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IEEE PES Power & Energy Society
IEEE Advancing Technology for Humanity

TradeRES
New Markets Design & Models for 100% Renewable Power Systems

Local Energy Markets and Strategic Interactions

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Imperial College London, Control and Power Group

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Introduction

EEM23

Imperial College London

Citizens Energy Communities (CEC)

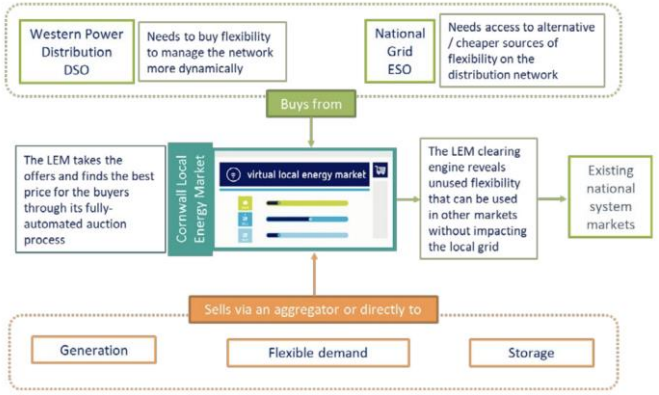
- **No geographical limitation**
- **Technology neutral**

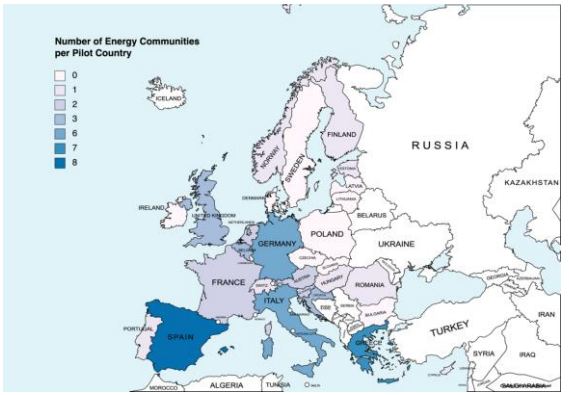
Renewable Energy Communities (REC)

- **Proximity of projects**
- **Limited to renewable energy technologies**

Cornwall Local Energy Market

In 2019, we achieved a world first. We enabled a distribution network operator and the National Grid Electricity System Operator (ESO) to buy flexibility simultaneously and in a coordinated fashion via a single third-party platform. It was all made possible by our ground-breaking Local Energy Market (LEM) trial in Cornwall.

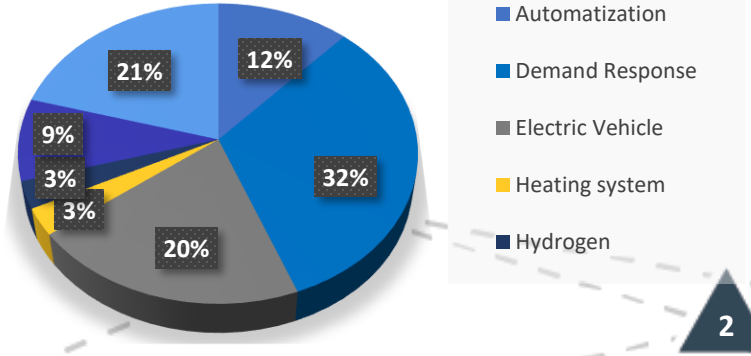




RESCOOP.EU

REScoop.eu is the European federation of citizen energy cooperatives.

Energy Services by Energy Communities



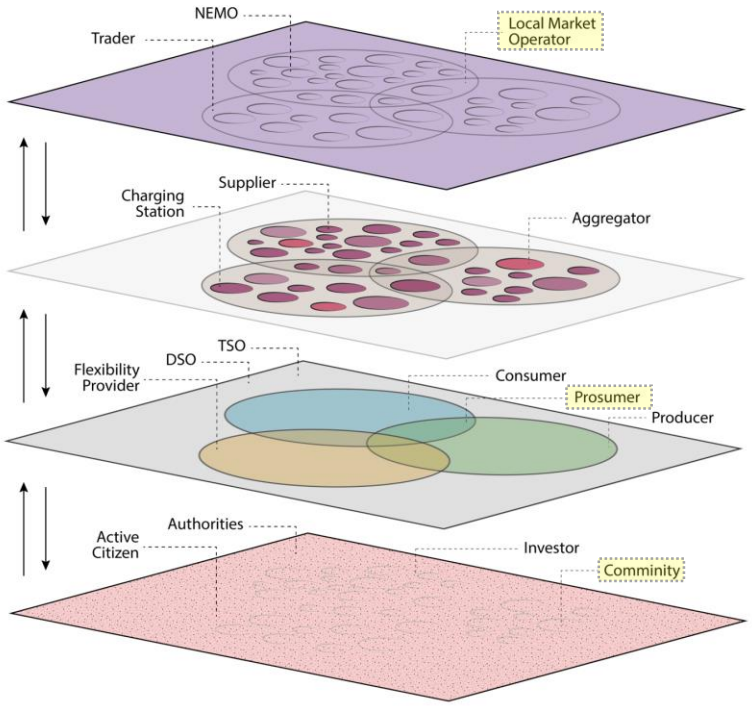
LES & Local flexibility marketplace in MERLON

bridge HORIZON 2020

Background (Actors)

Actors' Analysis within TradeRES

Positioning Prosumers, Communities and LEM withing TradeRES and its underlying models



Areas of LEM Simulation Framework focus

BESS: Battery Energy Storage System
CCGT: Combined Cycle Gas Turbine
CCS: Carbon Capture and Storage
CHP: Combined Heat and Power
CSP: Concentrated solar power
DSR: Demand Side Response
EVs: Electric Vehicles
OCGT: Open Cycle Gas Turbine
P2G: Power-to-Gas
PSH: Pumped Storage Hydropower
ICT: Information and Communication Technology

