



## Workshop on “Energy Communities: Operational and Functional Needs”

*University of Cyprus, Nicosia - May 8<sup>th</sup>, 2019*

Empowered Energy Communities  
enabled by Flexibility Trading  
and Dynamic Coalition Managers



[www.eera-set.eu](http://www.eera-set.eu)

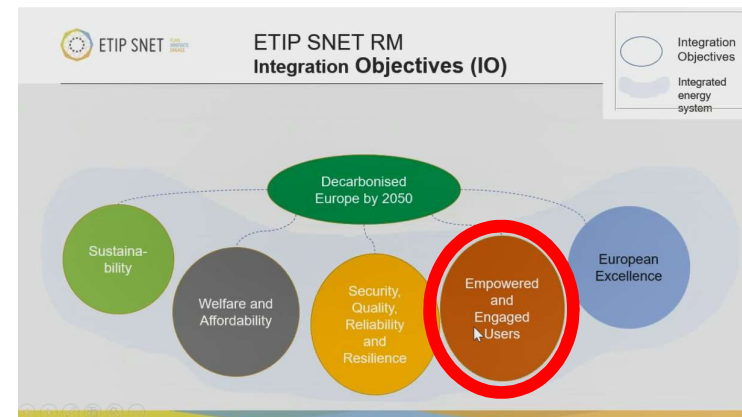
5/13/2019

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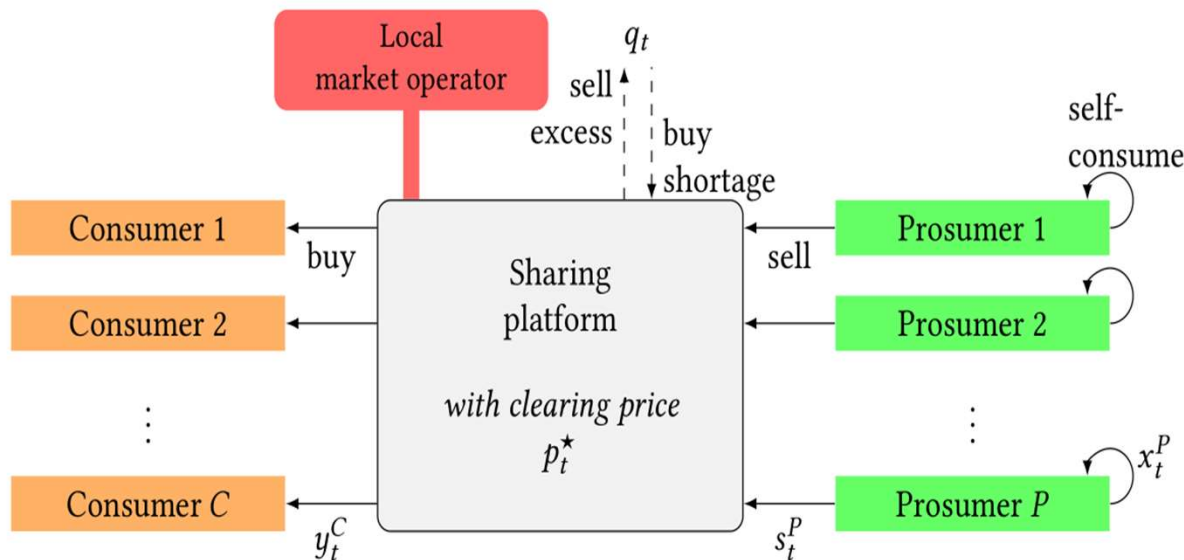


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- Clean Energy for all Europeans
  - Active and Empowered citizens / prosumers
  - (Local) Energy Communities



## Communal Demand-Supply Matching Business Model



*Equilibrium-based formulation of a two-sided local market*

where **consumers** have **preferences** towards characteristics of the products (RES-based generation, locality, etc.)

and are matched with the **prosumers**

## Mathematical formulations

$$U_C(y_t^C) = -\eta^C (y_t^C - y_t^{C\#})^2 + \tilde{\eta}^C$$

↑ Usage of demand  
-> to be maximised

↑ Target demand  
for a given hour

$$U_C^{Loc}(y_t^C) = -\eta_{Loc}^C \left( \sum_{P \in \mathcal{P}} \alpha_{Loc}^{CP} y_t^C - \xi_{Loc}^C y_t^{C\#} \right)^2 + \tilde{\eta}_{Loc}^C$$

$$U_C^{RES}(y_t^C) = -\eta_{RES}^C \left( \sum_{P \in \mathcal{P}} \alpha_{RES}^{CP} y_t^C - \xi_{RES}^C y_t^{C\#} \right)^2 + \tilde{\eta}_{RES}^C$$

↑ Preferences of consumer  
towards a producer P

↑ Share of demand that  
should come from RES or  
local generation

$$\tilde{U}_C(y_t^C) = w_{Loc} U_C^{Loc}(y_t^C) + w_{RES} U_C^{RES}(y_t^C) + w_0 U_C(y_t^C)$$

↑ Preferences of consumer towards  
individual product characteristics

↑ Matching probability

$$\mu(y_t, s_t) := \min \left\{ \frac{\sum_{C \in \mathcal{C}} y_t^C}{\sum_{P \in \mathcal{P}} s_t^P}, 1 \right\}$$

↓ Uniform price paid at the market

$$\begin{aligned} \max_{y_t^C} \quad & \Pi_C(y_t^C) = \tilde{U}_C(y_t^C) - p_t^* y_t^C \\ \text{s.t.} \quad & y_t^C \leq \kappa^C, \quad (\psi_t^C) \\ & 0 \leq y_t^C. \quad (\tilde{\psi}_t^C) \end{aligned}$$

Similar problem for Prosumer

Self-consumption

Sold energy

H. Le Cadre, E. Rivero Puente, H. Hoschle, Consensus Reaching with Heterogeneous User Preferences

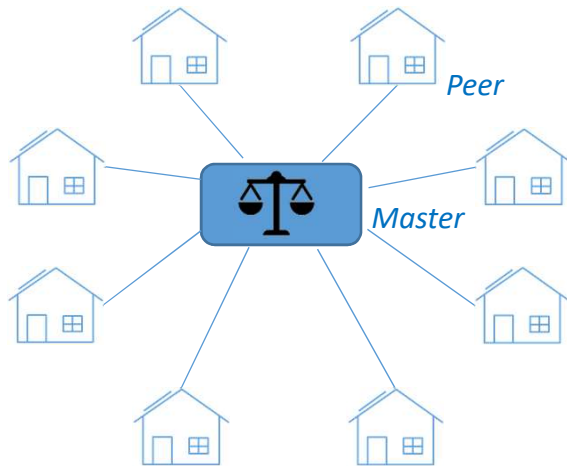
- [https://www.researchgate.net/publication/331149900\\_Consensus\\_Reaching\\_With\\_Heterogeneous\\_User\\_Preferences](https://www.researchgate.net/publication/331149900_Consensus_Reaching_With_Heterogeneous_User_Preferences)

- Published in book : Theory and Applications of Morels of Computation, DOI : 10.1007/978-3-030-16989-3\_11, 2019.

