised (based on day-ahead prices)
- Emission minimised (Based on marginal emission factors)

ROBUST

Operating Thresholds

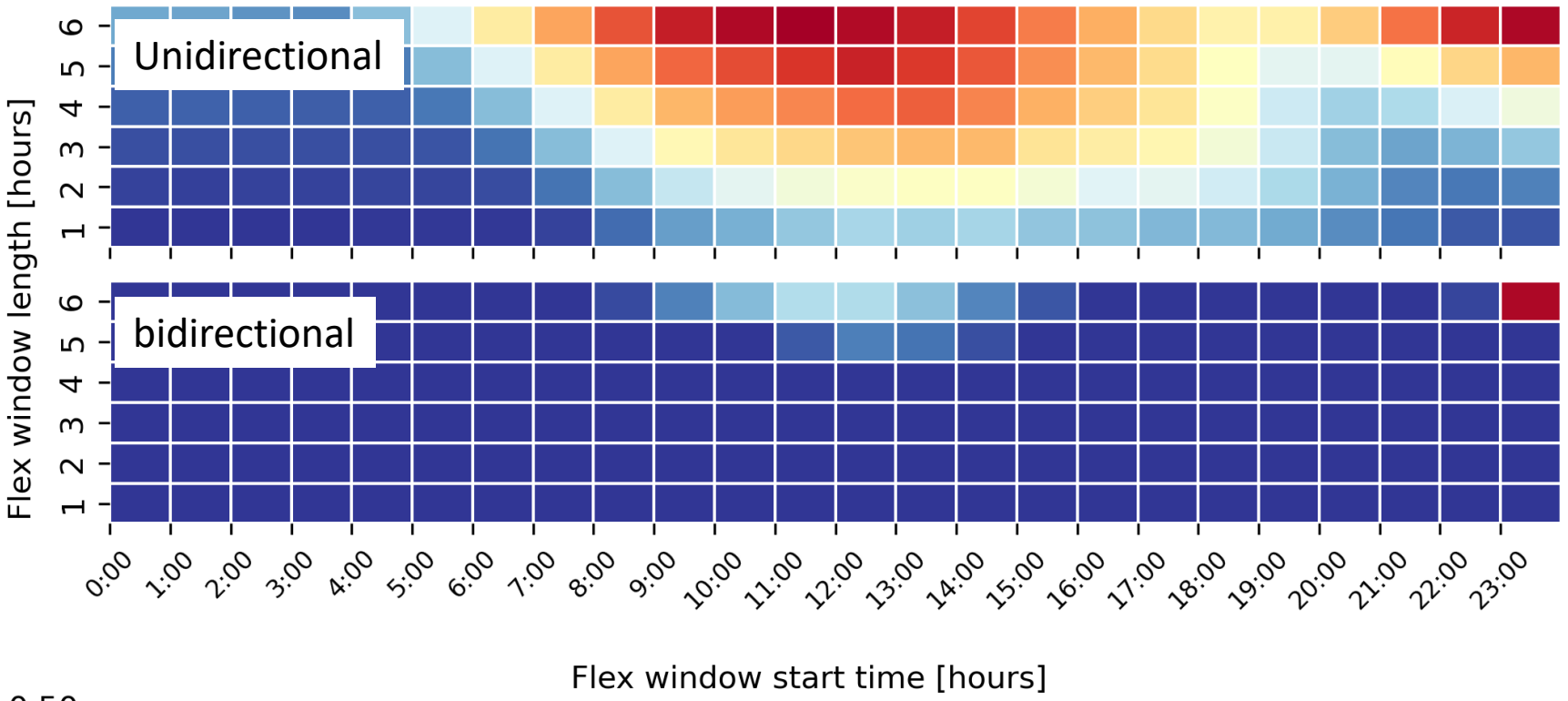


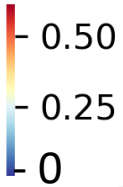
Product - Capacity limitation
CS type: Residential
Charging: Unidirectional

10:00 am – 16:00
As per historical data the average load is 0.60 kW per charging station

ROBUST

Operating Thresholds





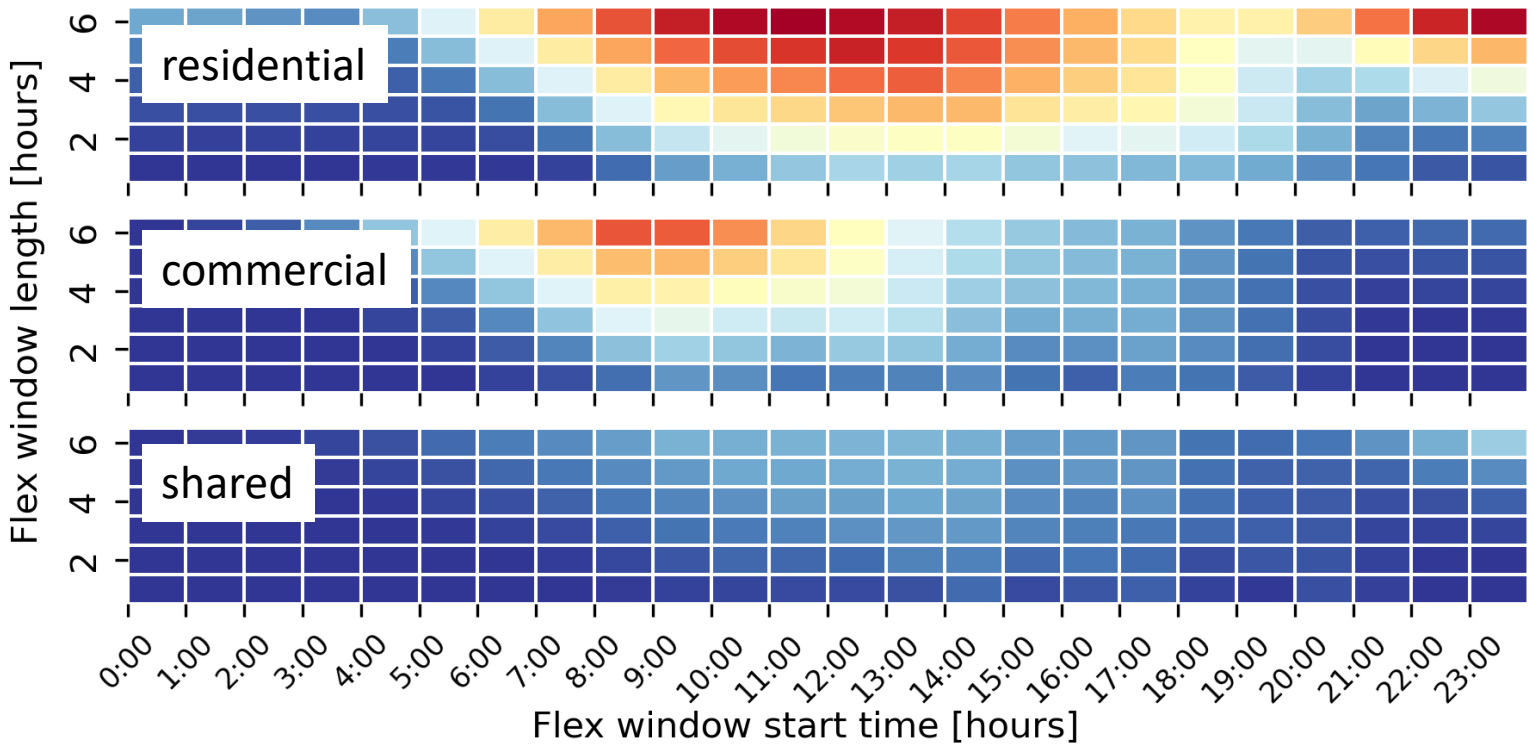
Load (kW) per charging station

Product - Capacity limitation
CS type: Residential
Charging: Unidirectional

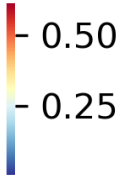
'bidirectional' charging can almost limit the load consumption to 0 kW per charging station

ROBUST

Operating Thresholds



More residential charging stations



Load (kW) per charging station

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4.