Intensity: High / Low

		Inflexible Demand	DSR	Flexible H&C	EVs	BESS	Heat Storage	PSH	P2G	PV	Wind	Biomass	Biogas	CSP	Geothermal	Other RES	CHP	Hydro	Nuclear	Gas CCS	OCGT	CCGT	Other non-RES	Distribution Network	Transmission Network	ICT
1. Prosumer	Residential	A_ RM	A_ RM	_ M	A_ RM	_ RM				_ RM	_ M															
	Enterprise	A_ RM	A_ RM	_ M	A_ RM	_ RM				_ RM	_ M															
	Industry	A_ RM	A_ RM	_ M	A_ RM	_ RM				_ RM	_ M															
	Community	A_ RM	A_ RM	_ M	A_ RM	_ RM				_ RM	_ M															

- General
- Inflexible Demand
- Demand Response
- Non-controllable generation
- Controllable generation
- Stortage/EV
- Network

Intensity: High / Low

		Capacity/ power limit	Power factor	Demand profile	Load curtailment	Shiftable fixed cycles	Continuously adjustable power	Energy saving	Capacity factor	Generation profile	Curtailment action	Minimum stable generation	Ramp-down/up limit	Startup/ shutdown time	Minimum up/down time	Minimum/Maximum energy limit	Charging/ discharging power	Charging/ discharging efficiency	Network topology	Voltage limits	Thermal Capacity	Line/node characteristics
1. Prosumer	Residential	_ _	_ _	A_ RM	A_ RM	A_ RM	A_ RM	_ _	_ _	_ _	_ _	_ _	_ _	_ _	_ _	A_ RM	A_ RM	_ RM	_ _	_ _	_ _	_ _
	Enterprise	_ _	_ _	A_ RM	A_ RM	A_ RM	A_ RM	_ _	_ _	_ _	_ _	_ _	_ _	_ _	_ _	A_ RM	A_ RM	_ RM	_ _	_ _	_ _	_ _
	Industry	_ _	_ _	A_ RM	A_ RM	A_ RM	A_ RM	_ _	_ _	_ _	_ _	_ _	_ _	_ _	_ _	A_ RM	A_ RM	_ RM	_ _	_ _	_ _	_ _
	Community	_ _	_ _	A_ RM	A_ RM	A_ RM	A_ RM	_ _	_ _	_ _	_ _	_ _	_ _	_ _	_ _	A_ RM	A_ RM	_ RM	_ _	_ _	_ _	_ _

- Self-interest drivers
- Non Self-interest drivers
- Influencing standards
- Other characteristics

Intensity: High / Low

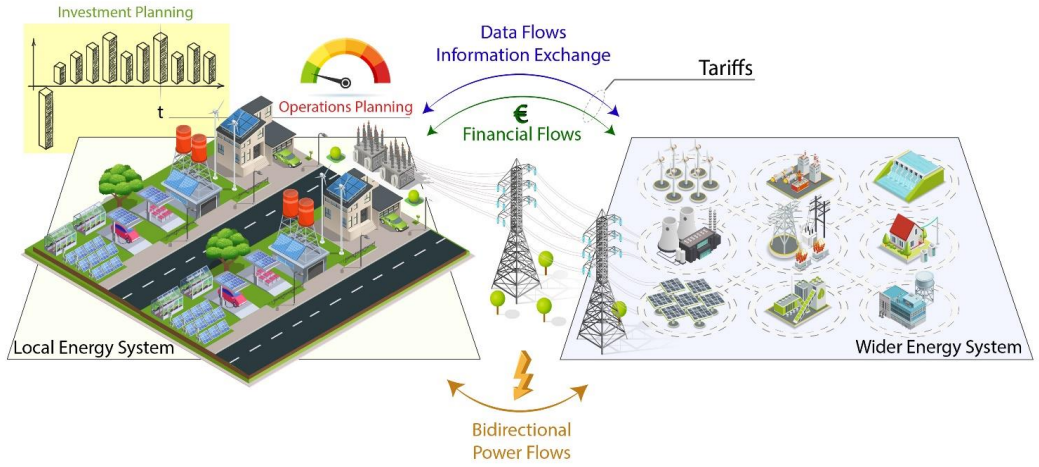
		Utility Maximization	Cost Minimization	Profit Maximization	Return of Investment	Environmental Concerns	Social Concerns	Sustainability Concerns	Financial Standards	Comfort Standards	Safety Standards	Technical Standards	Legislation Standards	Satisficing Behaviour	Attitude to Risk	Reputation and Conscience	Herd Behavior	Framin Effect	Loss Aversion	Status-quo / Activity Bias	Recency Bias
1. Prosumer	Residential	_ RM	_ RM	M	M	M	M	M	R	RM	_ _	_ _	M	R	RM	_ _	_ _	_ _	_ _	_ _	_ _
	Enterprise	_ RM	_ RM	M	M	M	M	M	R	RM	_ _	_ _	M	R	RM	_ _	_ _	_ _	_ _	_ _	_ _
	Industry	_ RM	_ RM	M	M	M	M	M	R	RM	_ _	_ _	M	R	RM	_ _	_ _	_ _	_ _	_ _	_ _
	Community	_ RM	_ RM	M	M	M	M	M	R	RM	_ _	_ _	M	R	RM	_ _	_ _	_ _	_ _	_ _	_ _

Operational and Behavioural Characterisation

Background (Tariffs)

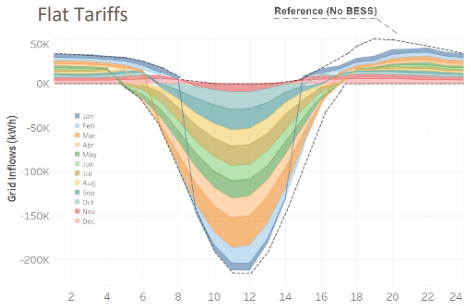
Effects of Tariff Structure in Revenue Streams of LES

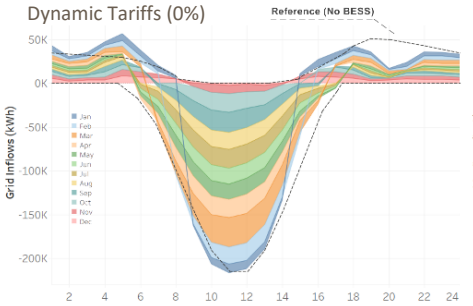
- Stacked value of flexibility
- Price signal influence investments
- Different business models and service provision

