Energy system planning with consumer preference for low voltage flexibility in the context of Belgium

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Table of contents

- Context for low voltage flexibility in Belgium
- Scenario analysis with TIMES BE
- Adequacy modelling with consumer preference

Context

Low voltage flexibility in Belgium

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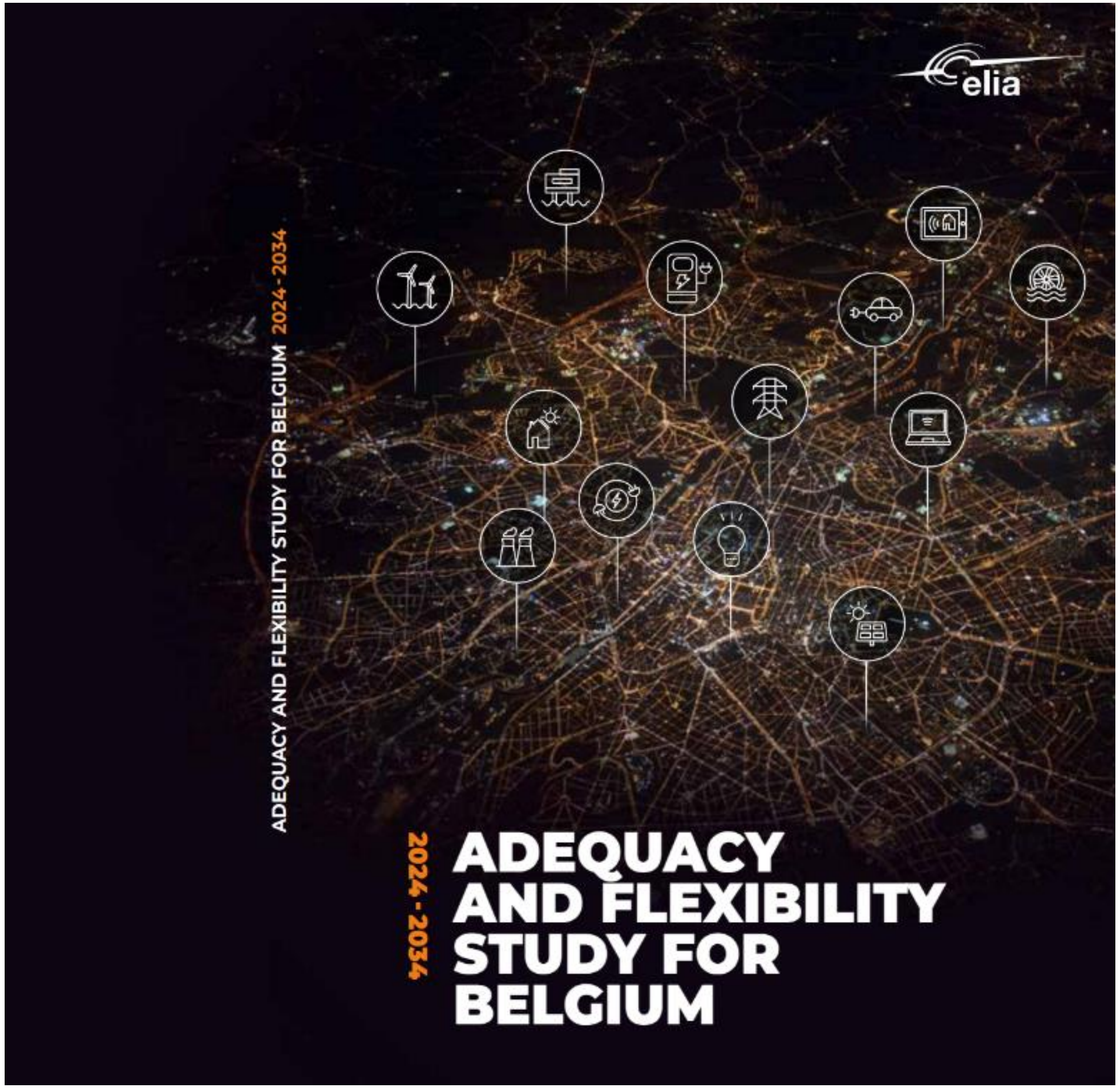
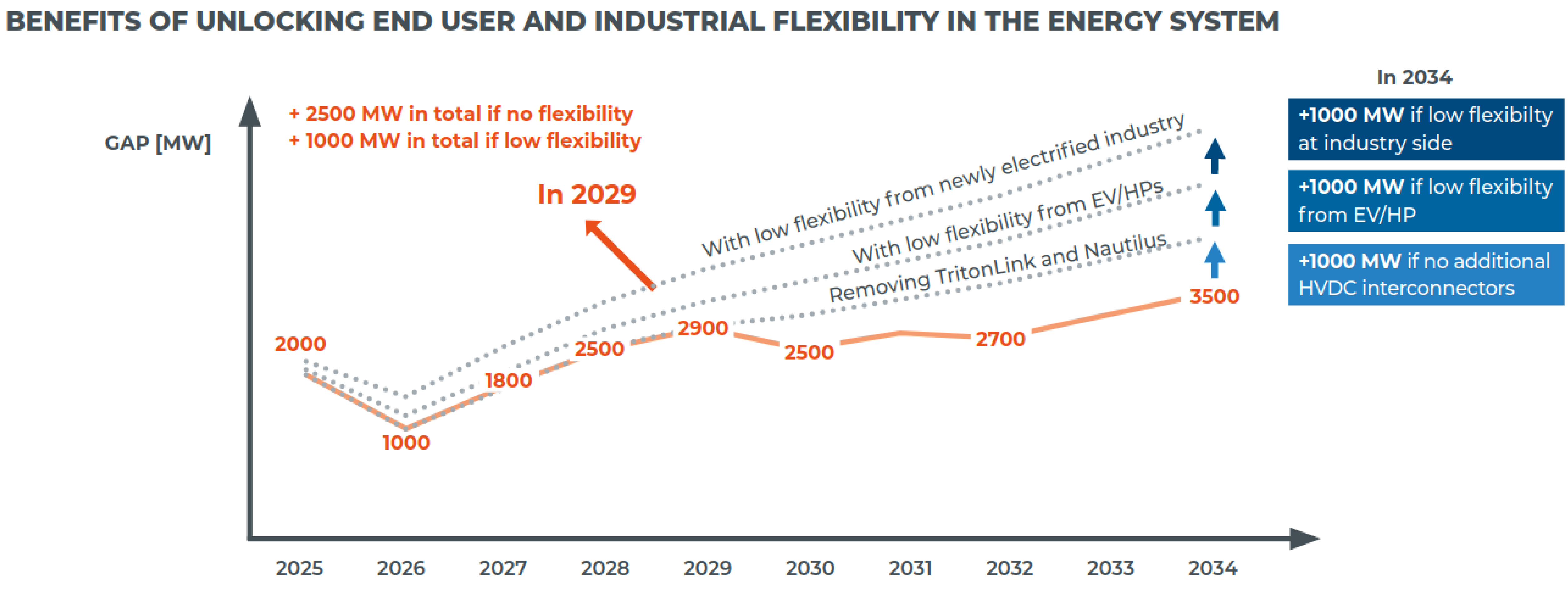
Perspective of Elia