- Consensus Reaching (for matching) Strategies

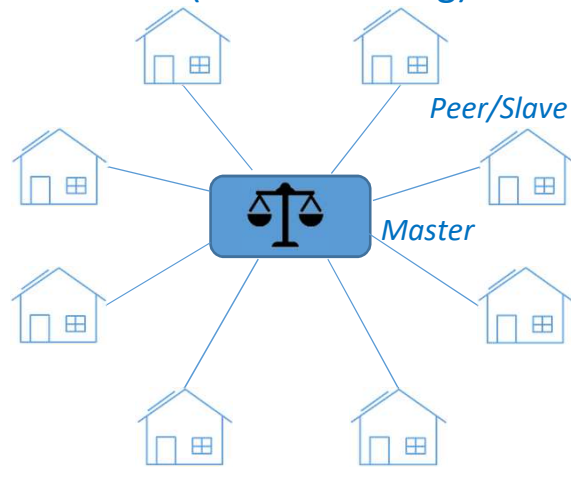
## Centralized\*

(bid  $\Rightarrow$  clearing)

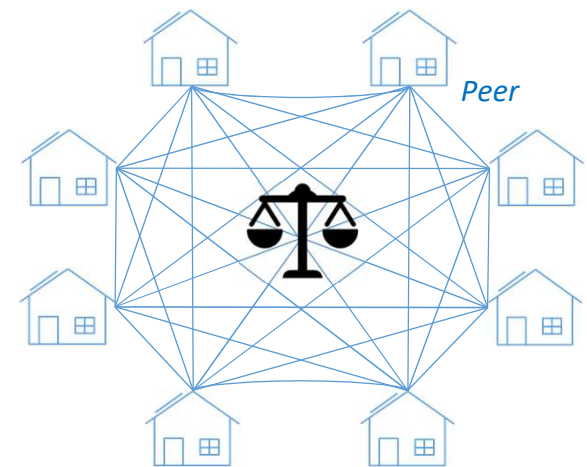


## De-centralized\*

(bid  $\overset{n}{\Leftrightarrow}$  clearing)



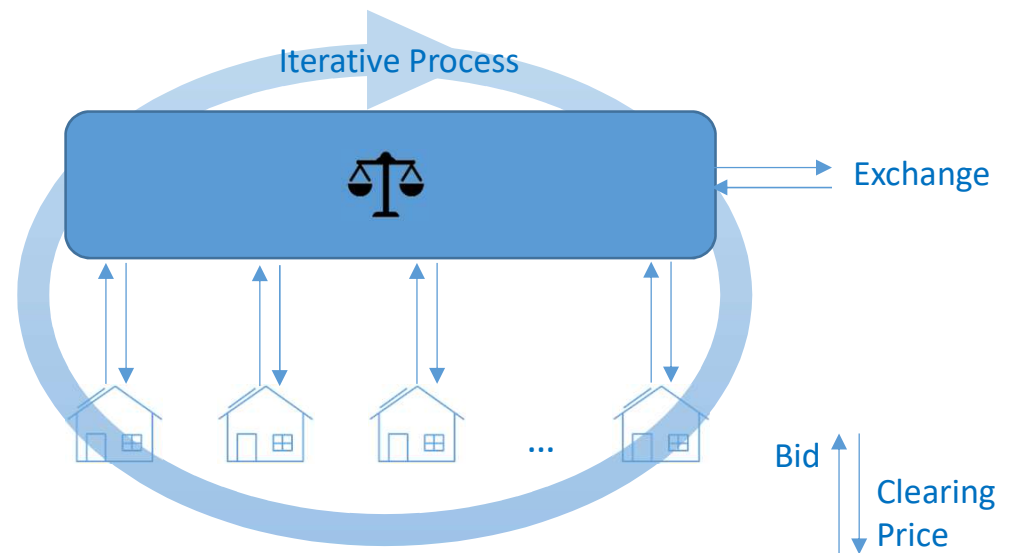
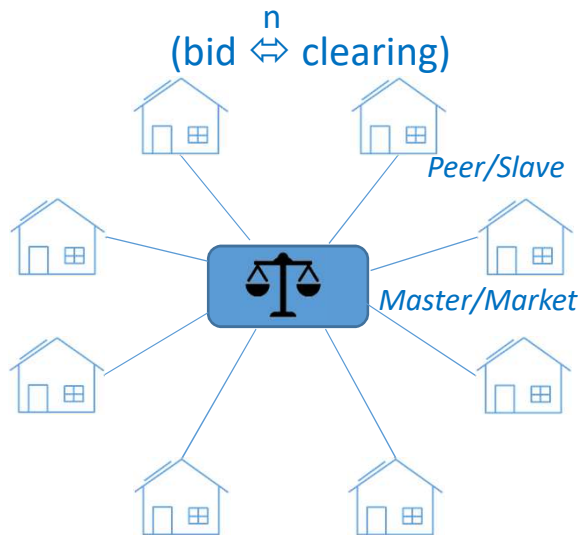
## Distributed (P2P)



\* in the community

- De-centralized matching: e.g. ADMM (Alternating Direction Method of Multipliers)

## De-centralized



- Matching Approaches
  - Central (middle-man, all relevant information)
  - De-central (middle-man, limited information + iterations)
    - Privacy & Complexity
  - Distributed (no middle-man) ... truly P2P
- Centralized / De-centralized assume a middle-man
  - Trust ? Service fee ?
  - Independent actor/ESCO ⇔ One of the peers
  - Distributed Consensus on which peer assumes the middle-man role
    - (blockchain) 'mining': Proof-of-Work / Proof-of-Stake / Proof-of-Authority

- Demand-Supply Equilibrium/Matching → ‘any’ objective
  - Peak-shaving, self-consumption, ...
  