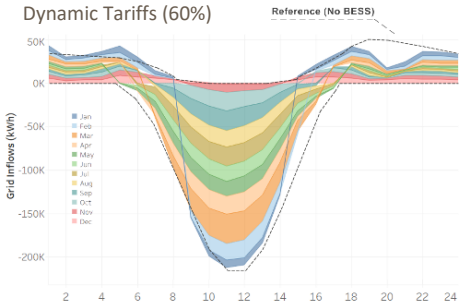


Flat/Dynamic Tariffs

		Margin			
	Tariff Type	0%	33%	50%	60%
NB	Fixed	-	-	-	7254
	Market + %	-23747	-11158	1985	15128
WB	Fixed	-	-	-	3406
	Market + %	-26630	-15600	-4552	6429
EB	Fixed	-	-	-	3848
	Market + %	2883	4442	6537	**8698**

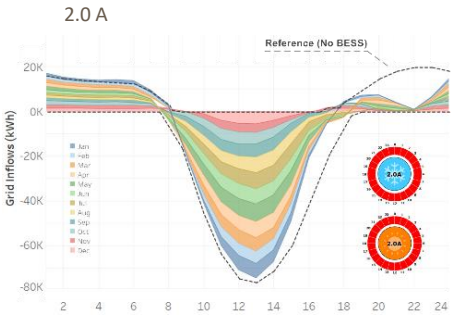


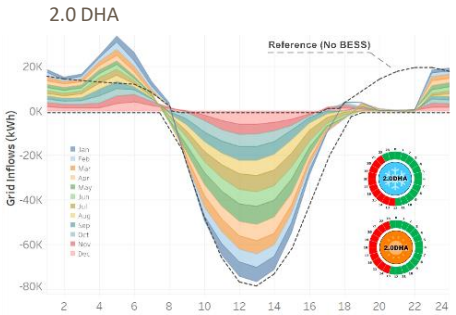


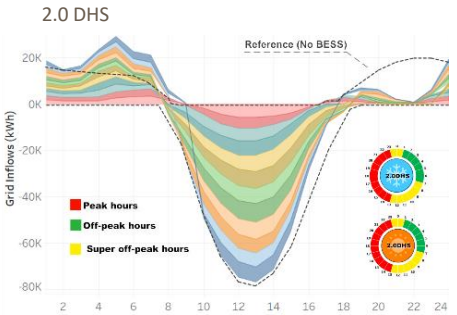


Time-of-Use Tariffs

	2.0A	2.0DHA	2.0DHS
Cost NB (€)	9,958	5364	6619
Cost WB (€)	6979	1068	2041
Economic Benefit (€)	2,979	4,296	**4,578**
Cost decrease (%)	29.9	**80.1**	69.2