Perspective of Elia



Perspective of consumer

Technology	Location	Time	preference	reference
EV	highway, shopping centre	2024	Sensitive to the charging price; trade off between waiting and price.	[1]
EV	home, work	2024	Willingness to wait is higher.	[1]
EV, smart home	home	2024	Interest to participate is more important than finances and environment.	[4]
appliances	Colombia	2020, 18-24h	Higher interest to participate in (manual demand response in) the evening.	[2]
all	all	all	Participation in demand response programs require financial benefits.	[2, 1]
all	all	all	Young, educated people tend to be more open for participation.	[1, 4]

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DCE on chargers for electrical vehicles

Attribute type	Attribute	Description
Battery	minimum battery level	A minimum state of charge is guaranteed before the charger is used flexibly.
	portable battery bank	You have access to a portable battery bank, as if you would carry a jerrycan in your gasoline car.
	road side charging insurance	When you run out of battery charge during your trip, a service vehicle shows up to charge your battery enough to get to the next charging station.
Privacy	data encryption	Data exchange between you and the energy retailer is encrypted.
Financial	fee	A reduction on your energy bill savings that are used by your retailer to provide the features above.

Attribute type	Attribute	Description
Control	solar charging	Charging your EV mostly with your PV.
	dynamic load management	Reduce the peak consumption of the home.
	smart controller at home	A local solution for controlling your EV.
	energy retailer	The retailer directly controls the charging of your EV.
	smartphone	You control the charging of the EV yourself through your smartphone.
Bidirectional charging	home	Allow discharging of your EV, but only for your own appliances.
	home and grid	Allow discharging of your EV to your own appliances and/or the local grid.
Financial	reward	An annualised financial benefit. The financial benefit can come from the optimal use of the battery or as a subsidy on the investment.
	price	Investment cost of the charger

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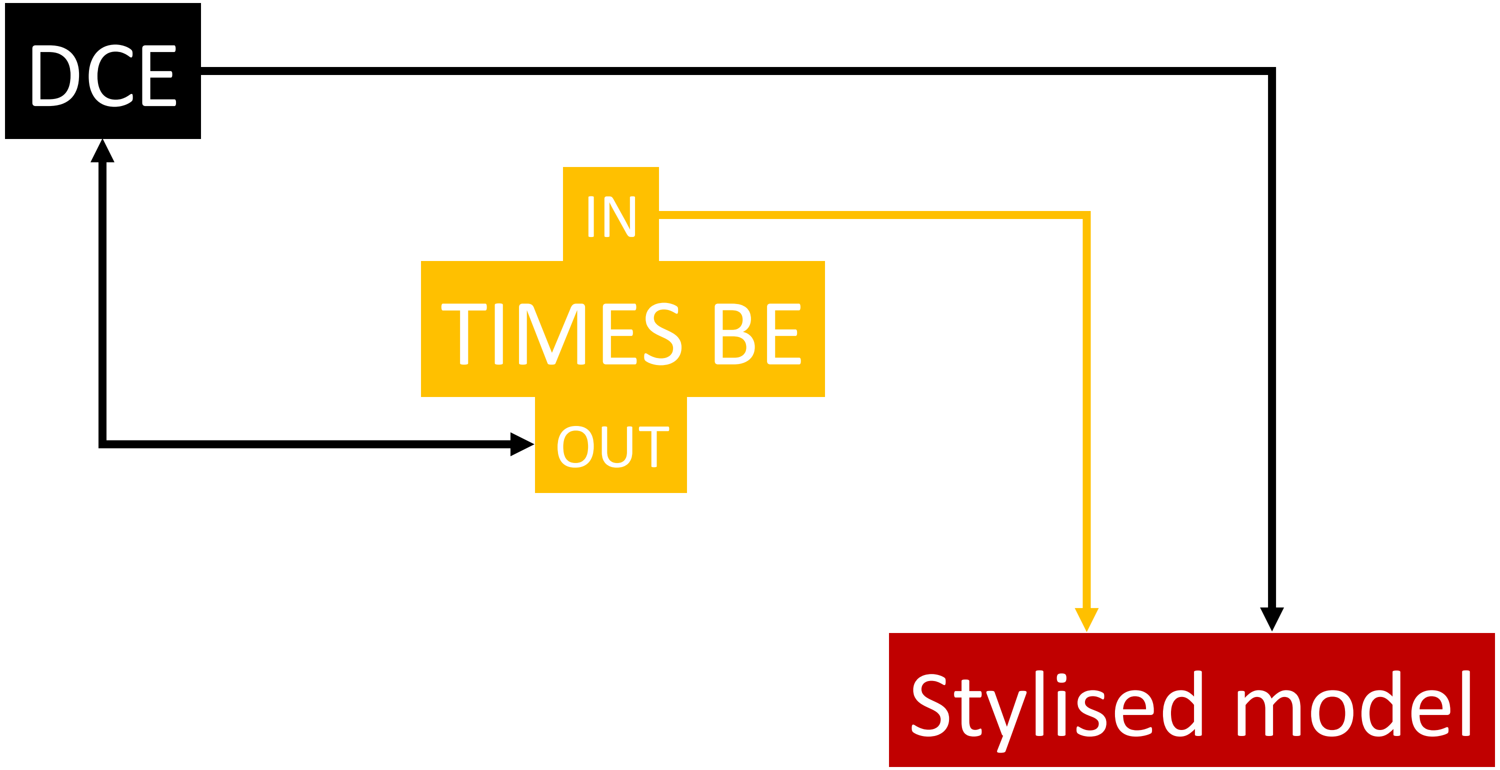
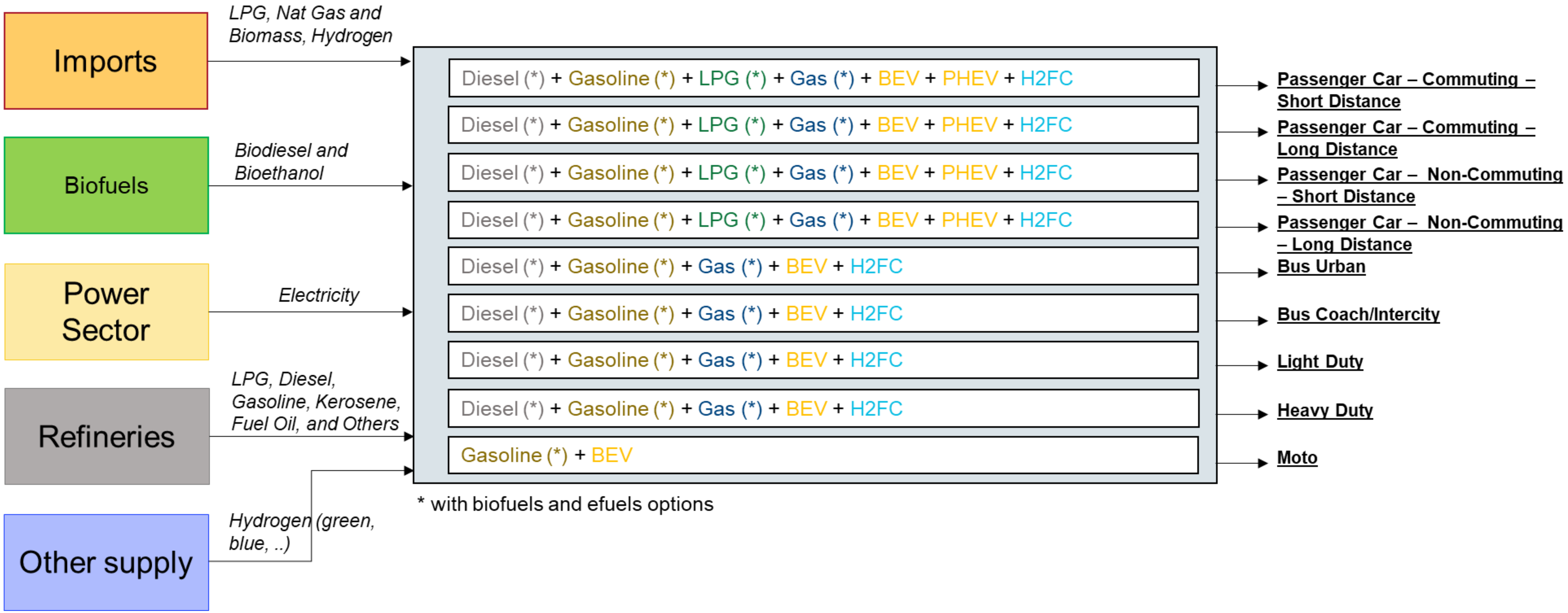
Modelling overview