- Community
  - peers improve their own objective by leveraging capabilities of others
  - coordinated optimization for a collective objective
  
- Flexibility Trading ⇔ (explicit) Demand Response



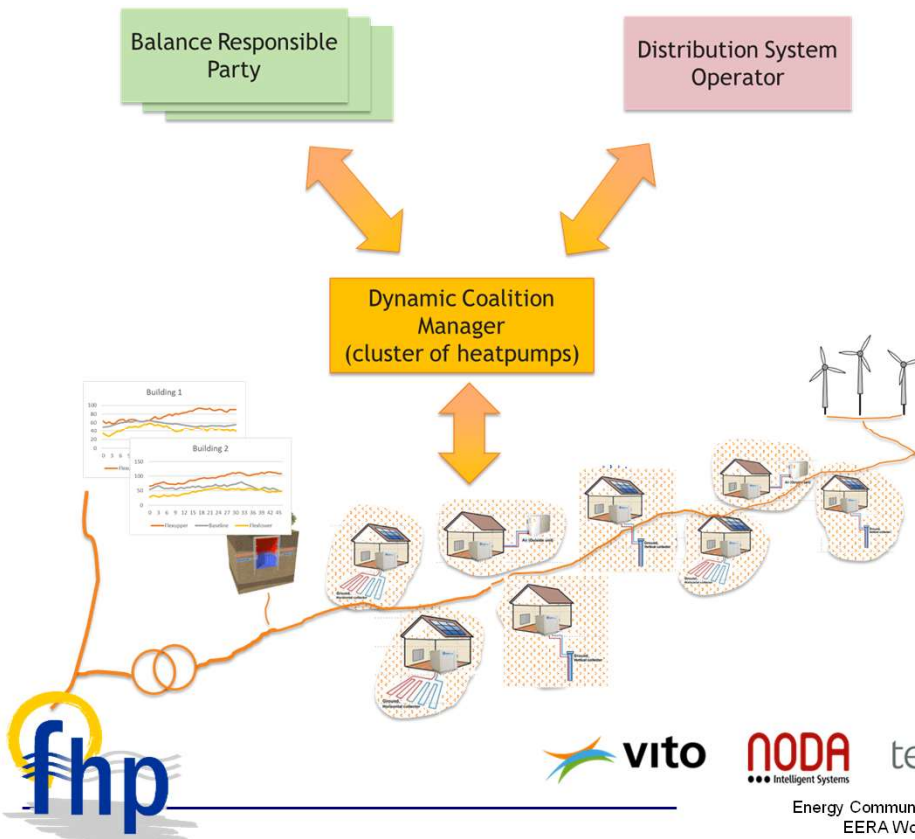
## Flexibility Trading versus Demand Response

### ■ Explicit Demand Response

- Ad-hoc request by Flex Needer (e.g. Aggregator)
- Flex Needer decides when, how much, from whom
- Conditions contractually agreed between Flex Owner and Flex Needer
- Flex Needer is in the lead

### ■ Flex Trading

- Dynamic trading by Flex Owner
- Flex Owner decides when, how much and under which conditions
- To one or multiple Flex Needers or a Flex Market Platform
- Empowered Flex Owner is in the lead



## Flexible Power and Heat

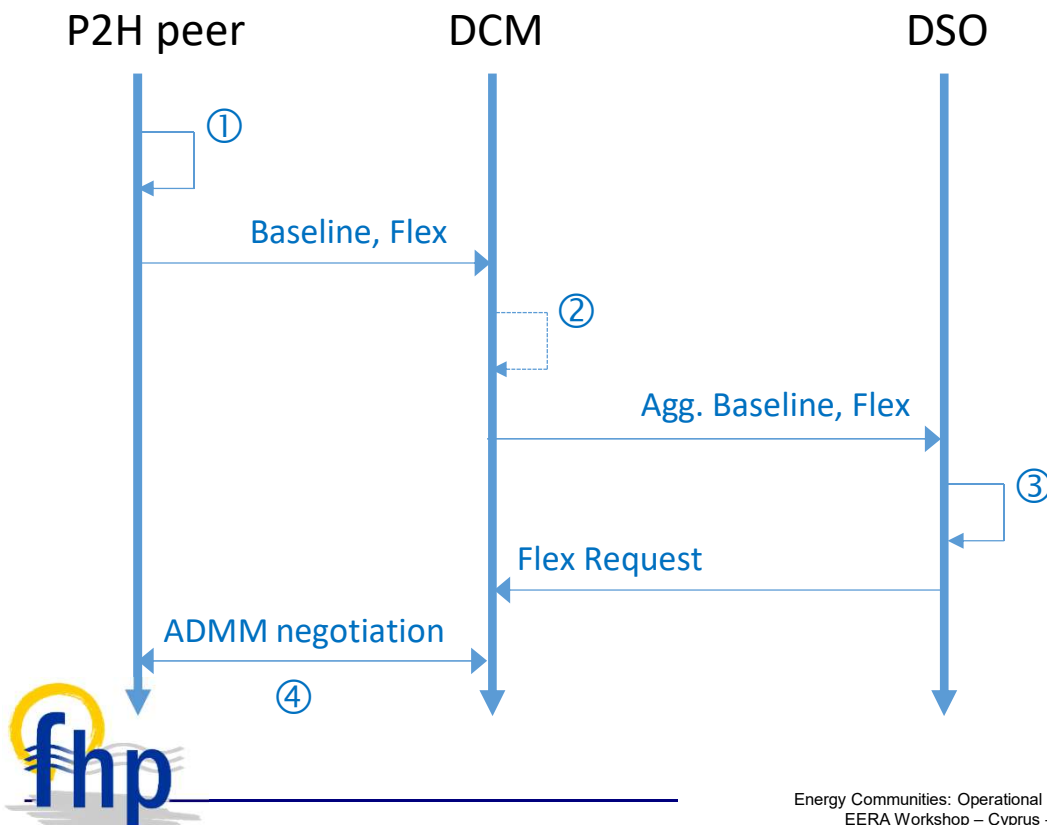
Managing community/collection of **active empowered** P2H resources