Takeaways

Conclusion

The integration of EV charging infrastructure in the power networks is a challenge, but also an **opportunity (Flexibility)**

Different categories of Evs have **different usage pattern**, that can deliver flexibility during different time windows

Bidirectional (V2G) EV charging outweighs the unidirectional charging in offering various flexibility products

The technical feasibility can full realised only with **proper regulations and policies**

Based on historical data, EV fleets can effectively deliver **flexibility products** for **congestion management**

For advanced charging methods such as V2G, **users can largely affect its realisation and positive impact**

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The role of legal research in transdisciplinary projects regarding the energy transition: harnessing flexibility for congestion management

Prof. Anoeska Buijze

ROBUST

1.

The importance of interdisciplinary research in solving net congestion

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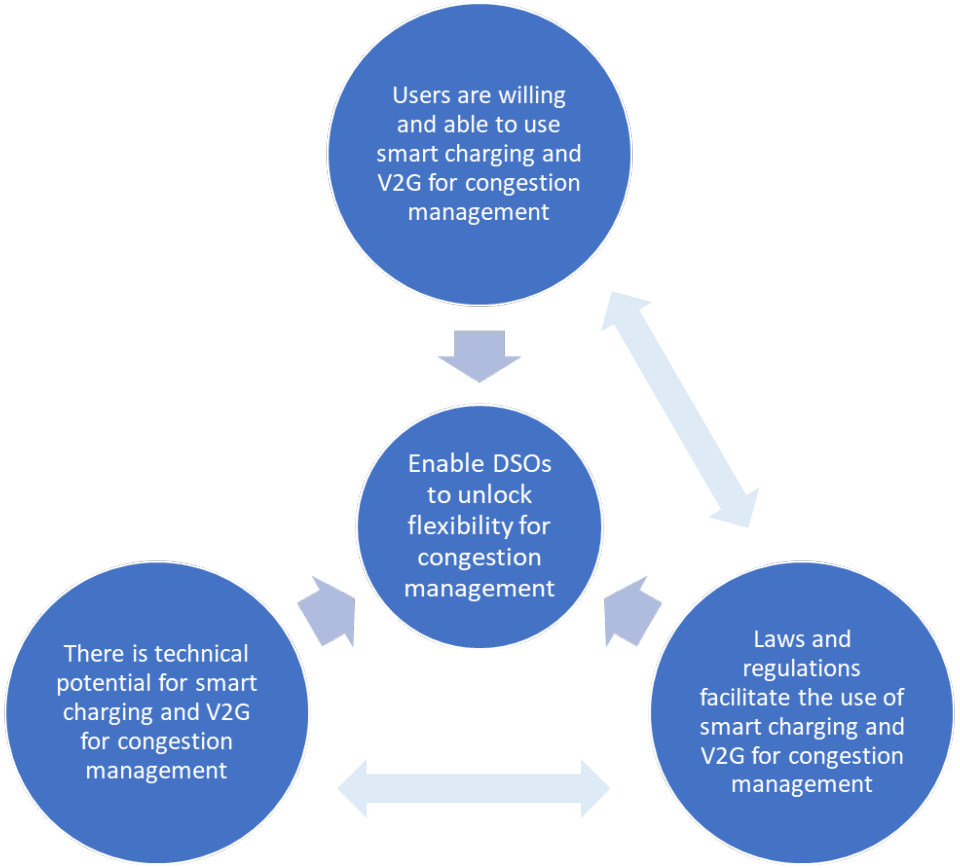
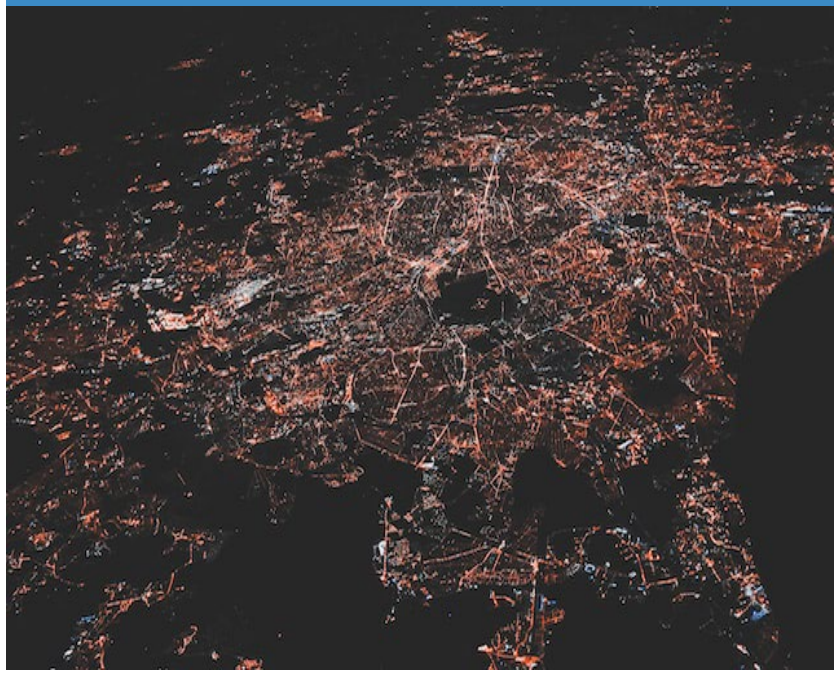
The importance of interdisciplinary research in solving net congestion



Laws and regulations can be changed to unlock flexibility potential that is actually there

ROBUST

2.



Congestion as a result of unfit legislation?

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Congestion as a result of unfit legislation?