TIMES BE

Scenario analysis on cost optimal pathways with flexible chargers

Energy system modelling



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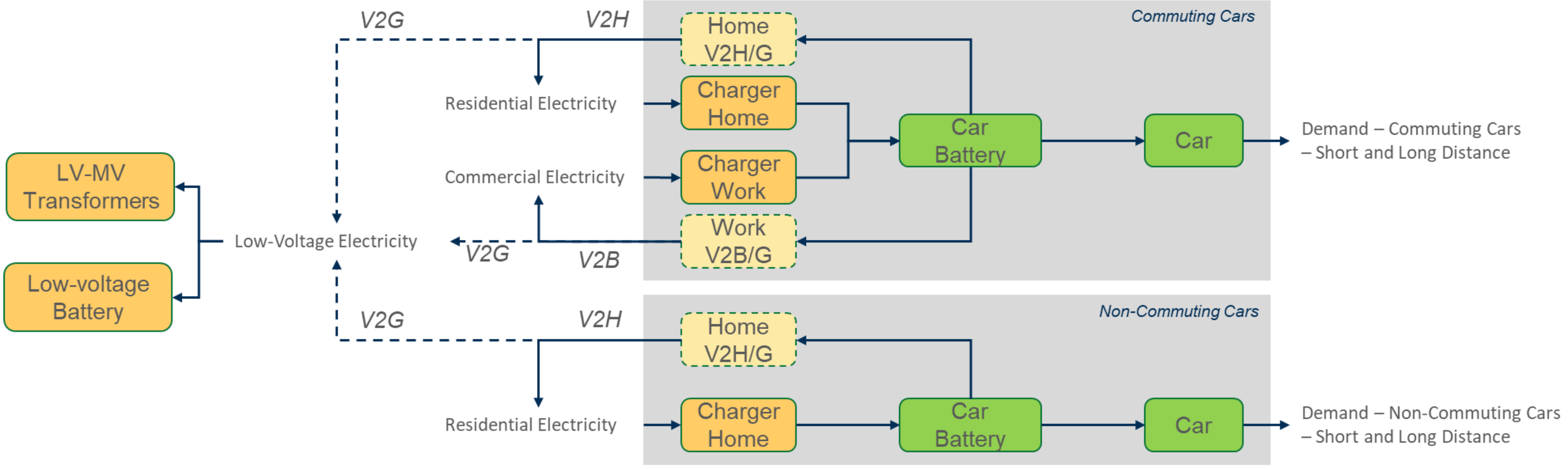
Charging infrastructure modelling