- Buildings with HP
- Large seasonal Thermal Storage, charged by HP

## Communal Flexibility Trading

- Local and system level services
- Grid-aware flex activations
- De-centralized consensus reaching

# Communal Flexibility Trading – FHP approach

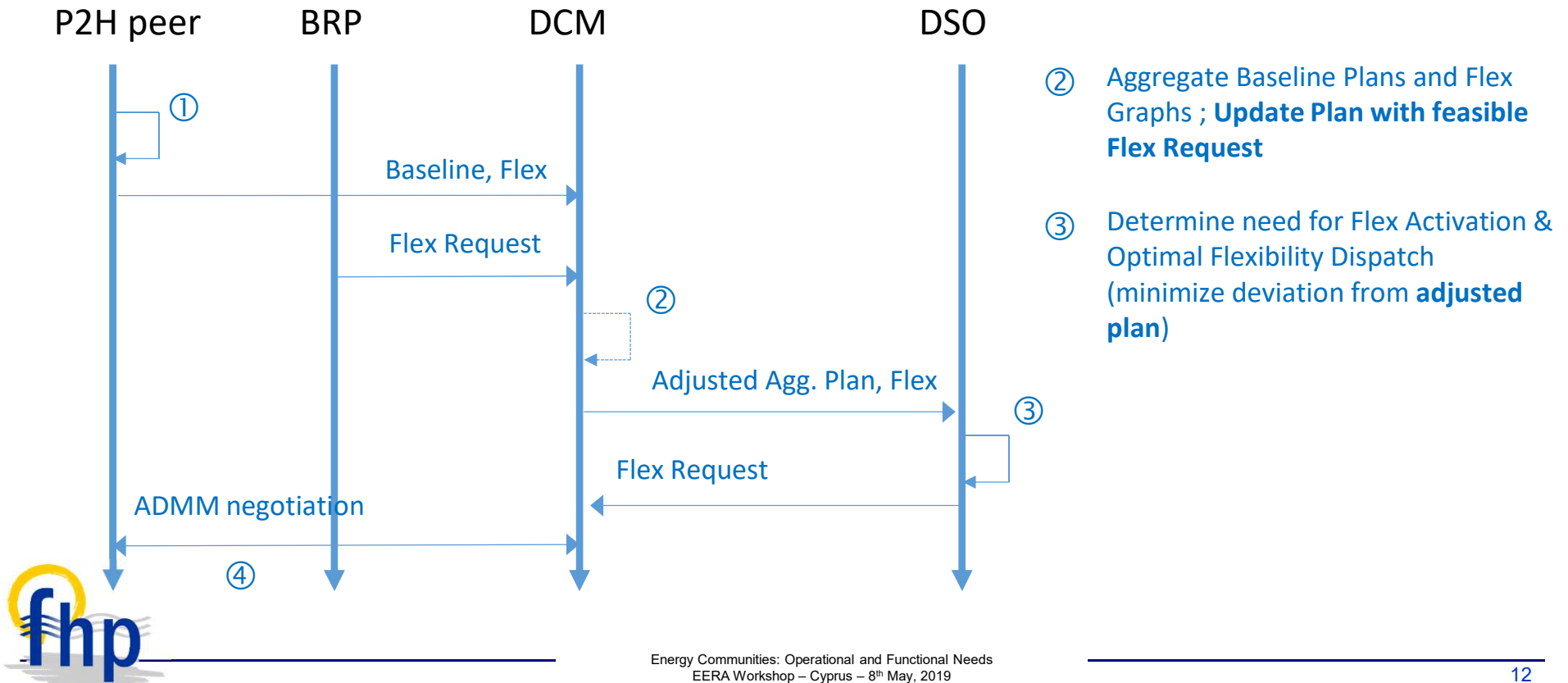


- ① Determine Optimal Baseline plan (e.g. Implicit DR) and flex (e.g. Flex Graph)



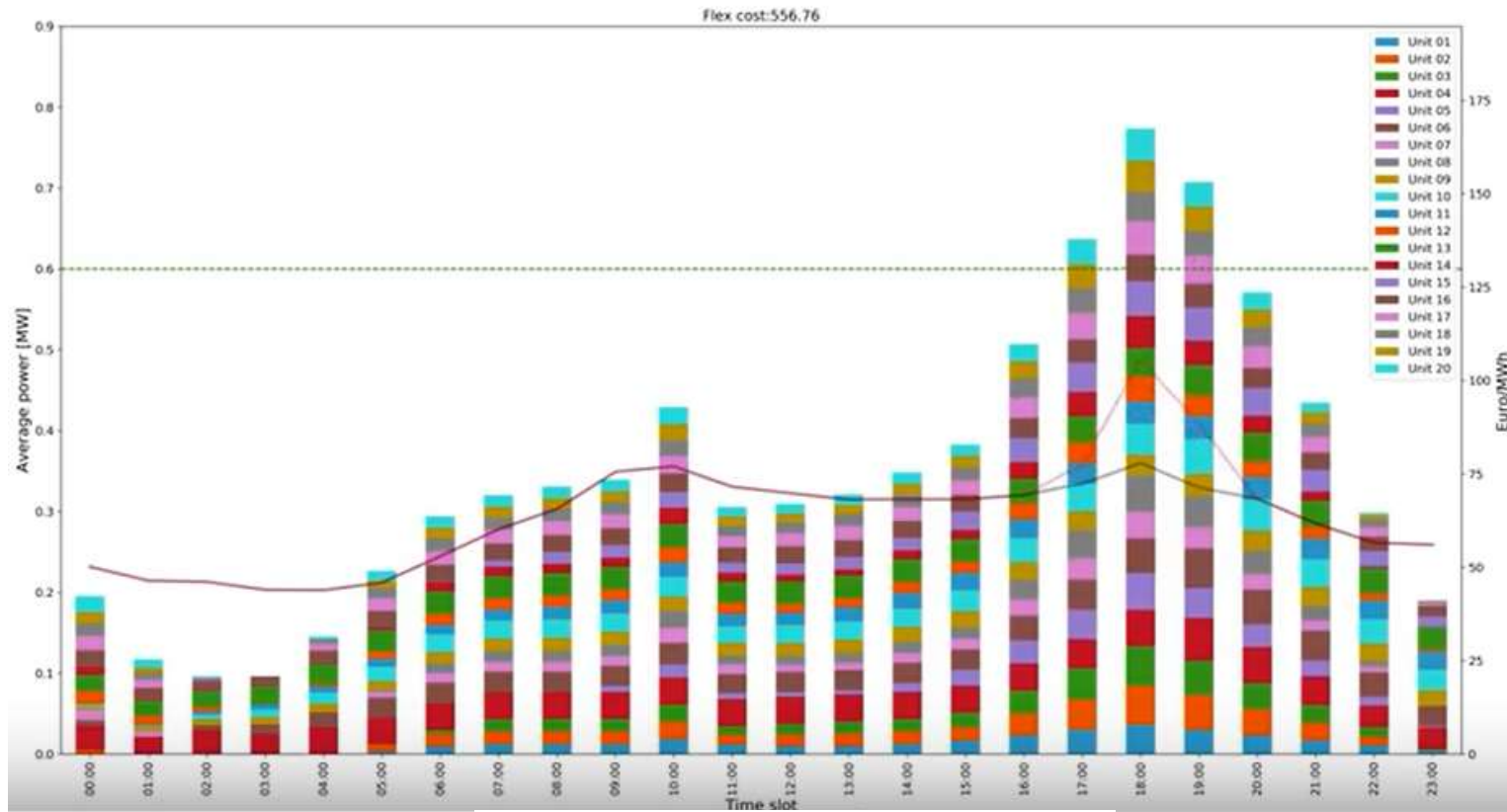
- ② Aggregate Baseline Plans and Flex Graphs (optionally: cluster level optimization)
- ③ Determine need for Flex Activation & Optimal Flexibility Dispatch (minimize curtailment, minimize losses)
- ④ Disaggregate Optimal Flex Activation (minimize deviation and cost)