Article 16 paragraph 1 Electricity Act: responsibility for the electricity network is attributed to the System Operators

Rules limiting investment in the electricity network (art. 21 section 10, para. D (necessity of investments must be shown, unnecessary investments will not be approved))

Prior to 2022 the Netcode did not facility congestion management by DSOs

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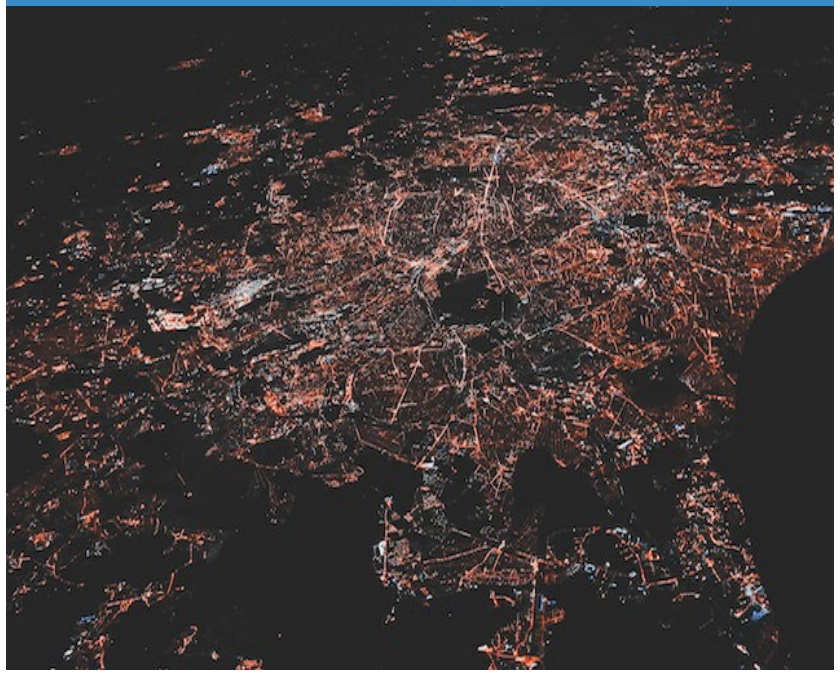
3.



Changing the law to facilitate congestion management

ROBUST

Changing the law to facilitate congestion management

2022 changes to the Netcode

Re-dispatch: deviation from the daily balance schedule upon the request of the DSO.

- Bids must be submitted by a CSP
- Minimum threshold: 100 kW
- For group bids, all connections must have the same BRP

Capacity limitation: contract between the DSO and one or more connections to lower their supply or demand in case of expected congestion

- The contract must at least specify the maximum usable transport capacity; the period during which supply or demand will be lowered; the price in euro/MW; the location and EAN code of the connection; the contract period.
- CSP optional
- No threshold, but large-scale use of small contracts is seen as impractical
- For group contracts, all connections must have the same BRP

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Daily balance schedule

A schedule which consists of:

- Expected physical injections and offtakes from the grid;
- Commercial power trades, i.e. purchases and sales, with other BRPs and/or related imports and exports on the borders;
- Which is submitted a day in advance to the TSO.

Changing the law to facilitate congestion management

2022 changes to the Netcode

Re-dispatch: deviation from the daily balance schedule upon the request of the DSO.

- Bids must be submitted by a CSP, who is responsible for communication with the DSO as well as the execution of the bid
- Minimum threshold: 100 kW
- For group bids, all connections must have the same BRP

Capacity limitation: contract between the DSO and one or more connections to lower their supply or demand in case of expected congestion

- The contract must at least specify the maximum usable transport capacity; the period during which supply or demand will be lowered; the price in euro/MW; the location and EAN code of the connection; the contract period.
- CSP optional
- No threshold, but large-scale use of small contracts is seen as impractical
- For group contracts, all connections must have the same BRP

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Changing the law to facilitate congestion management

- New provisions not working as expected
- Large users are unwilling to voluntarily provide flexibility
- Unlocking the flexibility behind small connections (charging points) is only possible if they have the same BRP
- Unlocking the flexibility behind small connections is technically difficult

BRP: responsible to help maintain the equilibrium between supply and demand on the energy grid. Each connection has a BRP. For small connections, the BRP is either the energy supplier or the energy supplier's BRP. Consumers cannot choose their BRP.

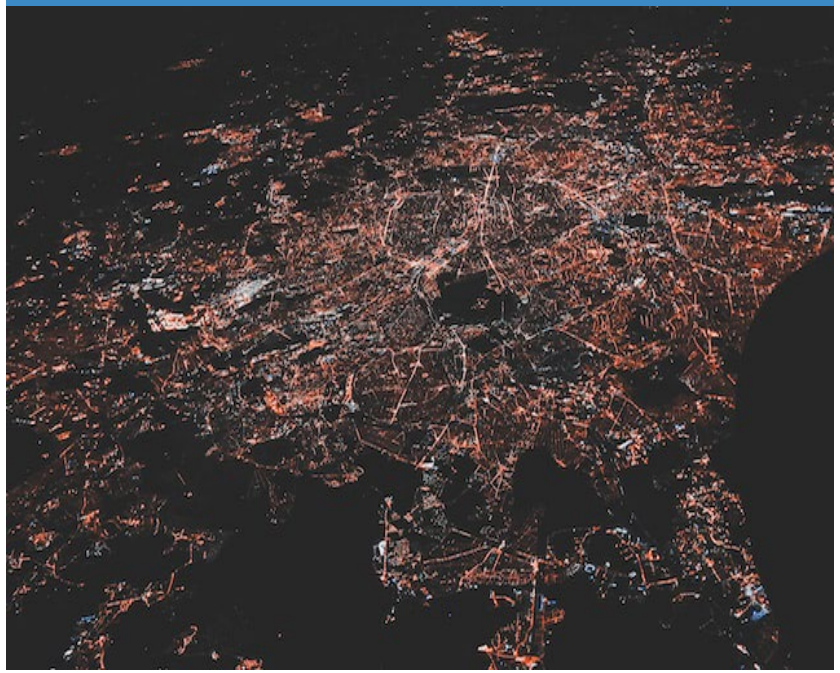
ROBUST

Changing the law to facilitate congestion management

- No formal limitation to aggregate small connections for capacity limitation, other than the BRP condition, but in practice the potential of small connections is not used
- In part, this is due to technical and administrative limitations
- Standard contracts might help
- Technical limitations are addressed in other parts of the project
- The potential flexibility of home charging points is difficult/impossible to use for congestion management
- For redispatch, a minimum capacity of 100 kW is needed. This impacts how individual charging points are grouped as well as the total amount of flexibility that can be used

ROBUST

4.



Future changes, as planned and as needed

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Future changes, as planned and as needed

- Proposal to change provisions on congestion management in the Netcode (Zaaknr. ACM/23/184221 / Documentnr. ACM/UIT/599029, September 2023)
  - No obligation for DSO's to make use of distributed flexibility;
  - For small connections, the condition that they have the same BRP does not change
- Netbewust laden (Network-conscious charging)
  - Agreement between DSOs and (amongst others) CPOs to limit total charging capacity of a CPO's charging points in case of local congestion
  - Compulsory under new Energy Act?
  - Consequences for congestion management?