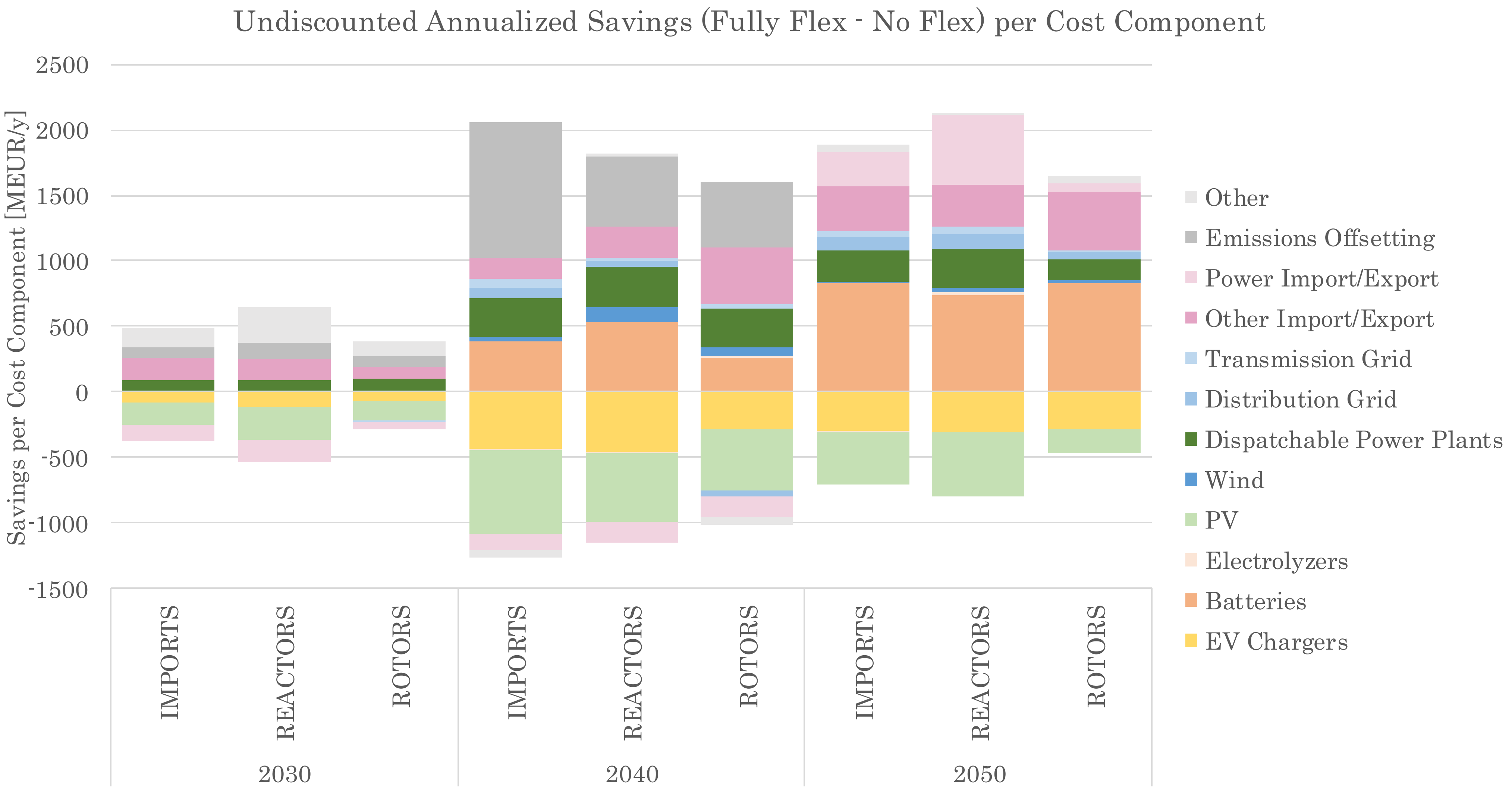


V2H: Vehicle to Home
V2B: Vehicle to Building (Commercial sector)
V2G: Vehicle to Grid
LV-MV: Low Voltage-Medium Voltage

Scenario analysis

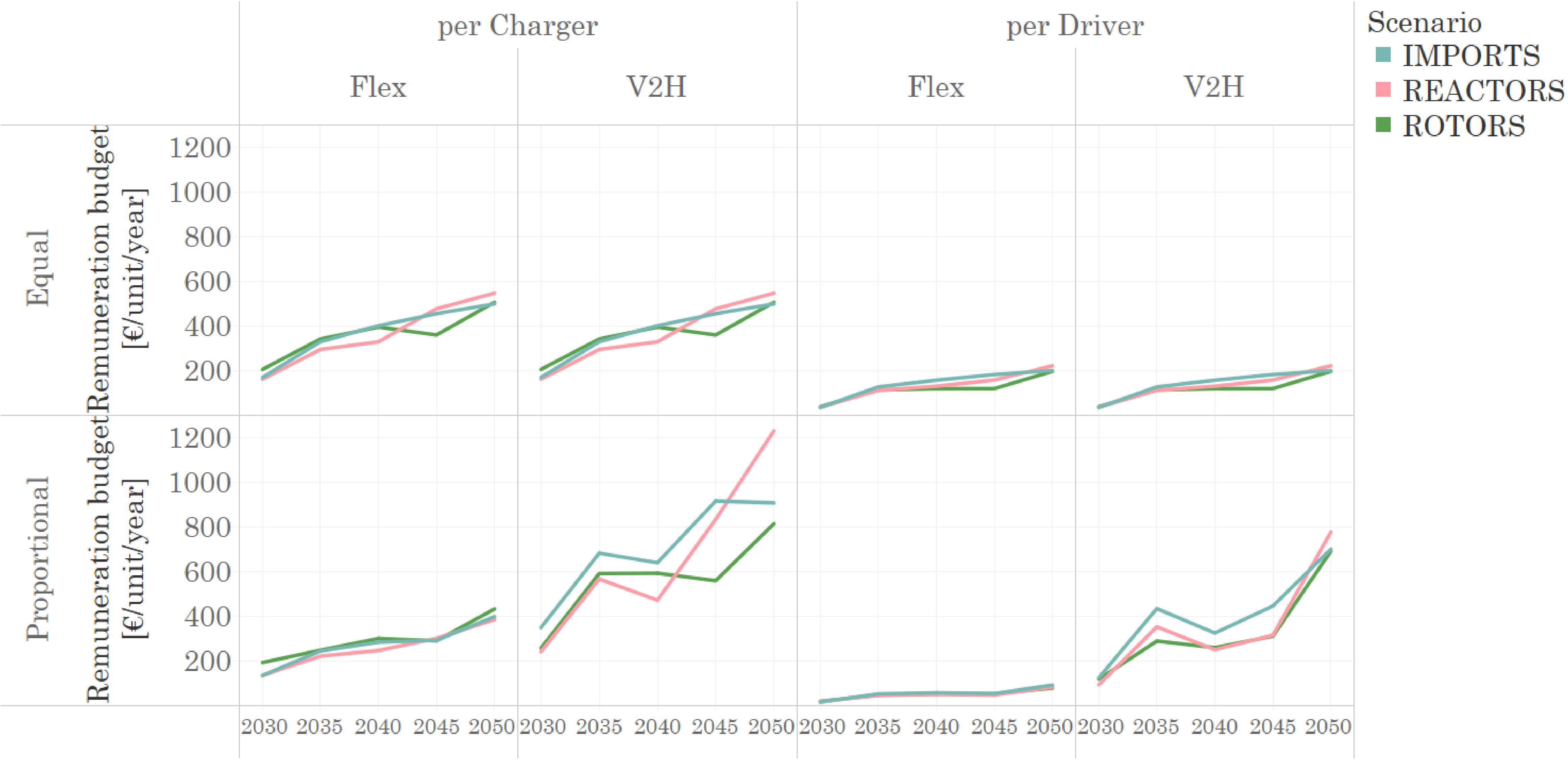
Scenario	Base Storyline (from PATHS)	Constraint 1 – Max Flex Chargers [%]	Constraint 2 –Max V2H [%]	Constraint 3 – Max V2G [%]
ROTORS	ROTORS	48%	38%	38%
R100_100_100	ROTORS	100%	100%	100%
R100_100_0	ROTORS	100%	100%	0%
R100_0_0	ROTORS	100%	0%	0%
R0_100_100	ROTORS	0%	100%	100%
R0_100_0	ROTORS	0%	100%	0%
R0_0_0	ROTORS	0%	0%	0%
MOLECULES	MOLECULES	48%	38%	38%
M100_100_100	MOLECULES	100%	100%	100%
M100_100_0	MOLECULES	100%	100%	0%
M100_0_0	MOLECULES	100%	0%	0%
M0_100_100	MOLECULES	0%	100%	100%
M0_100_0	MOLECULES	0%	100%	0%
M0_0_0	MOLECULES	0%	0%	0%

Scenario analysis



Scenario analysis

Remuneration budget per storyline, per Charger/Driver and technology



Stylised model

Adequacy modelling with consumer preference for the adoption of flexible chargers

Model features

~ relaxed clustered unit commitment

Included

- Investments, scheduled operation (commitment), non optimal maintenance, ramping and reserves
- Import/export with costs and limits
- Line with capacities
- Curtailment, demand response, heat pumps, storage and electric vehicles

Excluded

- Markets
- Multi-energy systems

Utility

$$V_{ik}(x) = \beta_0 + \beta_x \cdot x \quad (1)$$

With

V_{ik} the utility that individual i in class k has for features x

β_0 the baseline

β_x a coefficient for attribute x, determined from the DCE

x value for attribute x, e.g. a minimum battery level of 50%

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Probability

$$P_k(x) = \frac{exp(V_{ik}(x))}{exp(\beta_0) + exp(V_{ik}(x))} \tag{2}$$

with

$P_k(x)$ the probability or market share of a charger with features x due to latent class k, e.g. 20% adoption of flexible chargers with a minimum battery level of 40% due to likely adopters.