# Communal Flexibility Trading – FHP approach

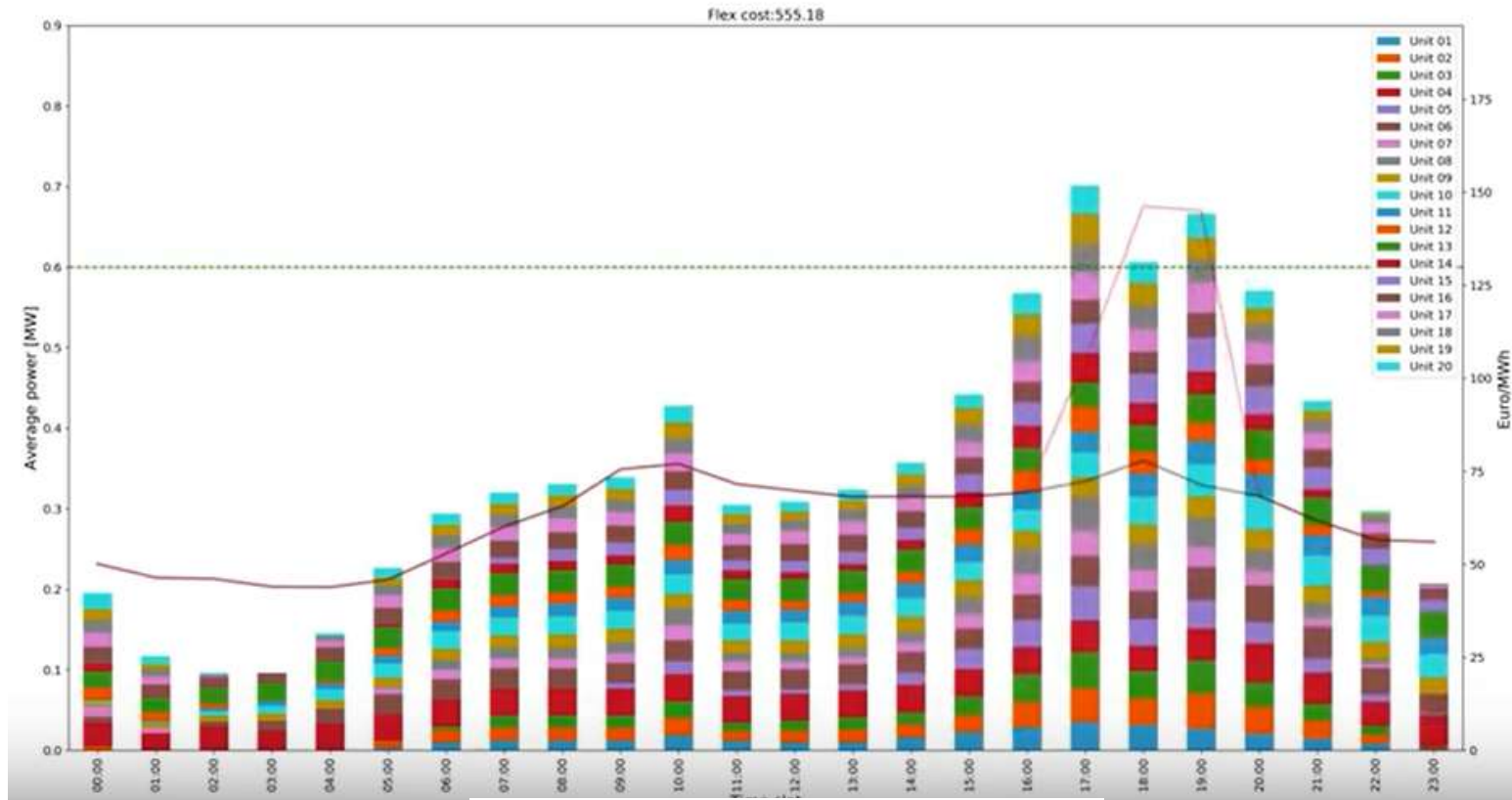


# De-centralized Optimization