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- Photo credits:

'Lighted city at night' by Nastya Dulhiier on Unsplash

Willingness to participate in vehicle-to-grid program: An exploration of battery electric vehicle users with various driving needs and charging preferences

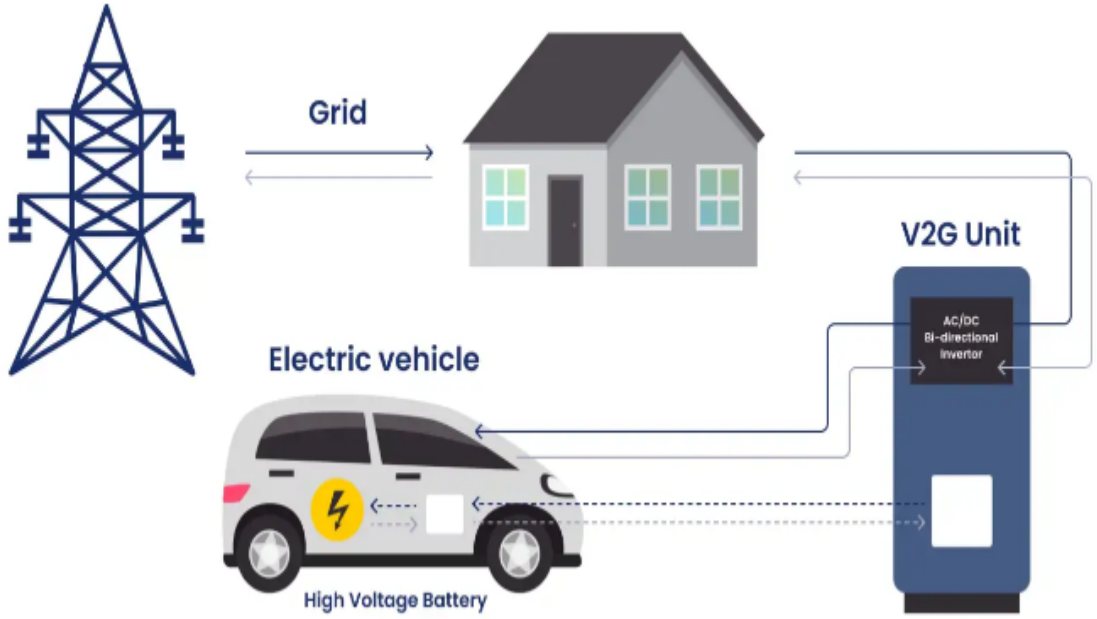
Yang Hu

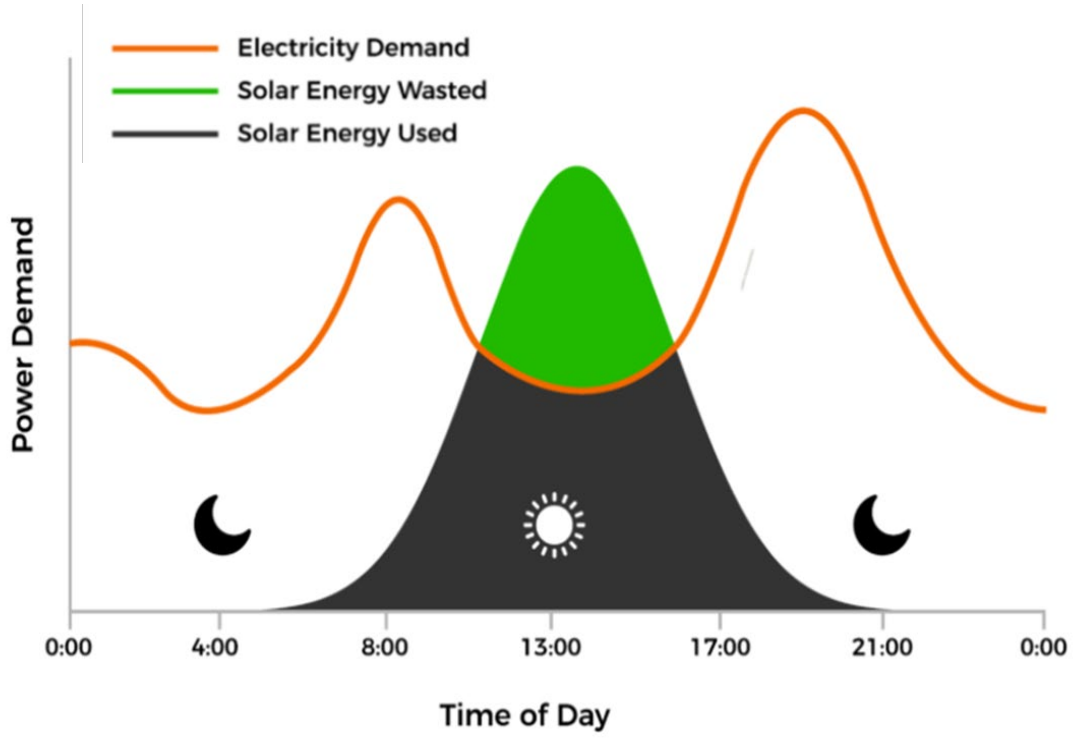
ROBUST

Introduction

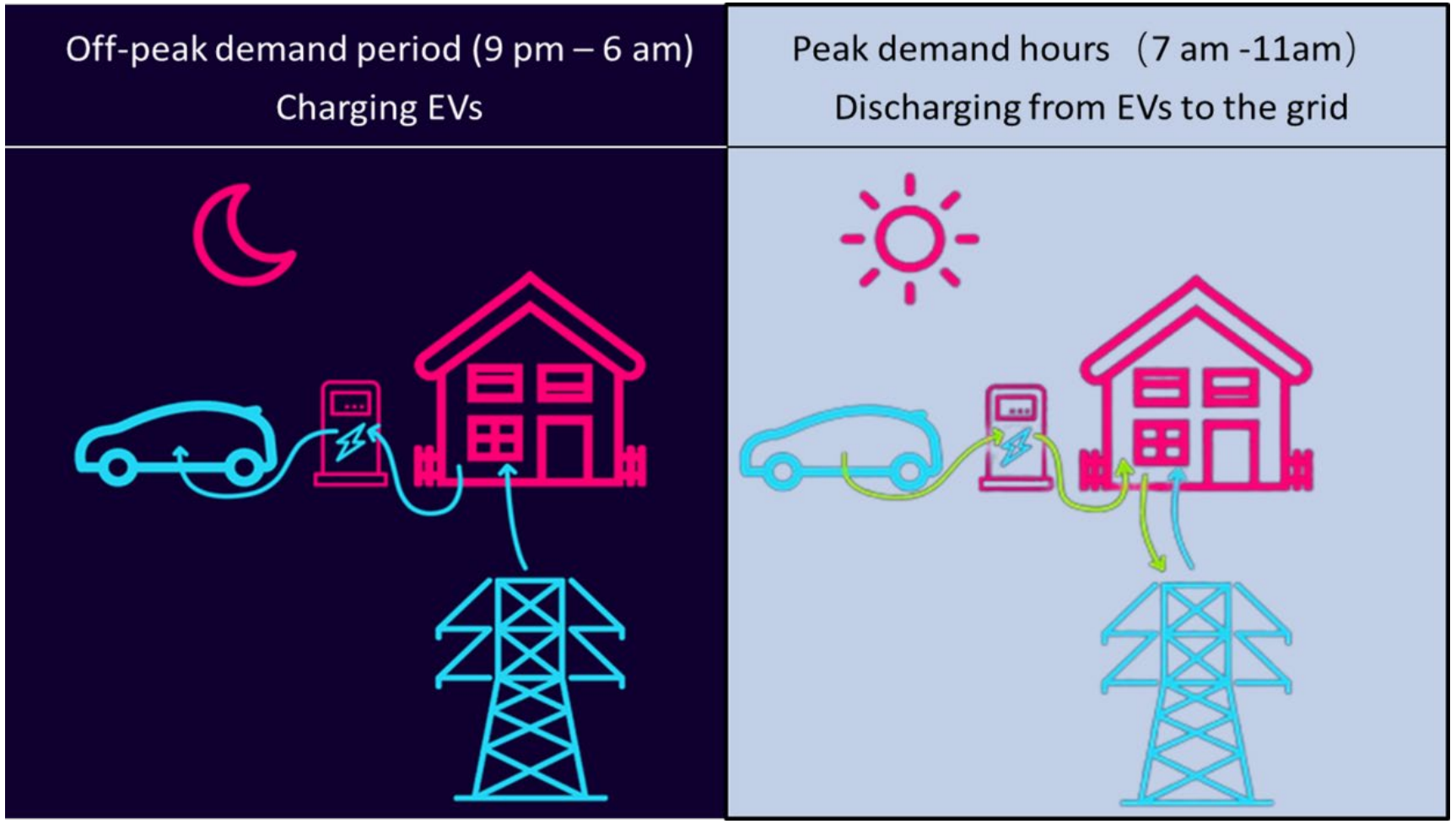
Electric vehicles (EVs): reduce reliance on fossil fuel consumption; increase burden within peak demand hours