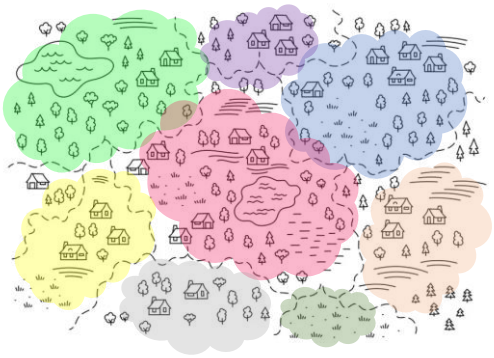




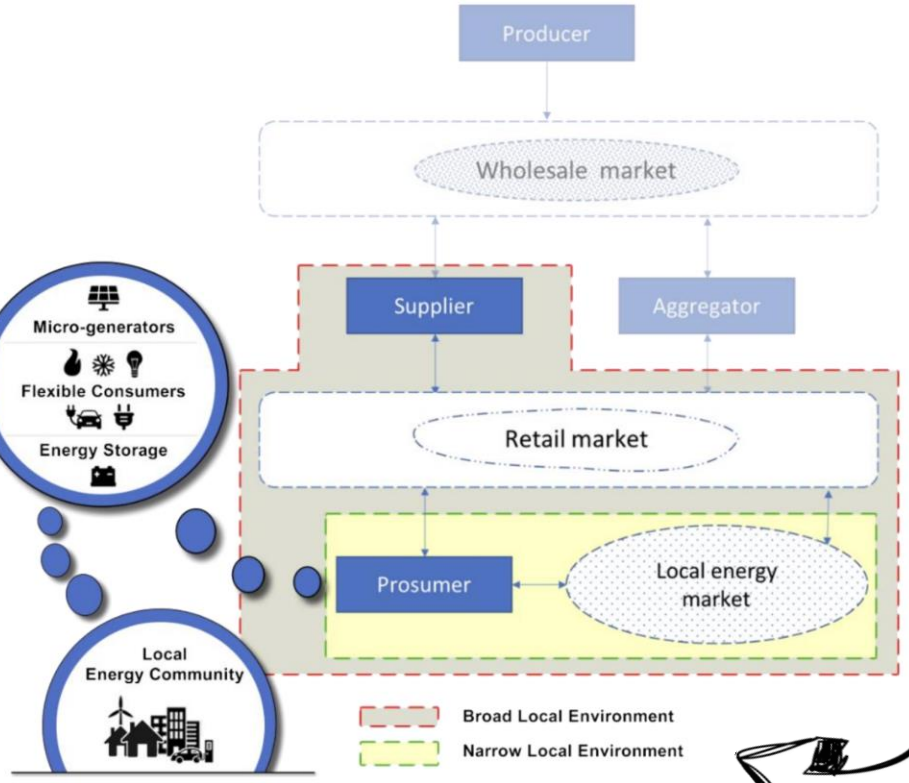
LECs: Case Study A

Each modelling chooses
- Granularity
- Technologies
- Option for common assets

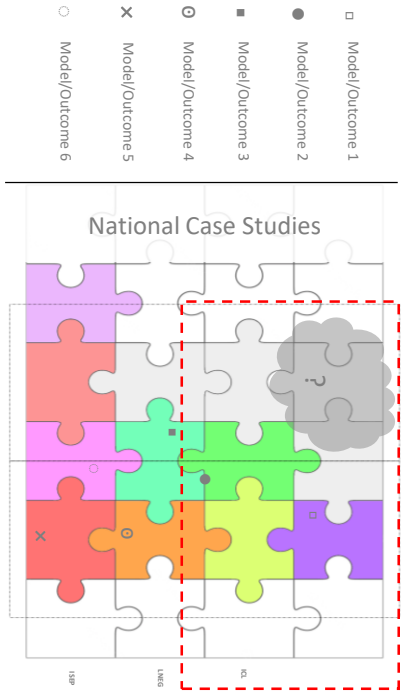
TradeRES T5.2
Artificial benchmark site

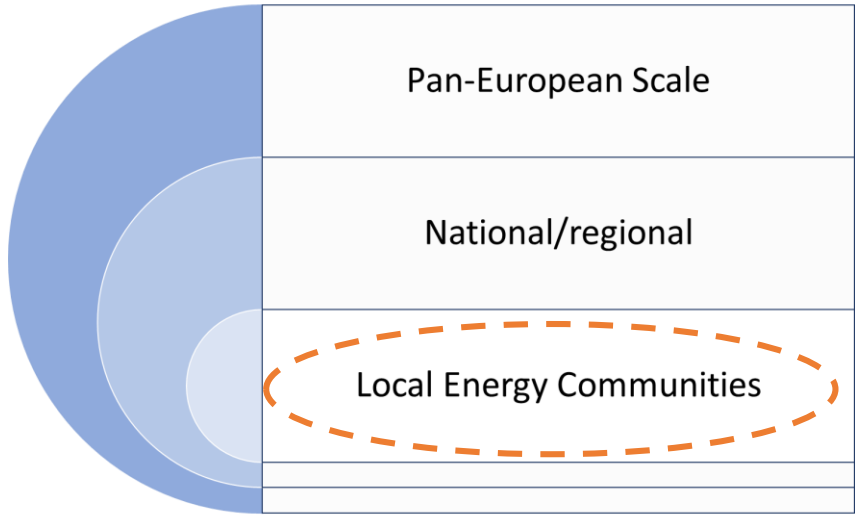


EEM23



Areas of LEM Simulation Framework focus





TradeRES Case Study Scales

General Approach in TradeRES:

First-best outcome through Optimization Models and Social Planner Perspective

VS

Second-best outcome through ABMs and Market (Design) Perspective

Planning of the analysis

Extension to Multi-Energy Micro-Grids ?

	Case	Mechanism	Approach	Knowledge	Privacy	Strategy
A	P2G	Trade with retailer	Optimisation	Yes	No	Static
B	Cen	Centralised	Optimisation	Yes	No	Static
	MMR-Opt	MMR pricing	Optimisation	Yes	No	Static
	MMR-RL	**MMR pricing**	**Learning**	**No**	**Yes**	**Dynamic**
	DA-Opt	Auction	Optimisation	Yes	No	Static
	DA-RL	**Auction**	**Learning**	**No**	**Yes**	**Dynamic**