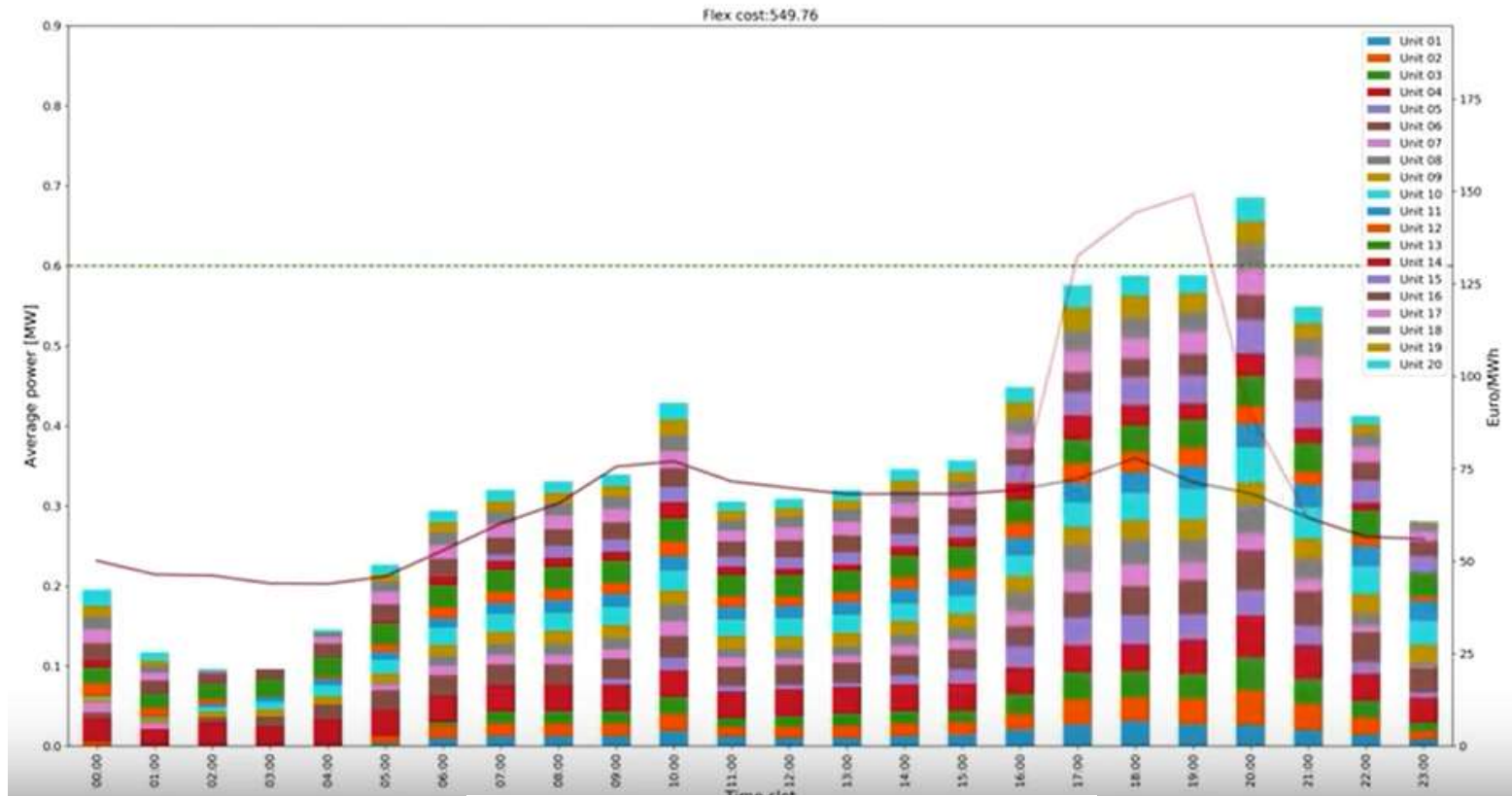
## Starting point



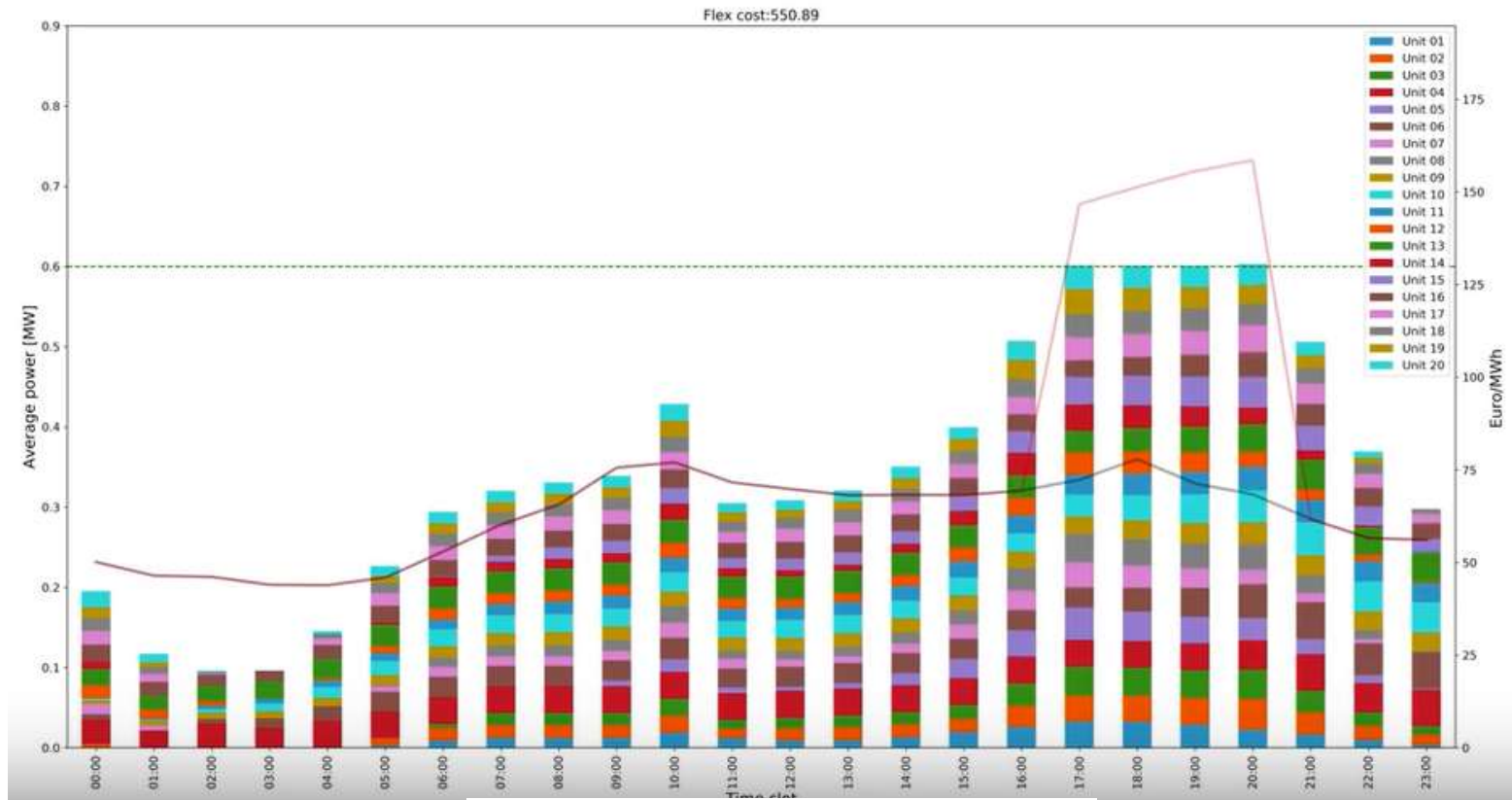
# De-centralized Optimization Intermediate 1