Linearised Probability

$$P_k(x) \sim P_0 + \gamma_{kx} \cdot (x - x_0) \qquad (3)$$

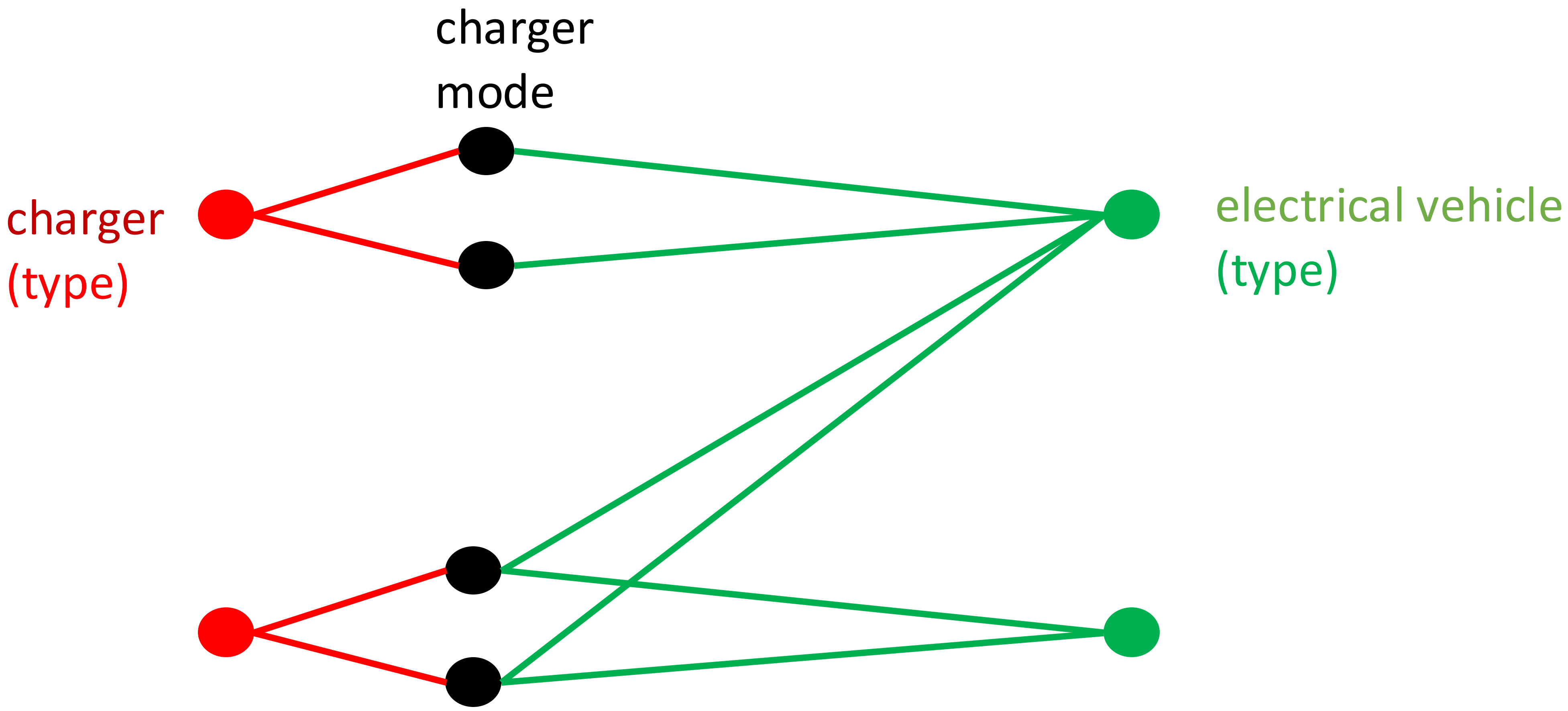
with

P_0 the probability of the baseline.

γ_{kx} a class specific linearised coefficient for the relation between the attribute value x and the market share for flexible chargers with these attributes.

x_0 the attribute value for the baseline.

Model equations



Model equations – financial reward

Total EV charging

$$p_{ch,t} = -P^{e}_{ev,t} \cdot (1 - \sum_{v} f_v \cdot P_v(r_v)) + \sum_{v} p^{d}_{ev,v,t} - p^{c}_{ev,v,t}$$

Flexible charging limit

$$p^{c}_{ev,v,t} \leq f_v \cdot P_v(r_v) \cdot C^{p}_{ch} \cdot A^{c}_{v}$$
$$p^{d}_{ev,v,t} \leq f_v \cdot P_v(r_v) \cdot C^{p}_{ch} \cdot A^{d}_{v}$$

Reward for flexible charger adoption

$$\min R^{0}_{v} \cdot f_v \cdot P_v(r_v) \cdot C^{p}_{ch}$$

Model equations – minimum battery level

Total EV charging

$$p_{ch,t} = -P^{e}_{ev,t} \cdot (1 - \sum_{v} f_v \cdot P_{ve,v}(b_{ve,v})) + \sum_{v} p^{d}_{ev,v,t} - p^{c}_{ev,v,t}$$

Flexible charging limit

$$p^{c}_{ch,v,t} \leq f_v \cdot P_{ve,v}(b_{ve,v}) \cdot C^{p}_{ch} \cdot A^{c}_{v}$$

$$p^{d}_{ch,v,t} \leq f_v \cdot P_{ve,v}(b_{ve,v}) \cdot C^{p}_{ch} \cdot A^{c}_{v}$$

Minimum battery level

$$f_v \cdot P_{ve,v}(b_{ve,v}) \cdot AV^{bl}_{ev,ve,v,t} \cdot C^{e}_{u} \leq e_{u,t} \leq C^{e}_{u}$$