Final Results

Stage 1
Initial Analysis

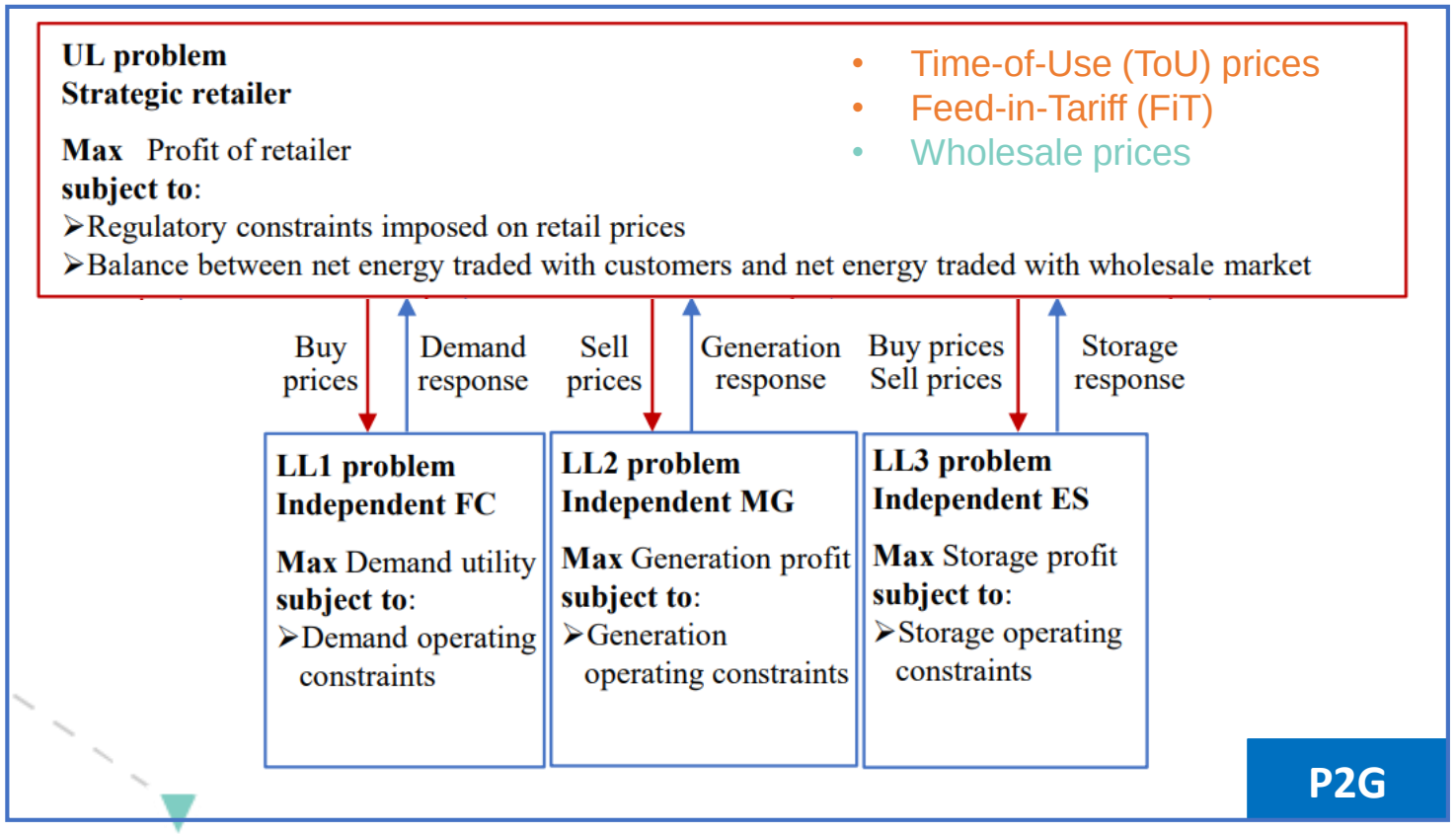
Preliminary Results

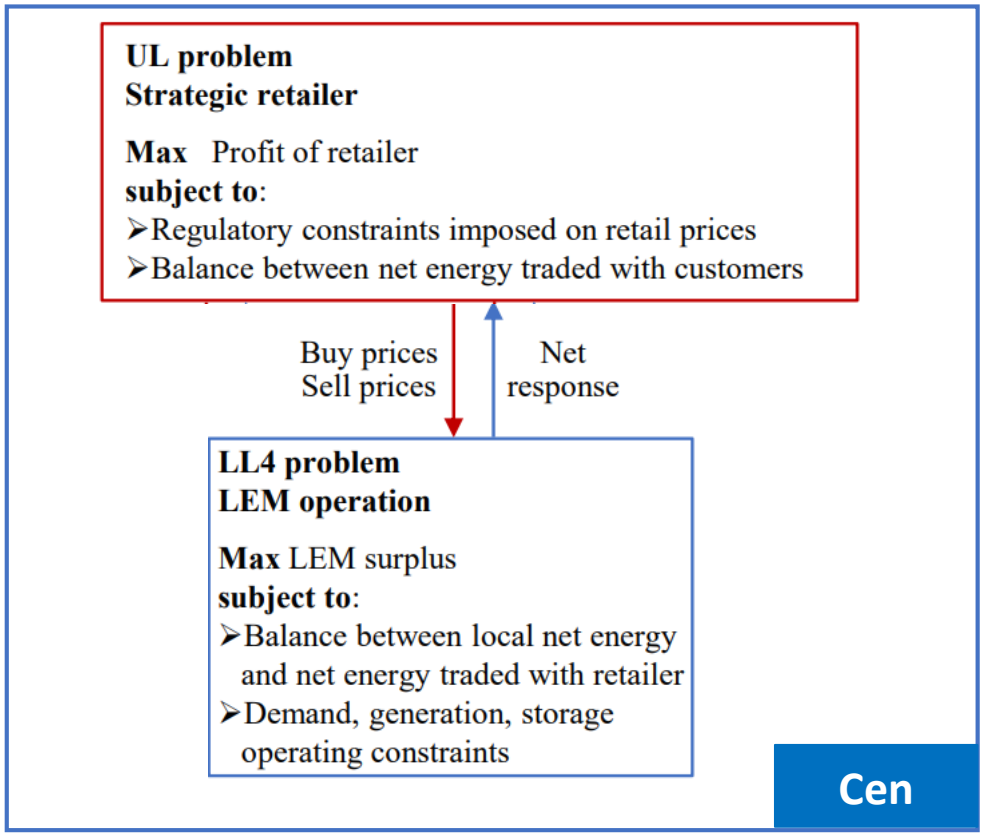
Stage 2
All cases
&
Extensions

Extensions

- ☑ Link with national case studies (specific ToU tariffs and FiT, wholesale prices) – Effects in outcomes
- ☑ Extensions of ToU tariffs to strategic dynamic retailing pricing
  - ○ Effects of market competitiveness level (impact of number of participants)
  - ○ Role of distributed ES to market outcomes

Stage 1 - Overview





"Initial Analysis" Added value:

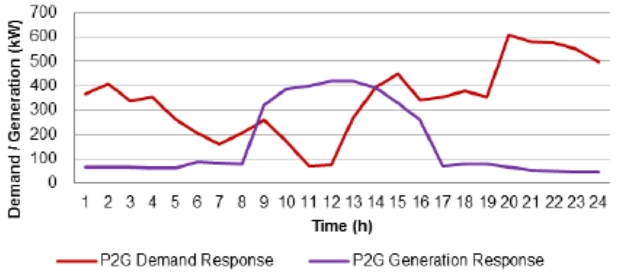
- Strategic retail pricing
- Evaluation of the benefits of DERs participating into local market rather than independently trading with the retailer.

Stage 1 – Subcases / Results (1/3)

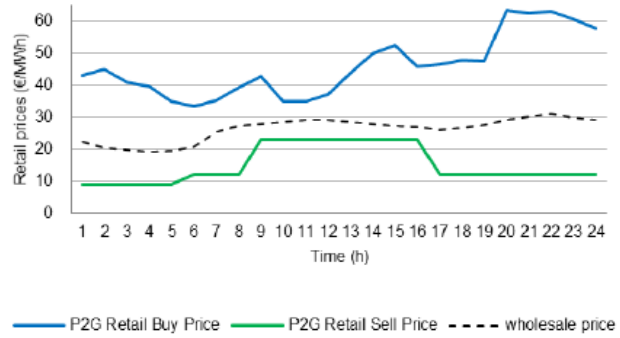
No Local Market – Peer to Grid (P2G)