Vehicle-to-grid (V2G) : integration of grid and EVs; optimize its energy distribution, reduce transmission congestions, and enhance its running efficiency





Introduction



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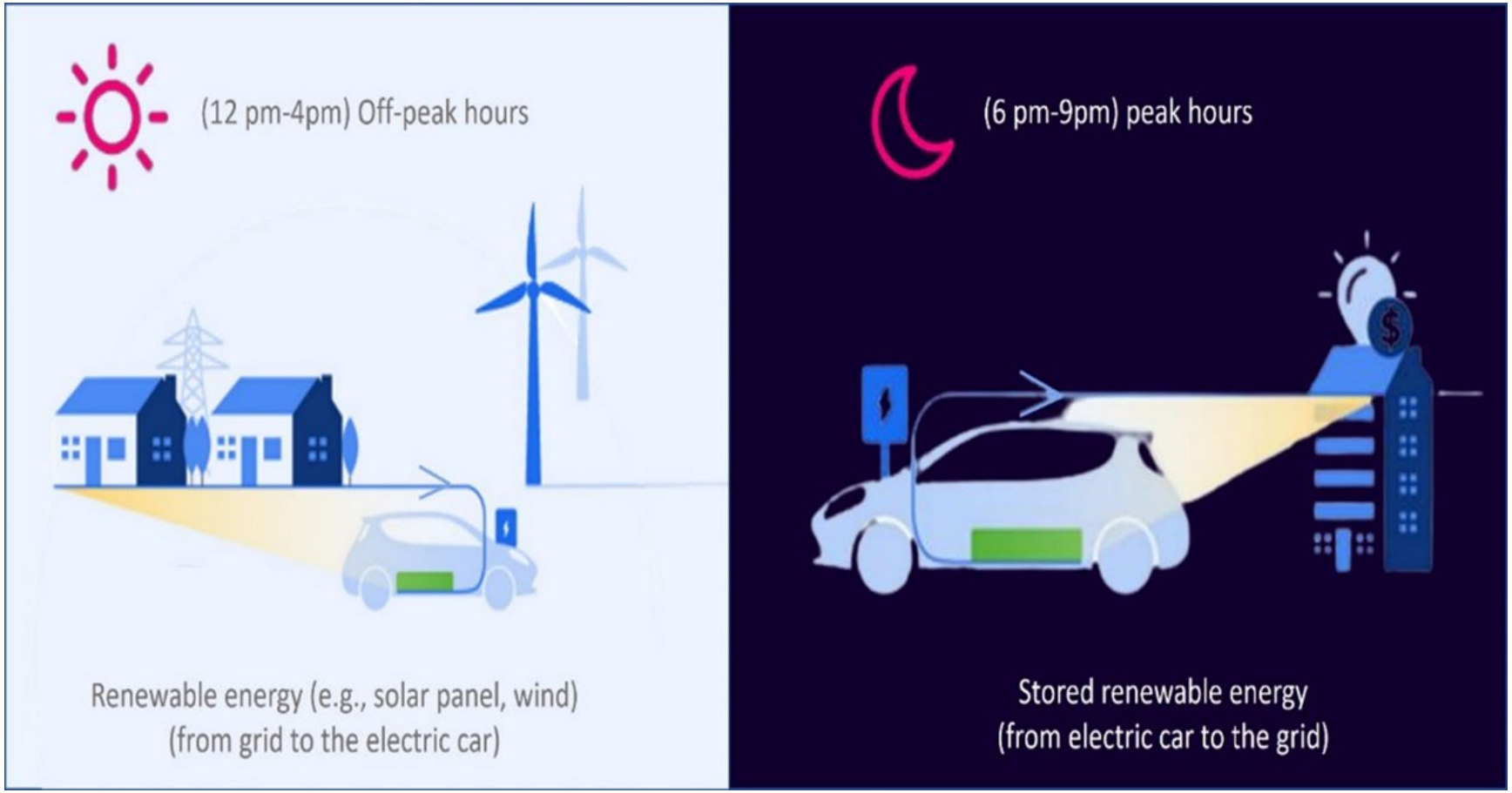
Introduction



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Introduction

While V2G use is a technical problem, EV users' particpation intention impacts the extent to which battery of EVs can be intergrated into grid system.

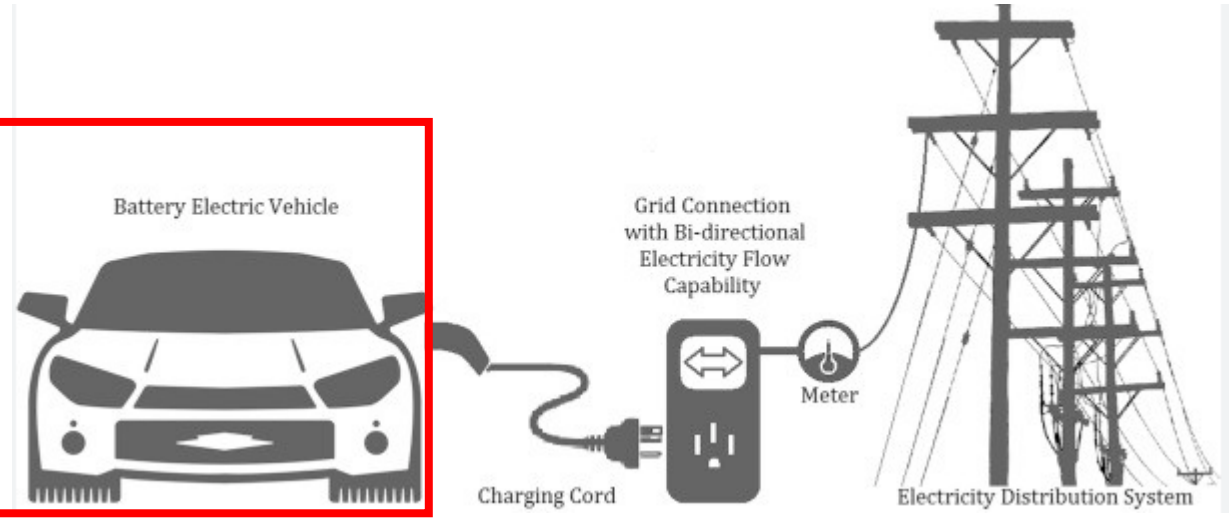
Ownership status
(leased vs. private EV)

Mobility patterns

Charging preferences

Acceptable minimum S.O.C

Use intention



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Research questions:

1) What are the concerns of EV users regarding battery life risk, financial rewards, technology trust, and EV use flexibility when V2G services are put into practice, and how do these concerns differ between private EV owners and leased EV users?