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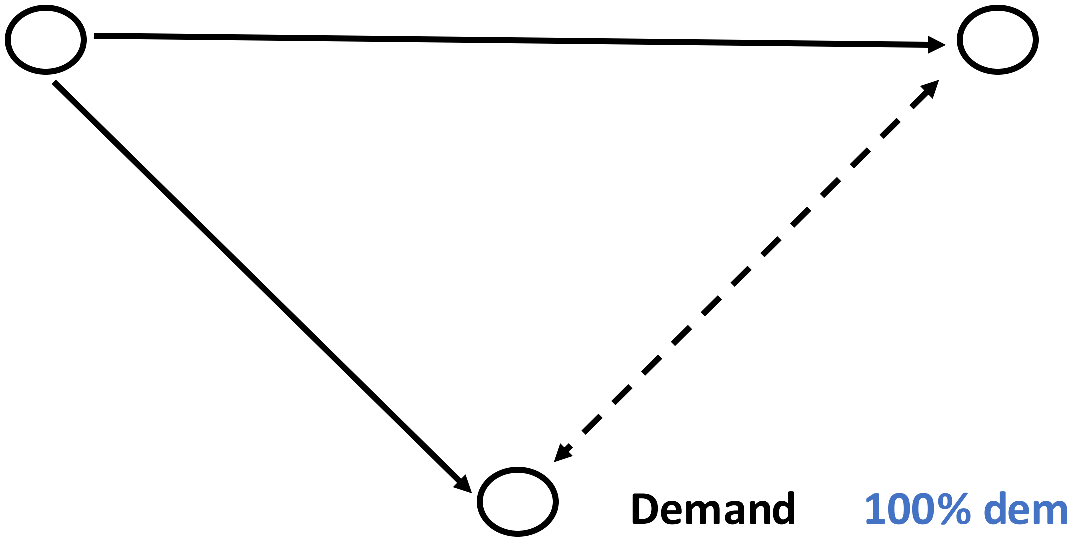
Example

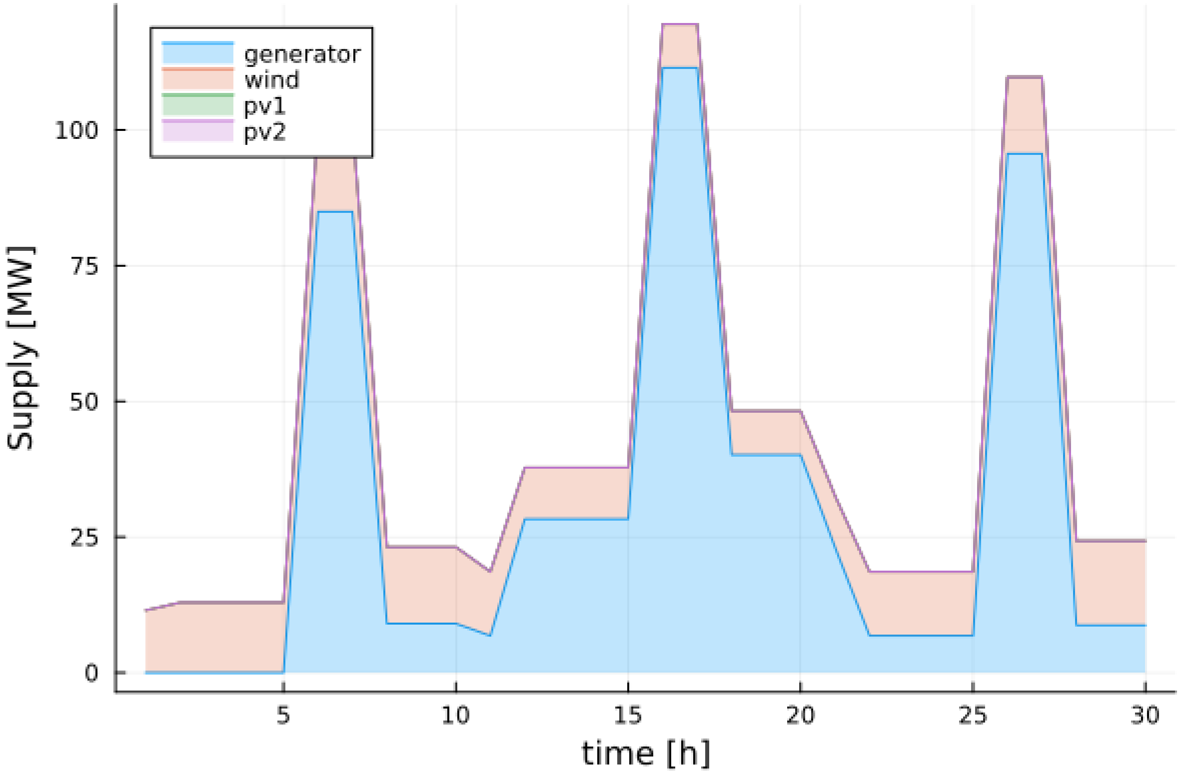
Generator	**100% ramping**
Wind	20% curtailment



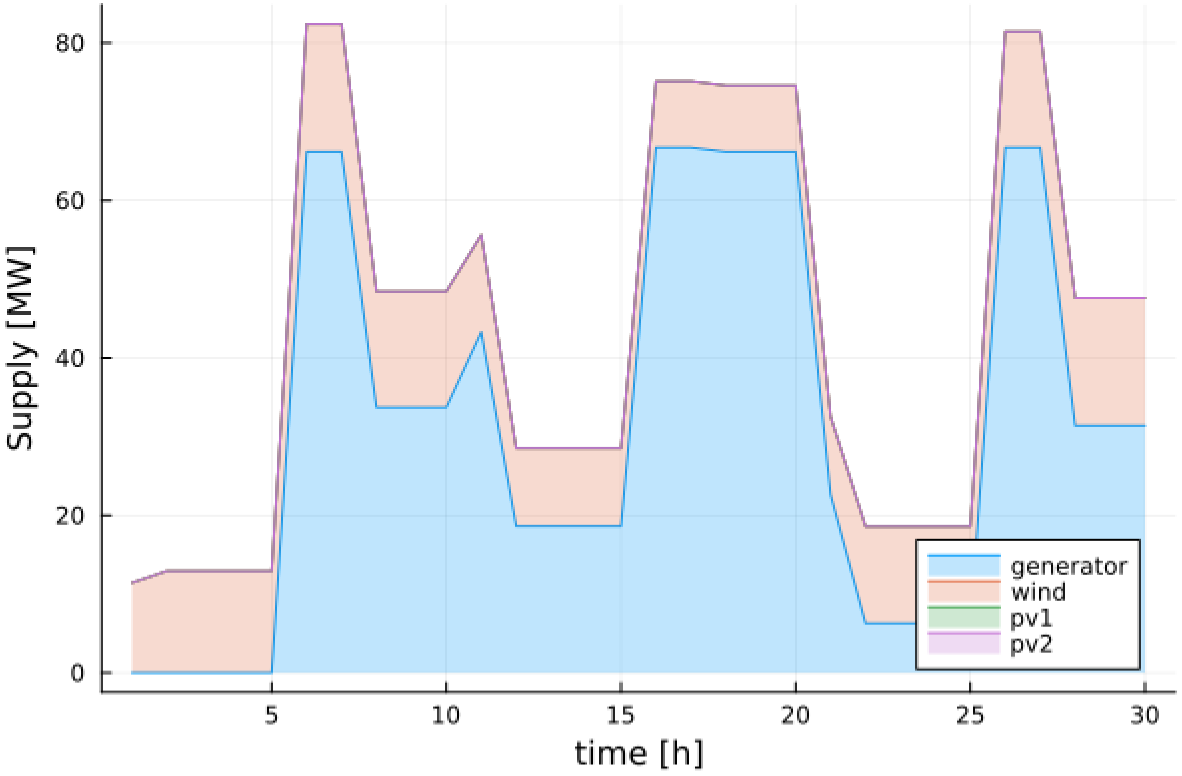
Demand	**0% demand response**
PV	0% curtailment
EV	Consumer preference