Simple Version of Dynamic Tariffs

Dem / Gen

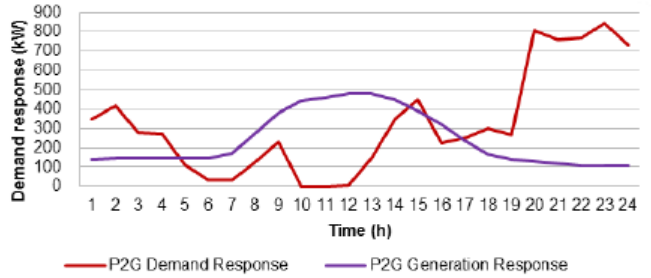


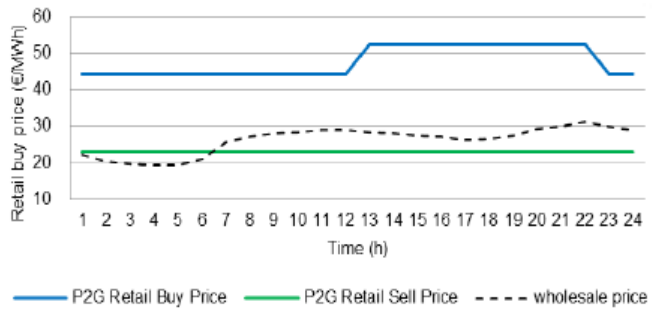
Prices



(DW) 105.77 + (RP) 220.85
=
326.62

ToU and Flat Tariffs





(DW) 146.50 + (RP) 189.62
=
336.12

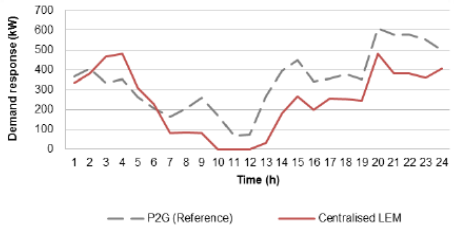
- In the benchmark scenario (w/o LEM), both the demand and generation served by the retailer exhibit the higher values across all hours. This is because in the absence of an LEM, the only option for the customers to buy and sell energy is through the retailer.

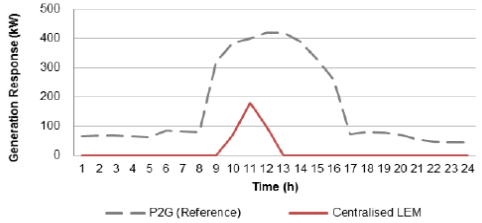
- 1 retailer (monopoly /monopsony)
- Large buy/sell spreads
- Retailer exercises market power
- Dynamic tariffs enhance the market power
- Importance of securing competition in the retail market

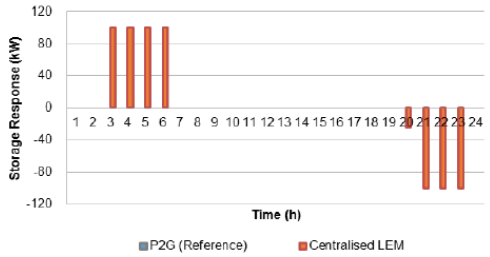
Stage 1 – Subcases / Results (2/3)

Local Energy Market – Centrally managed

Simple Version of Dynamic Tariffs



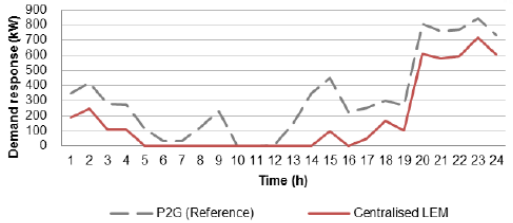


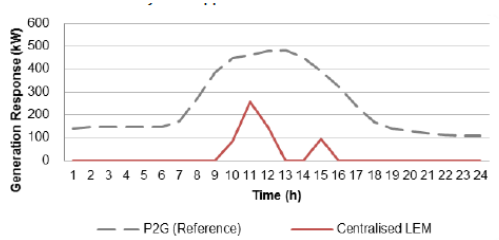


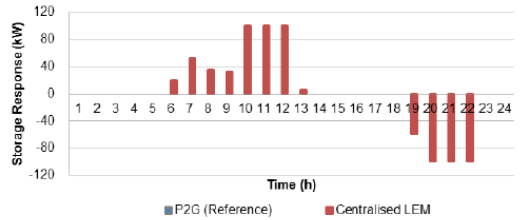
(DW) 105.77 + (RP) 220.85 = 326.62

(DW) 280.61 + (RP) 94.64 = 375.25

ToU and Flat Tariffs







(DW) 146.50 + (RP) 189.62 = 336.12

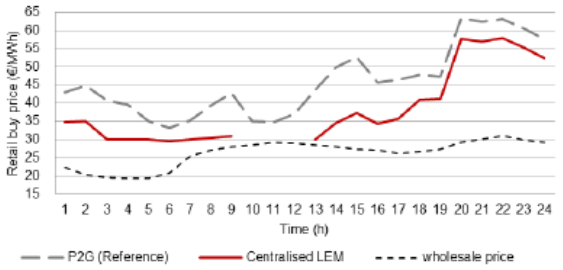
(DW) 317.92 + (RP) 66.28 = 384.2

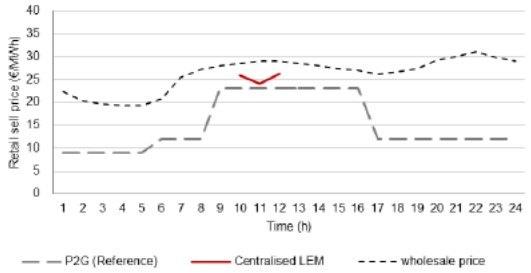
- The dependency of participants on the retailer is limited; both the demand and generation served by the retailer are significantly reduced.
- Storage response, facing the LEM clearing prices that enable arbitrage
- Introduction of LEM transferred welfare to DERs and increased the overall SW

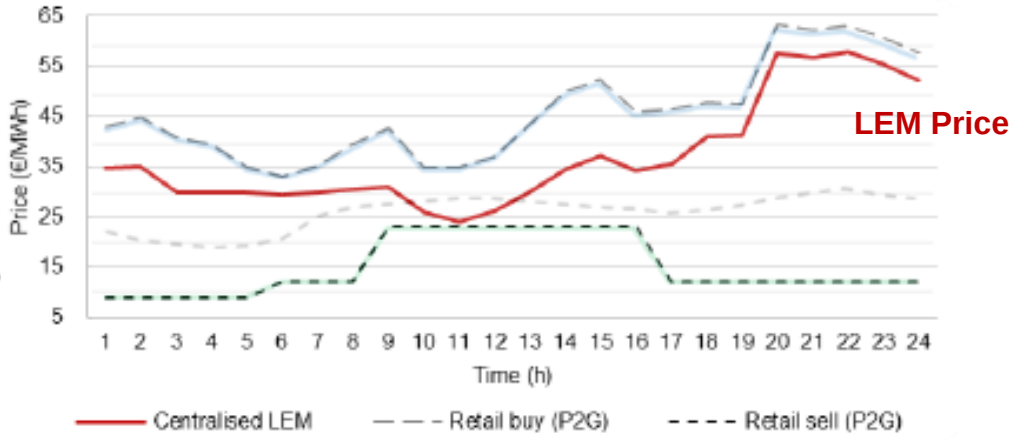
Stage 1 – Subcases / Results (3/3)