2) To what extent do the socio-demographics attributes, EV use patterns, acceptable minimums state of charge, and V2G concerns impact the V2G use intention ?

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Methodology

Data collection (Battery EV users)

Customer survey company
Flyer-distribution by ourselves

- Amsterdam
- Rotterdam
- Den Hague
- Utrecht
- Eindhoven
- Arnhem

- **673 respondents completed the survey**
  - 245 from the survey company
  - 428 were via flyers
- **616 respondents for further analysis**

Methodology

Data collection

- Socio-demographic
- V2G contract choice experiment
- V2G use intention
- V2G use concerns (5 point Likert scale)
- Charging behavior (location and frequency)
- EV use and charging preference (5 point Likert scale)
- Rang anxiety
- Information about EVs

616 Battery EV users

- 338 leased EV users
- 278 private EV users

	Definition	Leased EV users (%)	Private EV users (%)	Total (%)
Gender				
Female	The respondent is female.	23.4	35.9	29.1
Male	The respondent is male.	76.6	64.1	70.9
Age				
18 - 35	The age of respondents is between 18 and 35.	29.5	20.2	25.3
36 - 50	The age of respondents is between 36 and 50.	43.6	34.5	39.5
51 - 65	The age of respondents is between 51 and 65.	24.9	31.4	27.8
> 65	The age of the respondent is > 65.	2.0	13.9	7.4
Education degree				
Low	Education degree is between	8.1	24.7	15.6
Middle	Education degree is Hugo school or bachelor degree.	34.1	33.1	33.7
High	Education degree is the master degree or above.	56.7	41.1	49.6
Prefer not to say	Individuals do not mention their education degree.	1.2	1.1	1.1
Annual income				
Low	Individual annual income is ≤ € 75000.	19.7	34.5	26.4
Middle	Individual annual income is € 75 001 ~ 150000.	48.6	38.3	43.9
High	Individual annual income is ≥ € 150001	19.1	10.5	15.2
Prefer not to say	Individuals do not mention their income.	12.7	16.7	14.5
Household structure				
Cohabiting with children	The respondent is cohabiting with partners and also has children.	53.5	51.2	52.5
Cohabiting without children	The respondent is cohabiting with partners but does not have a child.	32.4	38.3	35.1
Single with children	The respondent is single and lives with children.	2.9	1.4	2.2
Single without children	The respondent is single and does not have a child.	11.0	8.4	9.8
Others	Other types.	0.3	0.7	0.5

V2G concerns (5-point Likert scale)

	Leased EV users	Private EV users	
	Mean(S.D.)	Mean(S.D.)	
I would be afraid that the battery life would be shortened by the frequent charging and discharging.	3.51(0.98)	3.64(0.98)	*
I would fear the battery is not sufficiently charged when I want to start a trip.	3.75(1.09)	3.54(1.03)	*
I would feel restricted in my freedom and independence.	3.22(1.08)	3.28(0.99)	
I am afraid that V2G is very complex to operate via an app in my smartphone.	2.03(1.02)	2.31(1.10)	*
I think some energy will be wasted and lost in the V2G bidirectional charging process.	2.83(1.08)	3.12(1.03)	*
I think V2G bidirectional charging can reduce CO2 emissions and is beneficial for the environment.	4.05(0.93)	3.90(0.89)	*
I am very optimistic about the future of V2G technology practice.	3.71(0.90)	3.61(0.87)	
The potential damage to the battery(due to the frequent charging and discharging) is a significant obstacle to the promotion of V2G adoption	3.42(1.04)	3.62(0.93)	*
I think that the amount of financial benefit is the key factor influencing my participation in V2G services.	3.84(0.98)	3.63(0.94)	*
I think that more remaining battery capacity (kilometers) is more important than subsidy benefits.	3.84(0.98)	3.63(0.94)	*
The potential risks and damage to the battery during the V2G process outweigh the earnings.	3.15(0.96)	3.34(0.94)	*
I think that V2G remuneration calculation based on Kilowatt hours is more reliable and transparent than that based on plug-in hours.	3.60(0.88)	3.60(0.85)	
Compared to the fixed contract, I prefer the flexible contract.	3.67(0.86)	3.52(0.81)	*

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Factor loadings of V2G concerns (Principal Component Analysis)

	Battery-concern	Pessimistic	SOC concern	Flexible reward
I would be afraid that the battery life would be shortened by the frequent charging and discharging.	0.86			
The potential damage to the battery (due to the frequent charging and discharging) is a significant obstacle to the promotion of V2G adoption	0.88			
The potential risks and damage to the battery during the V2G process outweigh the earnings.	0.72			
I think V2G bidirectional charging can reduce CO_2 emissions and is beneficial for the environment.		-0.76		
I am very optimistic about the future of V2G technology practice.		-0.75		
I am afraid that V2G is very complex to operate via an app in my smartphone.		0.65		
I would fear the battery is not sufficiently charged when I want to start a trip.			0.73	
I would feel restricted in my freedom and independence.			0.53	
I think that more remaining battery capacity (kilometers) is more important than subsidy benefits.			0.79	
I think that V2G remuneration calculation based on Kilowatt hours is more reliable and transparent than that based on plug-in hours.				0.78
Compared to the fixed contract, I prefer the flexible contract.				0.71
I think that the amount of financial benefit is the key factor influencing my participation in V2G services.			-0.52	
I think some energy will be wasted and lost in the V2G bidirectional charging process.				