Demand	**100% demand response**
PV	0% curtailment
EV	Consumer preference

Example

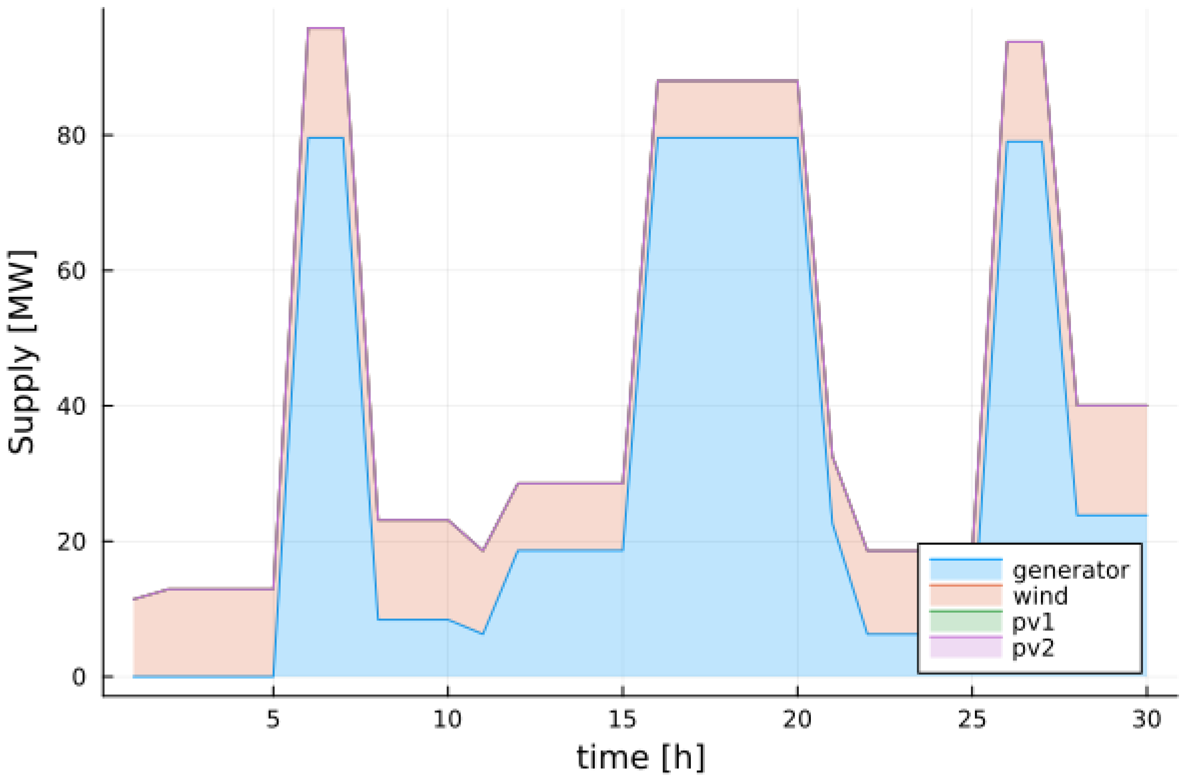


Dumb charger

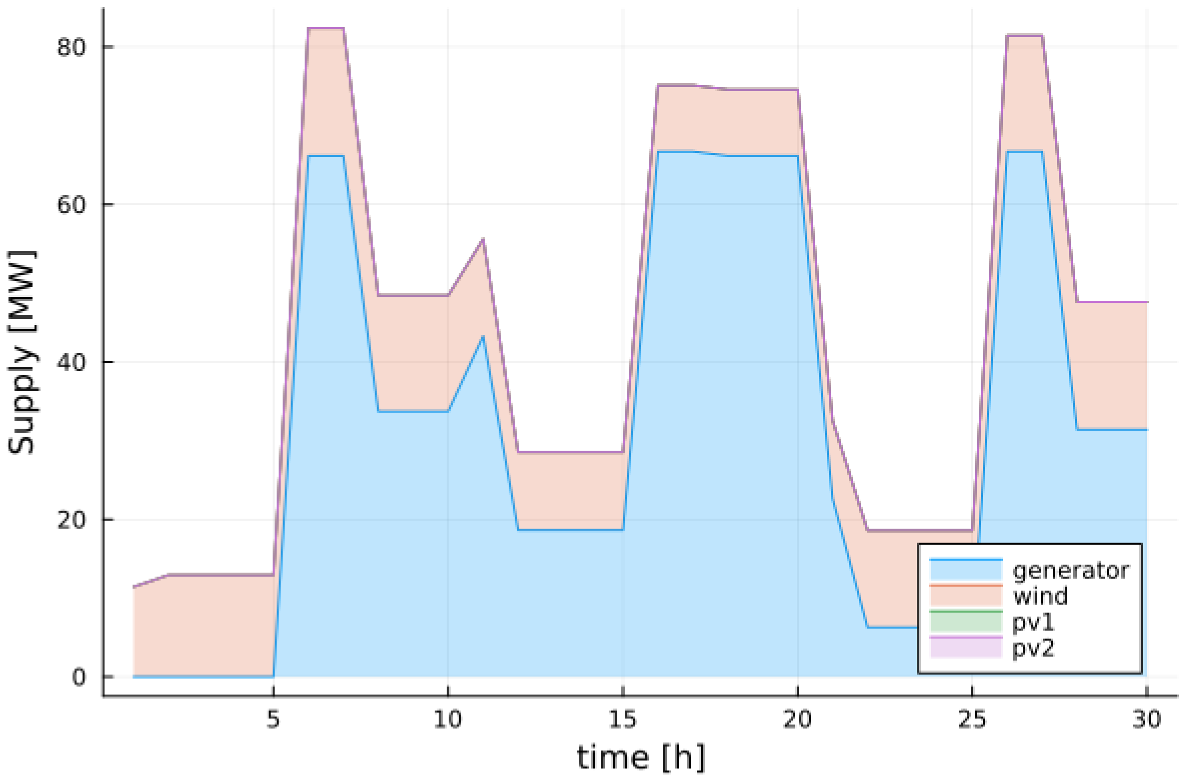


Optimal charger

Example



Consumer preference



Optimal charger

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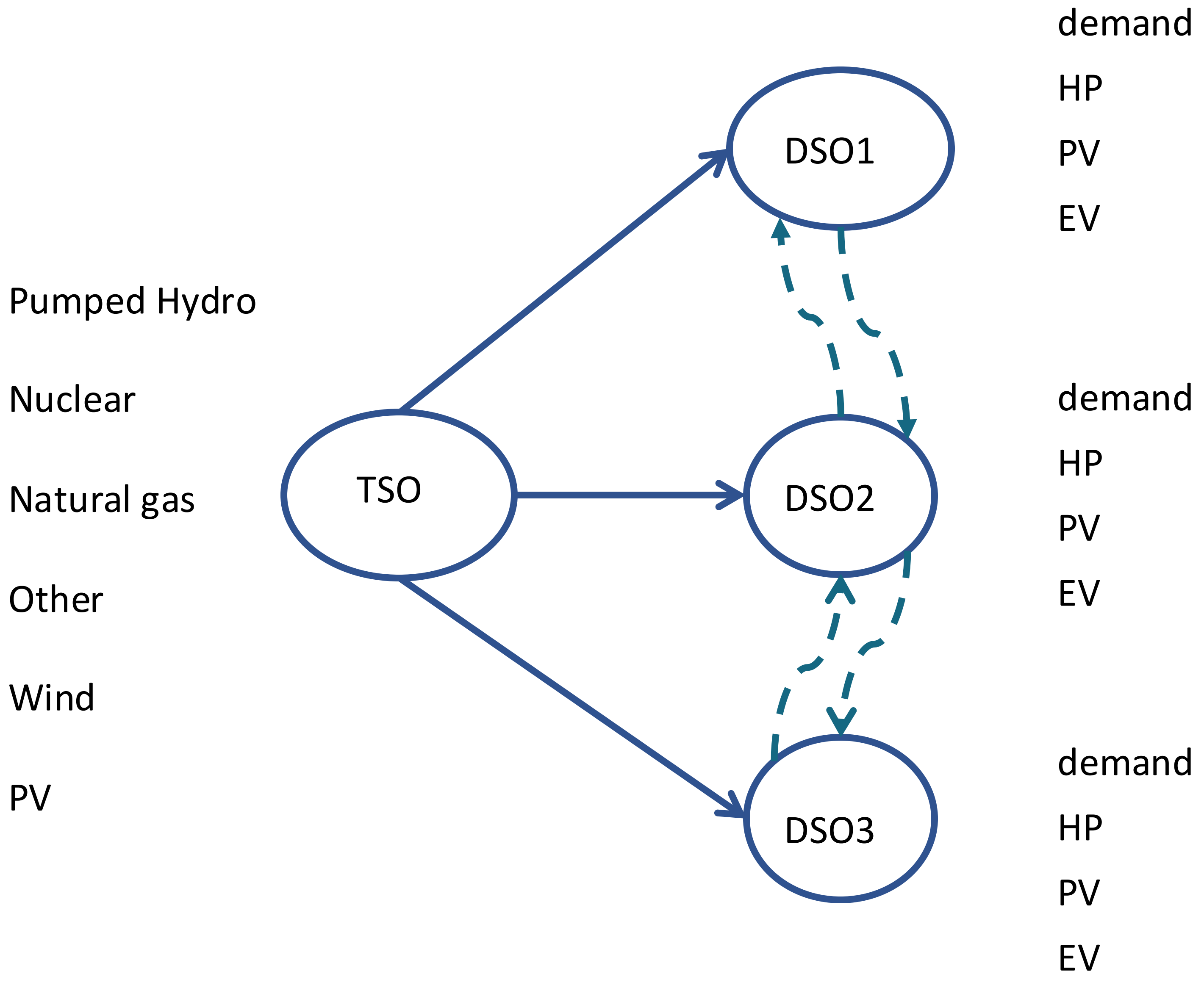
Setup for financial reward



Case for driving range anxiety

Pumped Hydro