Local Energy Market – Centrally managed

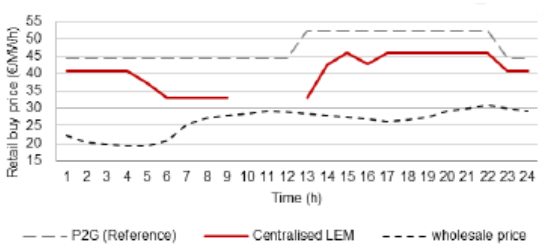
Simple Version of Dynamic Tariffs

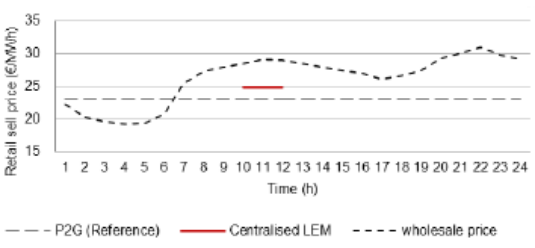


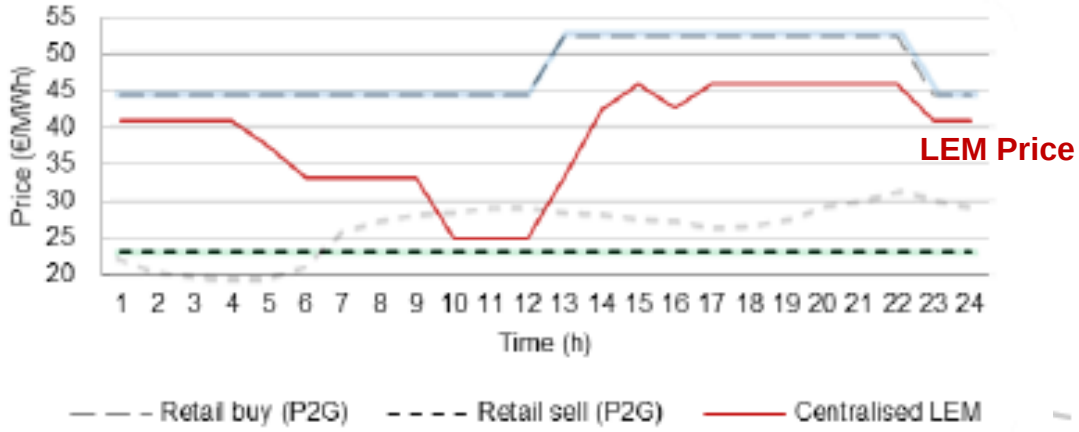




ToU and Flat Tariffs

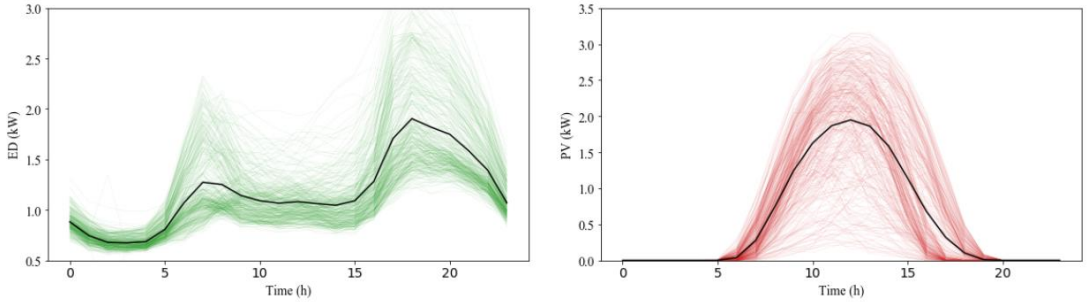






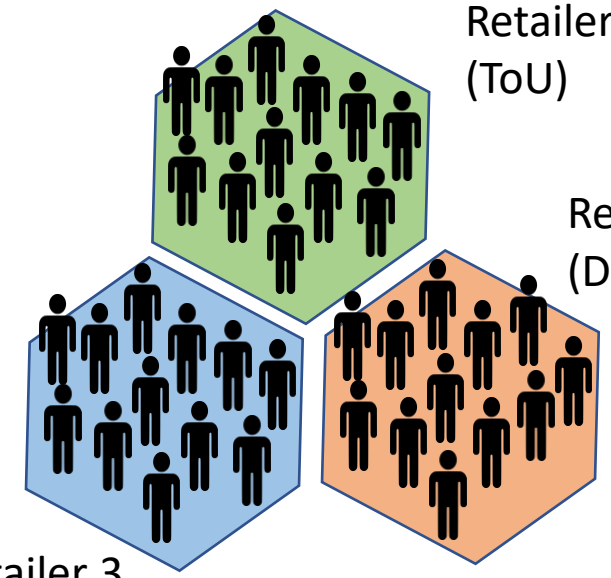
Stage 2 – Preliminary results

- 300 Prosumers Input Data



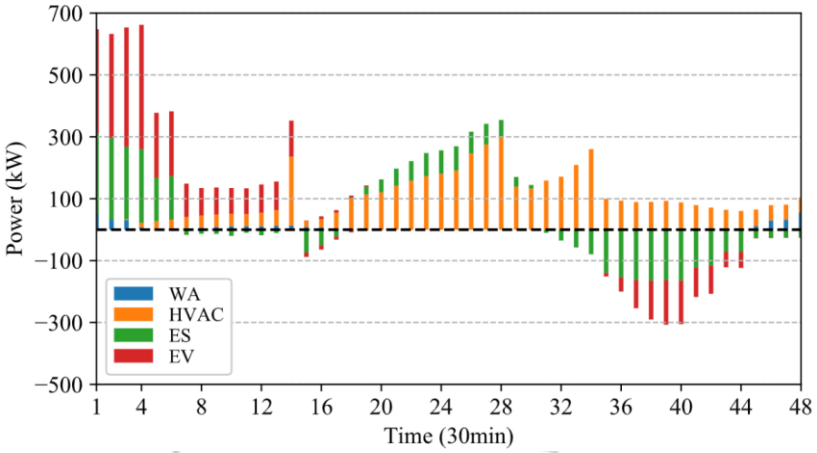