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V2G use intention —— 3 levels

		N	%	%
Level 1	No, I will not.	22	3.6	8.6
	I am very interested in this technology, but will not use it.	31	5.0	
Level 2	I will think about it, based on the flexibility of car use, cost (e.g., battery degradation) and benefits (e.g., rewards)	416	67.5	67.5
Level 3	Yes, I will use it	147	23.9	23.9

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Modeling approach

Dependent variable: V2G use intention (3 levels)

Ordinal logit model

a) V2G use intention = f (Socio-demographics) + ε
b) V2G use intention = f (Socio-demographics, Mobility patterns) + ε
c) V2G use intention = f (Socio-demographics, Mobility patterns, Acceptable minimum S.O.C) + ε
d) V2G use intention = f (Socio-demographics, Mobility patterns, Acceptable minimum S.O.C, V2G concerns) + ε

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	Model 1	Model 2	Model 3	Model 4
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
Gender (ref. Male)				
Female	0.69(-3.35)	-0.73(-3.47)	-0.73(-3.46)	-0.50 (-2.25)
Age (ref. 18 ~ 35)				
35 - 50	0.23(0.97)	0.21(0.88)	0.22(0.93)	0.22(0.87)
51 - 65	0.19(0.74)	0.16(0.62)	0.2(0.78)	0.13(0.47)
65 +	-0.53(-1.3)	-0.59(-1.43)	-0.56(-1.35)	-0.32(-0.73)
Income (ref. Low)				
Middle	-0.4(-1.7)	-0.45(-1.9)	-0.5(-2.09)	-0.4(-1.58)
High	-0.35(-1.13)	-0.39(-1.23)	-0.42(-1.34)	-0.46(-1.35)
Prefer not to say	-0.73(-2.38)	-0.77(-2.5)	-0.77(-2.48)	-0.3(-0.92)
Education (ref. Low)				
Middle	0.52(1.82)	0.49(1.68)	0.46(1.6)	0.19(0.62)
High	0.65(2.21)	0.62(2.07)	0.59(1.98)	0.14(0.44)
Others	0.1(0.11)	0.24(0.2)	0.19(0.21)	0.07(0.07)
Household structure (ref. Cohabiting with children)				
Cohabiting without children	-0.16(-0.78)	-0.16(-0.76)	-0.14(-0.64)	-0.19(-0.8)
Single with children	-0.49(-0.79)	-0.51(-0.82)	-0.48(-0.77)	-0.71(-1.05)
Single without children	-1.03(-2.99)	-1.1(-3.16)	-1.08(-3.1)	-1.01(-2.85)
Others	-0.62(-0.43)	-0.56(-0.39)	-0.68(-0.49)	-0.57(-0.46)
EV status (ref. Private EV users)				
Leased EV users	0.21 (1.13)	0.2(1.07)	0.22(1.18)	0.24(1.19)

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	Model 1	Model 2	Model 3	Model 4
	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)	Coefficient (t value)
Mobility patterns				
✧I have a constant weekly routine.		-0.02(-0.21)	-0.04(-0.37)	0.04(0.37)
✧I know which trips I will take the next day		0.21(1.81)	0.2(1.77)	0.05(0.39)
✧Regarding trip distances, almost every workday is actually the same for me.		-0.06(-0.66)	-0.04(-0.52)	-0.02(-0.19)
EV driving mileage (km) (A typical working day)		0(-1.35)	0(-0.91)	0(0.15)
Acceptable minimum state of charge before departure			-0.01(-2.23)	0(-0.71)
V2G concerns				
Pro-battery-concern				-0.5(-5.15)
Pro-pessimistic				-0.91(-8.26)
Pro-remaining-electricity				-0.5(-5.05)
Pro-flexibility				0.07(0.79)
N	616	616	616	616
Log-likelihood	-428.60	-478.96	-476.46	- 416.05
ρ-square	0.04	0.05	0.05	0.17

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Conclusion

- **V2G participation concern differs between EV users in various ownership status (leased vs. private EV)**

  Private EV users： care more about their EV battery life and think that this is the barrier for V2G promotion

  Leased EV users： remaining power is important for them

- **V2G participation concern plays an significant role in V2G use intention**

  (Battery concern; Pessimistic; SOC concern)

- **V2G participation concern comes from their income, education degree, mobility patterns, and acceptable minimum S.O.C**

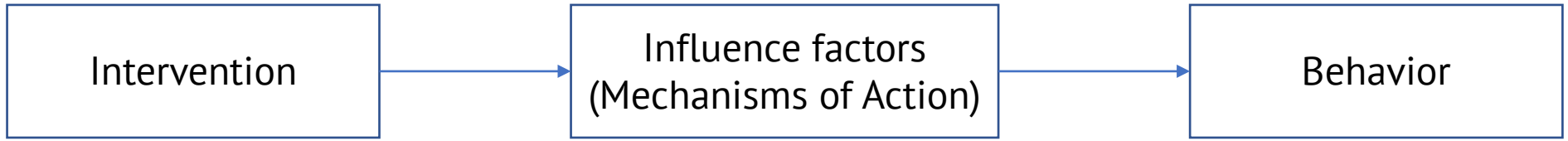
ROBUST

Identifying Barriers and Facilitating Factors for Smart Charging Behavior of Electric Vehicles. Insights from applying the COM-B framework

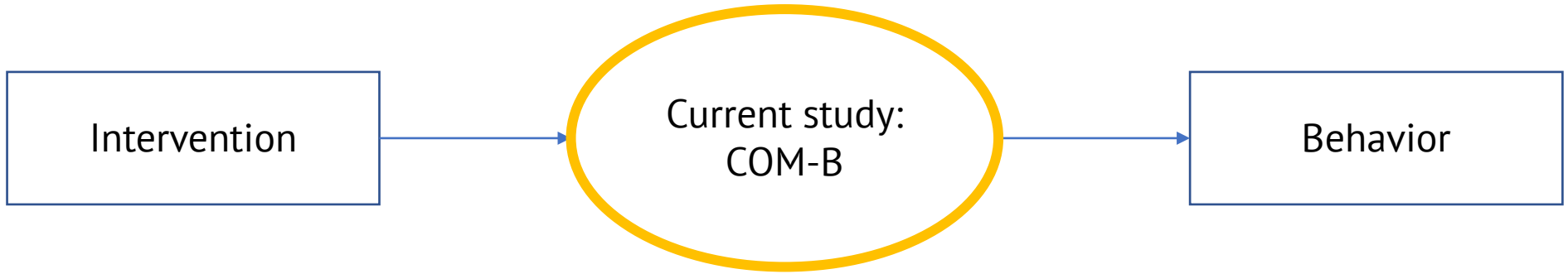
Janna de Graaf

ROBUST

End user behavior:
from current charging habits to smart charging behavior



End user behavior:
from current charging habits to smart charging behavior



Theoretical framework:
COM-B model and Theoretical Domains Framework

Sources of behaviour

TDF Domains

Soc - Social influences
Env - Environmental Context and Resources
Id - Social/Professional Role and Identity
Bel Cap - Beliefs about Capabilities
Opt - Optimism
Int - Intentions
Goals - Goals
Bel Cons - Beliefs about Consequences
Reinf - Reinforcement
Em - Emotion
Know - Knowledge
Cog - Cognitive and interpersonal skills
Mem - Memory, Attention and Decision Processes
Beh Reg - Behavioural Regulation
Phys - Physical skills

1. Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6(1):1–12.
2. Cane, J., O'Connor, D., & Michie, S. (2012). Validation of the theoretical domains framework for use in behaviour change and implementation research. Implementation Science, 7(1), 1–17.
3. Atkins, L., Francis, J., Islam, R., O'Connor, D., Patey, A., Ivers, N., ... & Michie, S. (2017). A guide to using the Theoretical Domains Framework of behaviour change to investigate implementation problems. Implementation science, 12(1), 1-18.