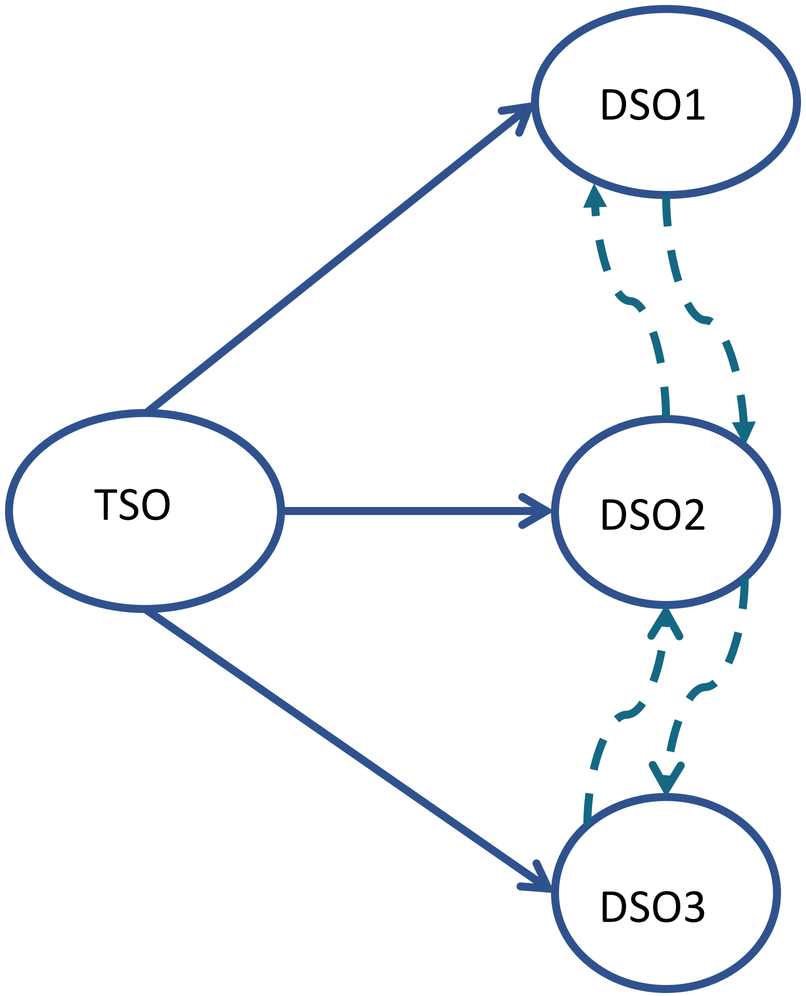
Nuclear

Natural gas

Other

Wind

PV



class: long drive	class: short drive
demand	demand
HP	HP
PV	PV
EV	EV

class: long drive	class: short drive
demand	demand
HP	HP
PV	PV
EV	EV

class: long drive	class: short drive
demand	demand
HP	HP
PV	PV
EV	EV

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https://alexander-project.vito.be/en

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