Random or Dynamic

Allocation

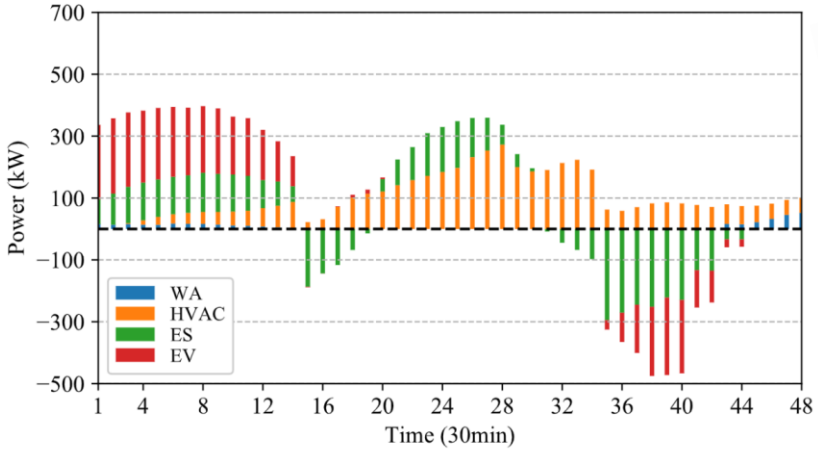


- Preliminary results: Dispatch of Flexible DERs (with/without LEM)

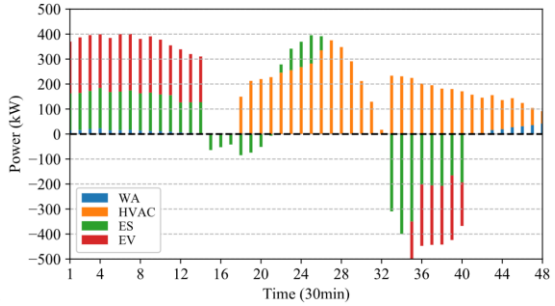
Without the LEM



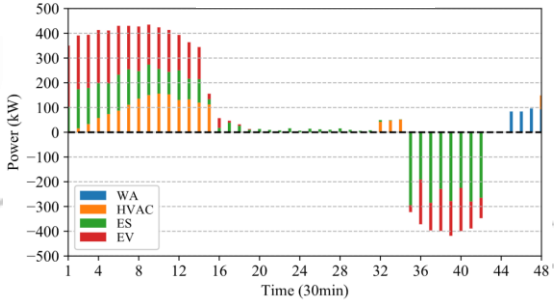
With the LEM



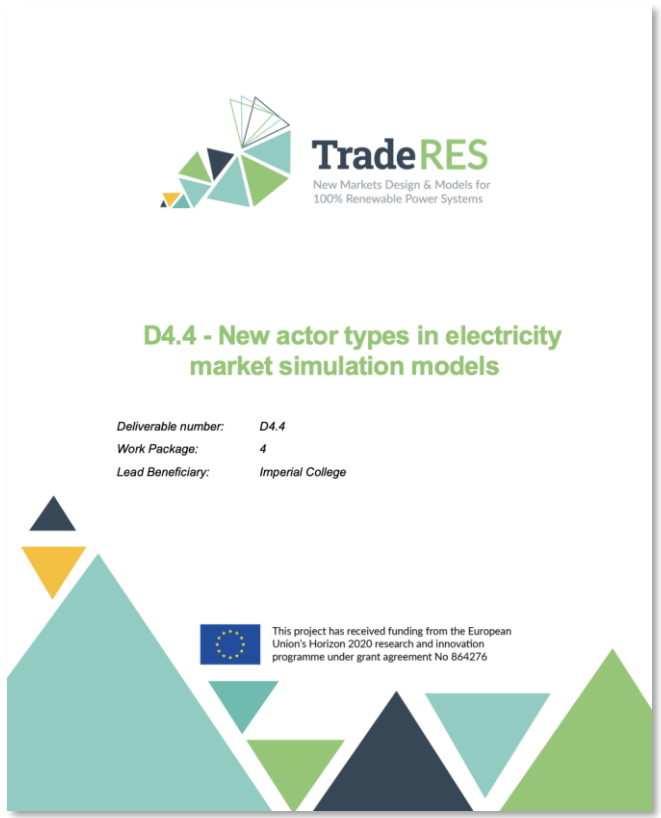
Summer

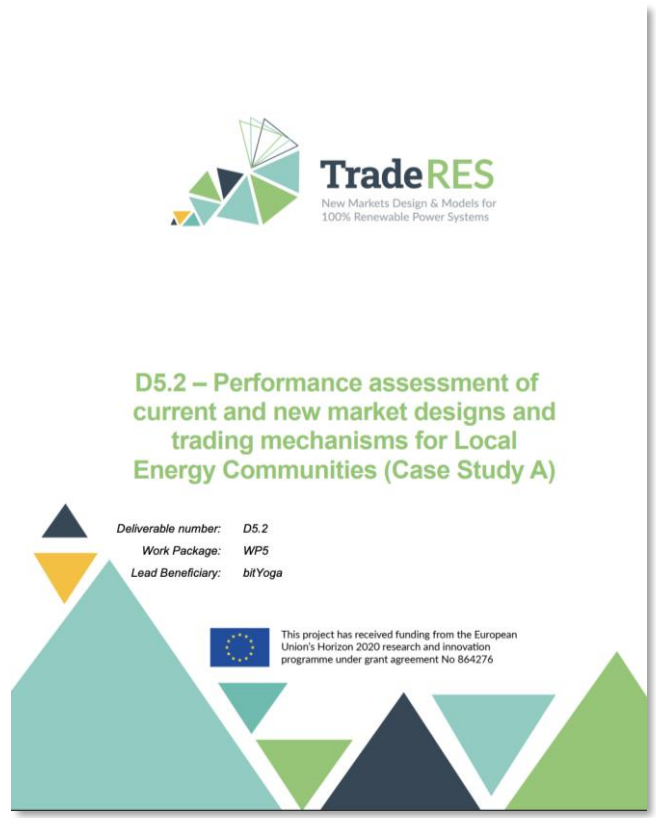


Winter



References





https://traderes.eu/documents/