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Method

- Semi-structured face-to-face interviews or via Microsoft Teams
- +- 45 minutes
- Recruitment strategies:
  - Neighborhood magazine/outlets
  - Twitter (X): 030Elektrisch
  - QR-stickers on charging stations

Participant characteristics (N=55)

Gender

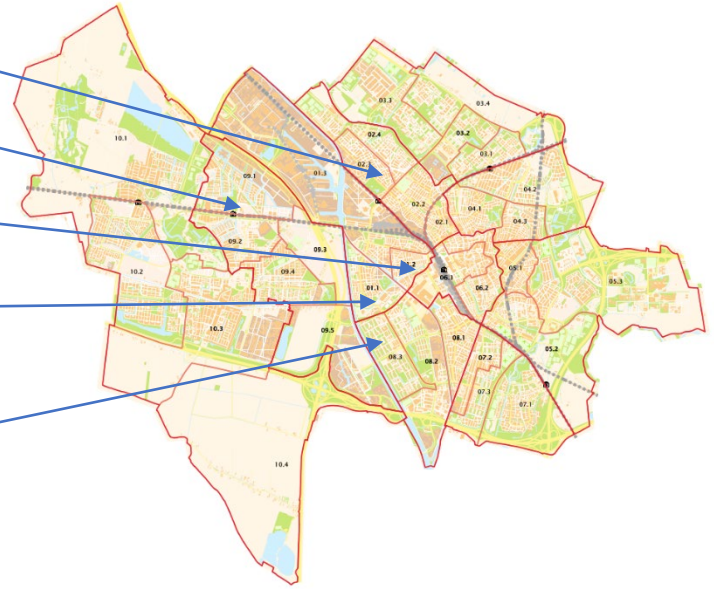
♀	20
♂	35

EV

BEV	38
PHEV	9
Non-EV	8

Neighborhood

Zuilen	14
Leidsche Rijn	11
Lombok	11
Oog in Al	9
Kanaleneiland	10



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1. Gemeente Utrecht, retrieved from: https://www.utrecht.nl/bestuur-en-organisatie/publicaties/onderzoek-en-cijfers/zelf-cijfers-zoeken/wijken-en-buurtenkaarten/

Preliminary results
Capabilities

> *“I also use that at home as now. With the laundry machine, dishwasher… Preferably after 11PM or during the weekend, rather than during the day. So, I’m a bit mindful of that”*
> P01, Female, Kanaleneiland, Conventional vehicle

- Participants make comparisons to already using off-peak rates for e.g., laundry machines

> *"And we try to do as much laundry as possible on the weekends because the rate is lower then.“*
> P36, Male, Leidsche Rijn, Electric vehicle

> *"Yes, actually… With my dishwasher, I can set it to start a few hours later, you know. But I'm not sure if that's possible with cars.“*
> P33, Male, Leidsche Rijn, Electric vehicle

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Preliminary results
Capabilities

"So, you can add many more charging stations because you have the power, just not between 8:00 AM and 5:00 PM. So, if you're only balancing charging stations and you say, 'I have 100 kilowatts for 10 charging stations,' then I say, 'No, you have 100 kilowatts, plus 300 kilowatts from that company, for those charging stations after 6:00 PM. And you have 100 kilowatts between 8:00 AM and 5:00 PM. So, smart charging is much broader than just unilaterally saying, 'Okay, I give this to charging stations, and let the charging stations figure it out among themselves, what they do..."

P42, Male, Kanaleneiland, Electric vehicle

- Knowledge about the concept differs:

  some participants have in depth knowledge; others are more uncertain.

"..that you charge when there is a lot of green energy available or when cheaper electricity is available, yes."

P03, Male, Oog in Al, Electric vehicle

"Yes, what I'm thinking is that you make sure that before your journey starts, you are charged [...]

but for the rest, not familiar with it."

P60, Male, Kanaleneiland, Electric vehicle

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Preliminary results
Opportunities

- A private charging station
- Combined with a dynamic tariff energy contract

"Yes, yes... And Tibber helps me a lot with that, I let the app figure it out; it knows exactly..."
P36, Male, Leidsche Rijn, Electric vehicle

""We also bought a new charging station with three phases, so that when we have that car later, it can charge at full speed at night. And we've taken another energy contract because... Well, those ridiculous energy prices weren't quite it. So, we're looking into the concept where you can also charge smartly at night, picking smart rates during the night. The low rates at night. So, at the moment when there's a surplus on the energy market, I want my car to absorb that, that's the idea.“
P25, Male, Leidsche Rijn, Electric vehicle

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Preliminary results
Opportunities

> *"But, yeah, if I place that thing and I tell that device to 'wait until the electricity is cheapest,' then I think: hey, wait a minute! Get away from my parking spot and my charging station. Because I might want to charge as well, and I might need to leave, and there's someone 'waiting' at the post for a cheap rate. Yes, I find that very challenging for public charging stations."*
> P25, Male, Leidsche Rijn, Electric vehicle

- Injunctive social norm: Don't keep the (public) charging station occupied (unnecessarily)

> *"Well, I am, let's say... If I know that's happening and I don't get the neighborhood on my back for having the car plugged in for 12 hours... Because that's, of course, what happens, then I'll leave it connected longer, so... So, I like the idea, but it also means that, by definition, I have to leave it connected to the post for a longer time because the post has to choose a smart moment."*
> P09, Male, Oog in Al, Electric vehicle

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Preliminary results
Motivation

- Using own energy system in most efficient way (as a hobby/enjoyment)

"Well, I am working on home automation. So, I enjoy making my house smarter, and in that way, I'm also interested in electronics, smart switching, and monitoring energy usage, those kinds of things."
P11, Male, Zuilen, Electric vehicle

- Financial incentive

R:"Yes, as long as there's a good incentive...
I: And what are the most important incentives for you?
R: Money.
I: Yes.
R: (laughs) Yes, it just has to be cheaper. Because I don't want anything else from it, of course."
P27, Male, Leidsche Rijn, Electric vehicle

"No, so I do take it into account, but it also depends on the price difference, I think. If it's significant, people will obviously pay a lot of attention to it. If it's just a matter of cents, then, well, it doesn't matter that much."
P26, Male, Zuilen, Electric vehicle

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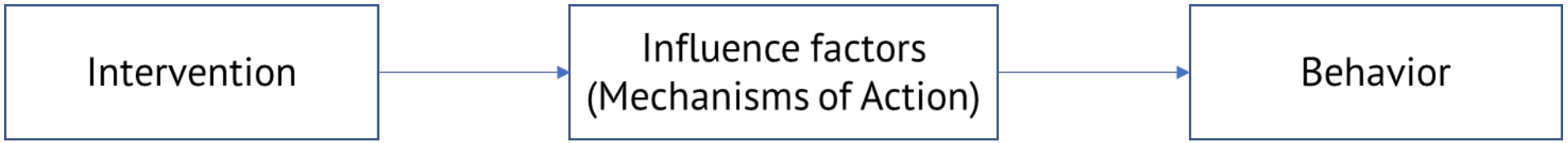
Discussion

- Continue with representative sample survey
- Inform interventions or policies



Thanks for your attention!

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