# De-centralized Optimization Intermediate 2

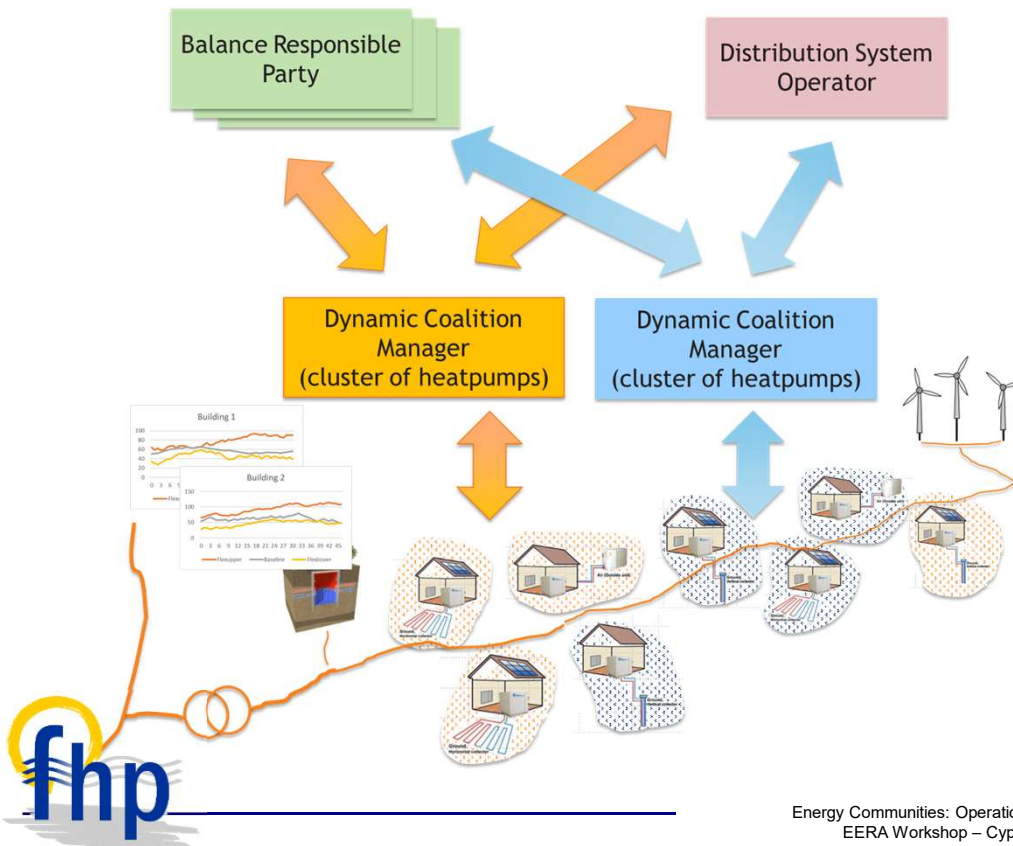


# De-centralized Optimization Final result





# Communal Flexibility Trading: Competition through Dynamic Coalitions

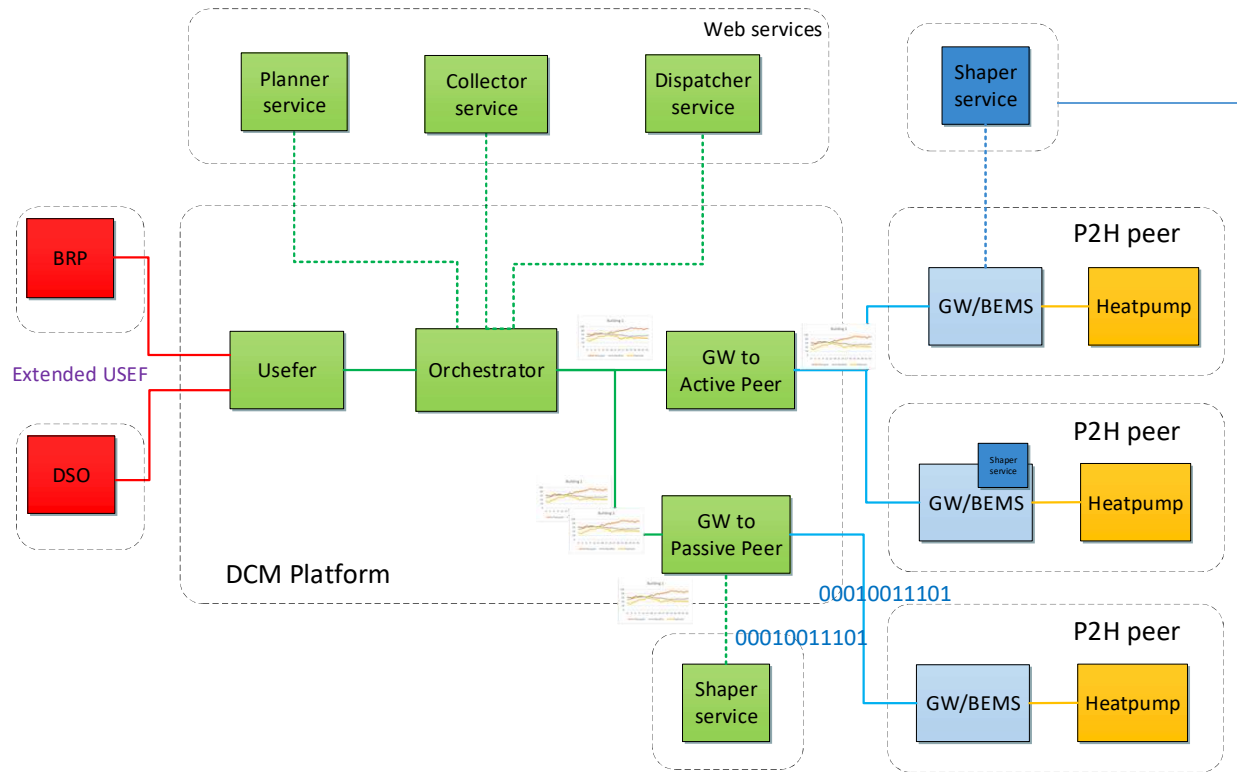


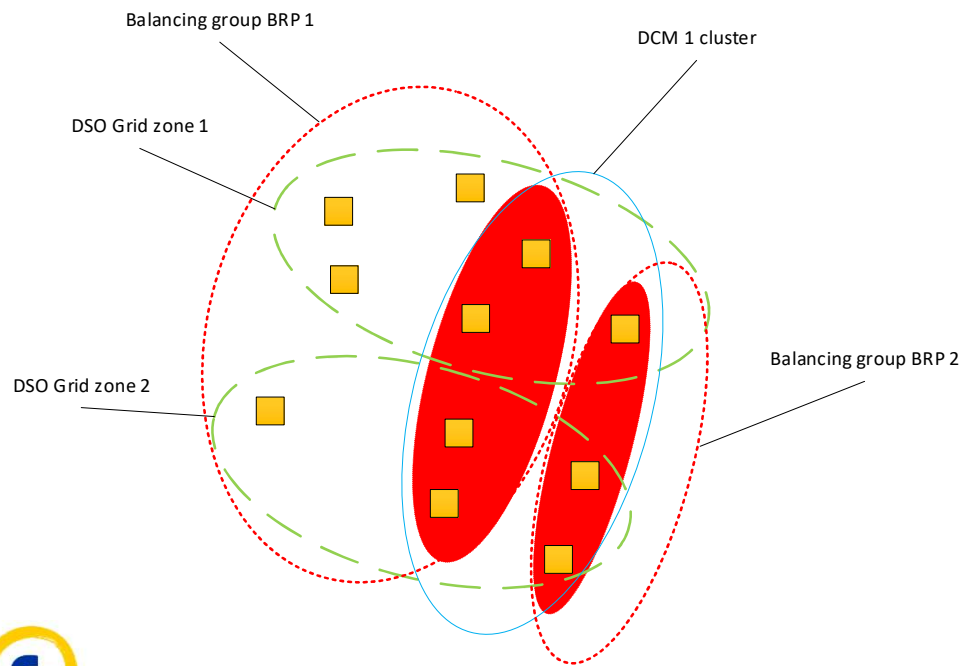
Flex Trading enables a dynamic competition between ‘Aggregators’

‘Aggregators’ have dynamic pool of assets

- All needed info provided by the assets themselves (Flex Trading)

# Communal Flexibility Trading: FHP Multi-agent platform





At any given moment, an active (e.g. participating in trading) peer belongs to:

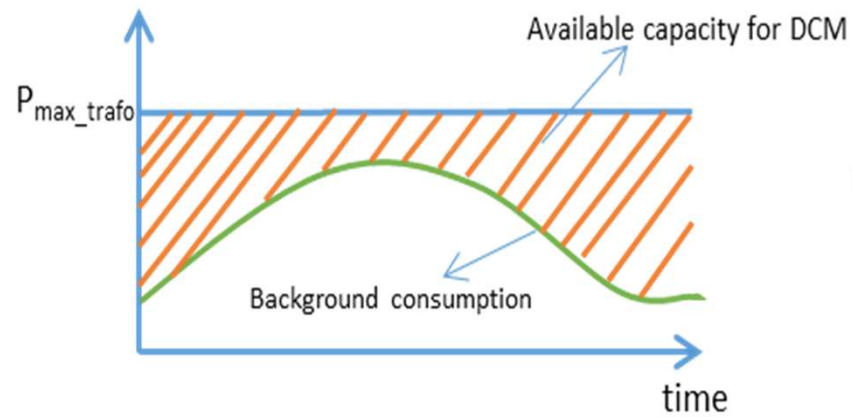
- one **balancing group** (**static**: retailer contract)
- one **grid zone** (**semi-static**: grid-state dependent)
- one **DCM** (**dynamic**: best incentive)

- Location aware activations of distribution-grid connected flexibility
  - Grid is no copper plate
  - Ensure activations of flexibility will not cause grid problems
    - Local activations for solving local problems
    - Local activations for solving system level problems
  - Make optimal use of available assets and available grid infrastructure and capacity

- Example 1: USEF\* (Universal Smart Energy Framework)
  - Aggregator/DCM informs DSO about (plan +) flex activation plan
  - DSO checks the plan + planned flex (Powerflow Check)
  - Flex Request to Aggregator if needed
    - What times to increase/reduce how much to solve the problem → shift
    - Constraints at other times (so no new problems are created)
  - Aggregator updates flex activation plan
  - (iterations)

\*<https://www.usef.energy>

- Example 2: Dynamic Safe Band
  - DSO provides Dynamic Safe Band to DCM/Aggregator
  - DCM has freedom to operate within this safe band



- Example 3: FHP DSO **Optimal Flexibility Dispatch**
  - Inspired by USEF, but increased DSO empowerment
  - DCM informs DSO about (plan +) flex activation plan
  - **DCM informs DSO about flexibility (Flex Graph)**
  - DSO checks the plan + planned flex activation (Powerflow Check)
  - **Optimal Flexibility Dispatch** if needed
    - DSO uses knowledge of available flexibility to determine optimal Flex Activation (→ proposal to DCM) (*not merely solving the problem*)
  - DCM updates flex activation plan

- Active consumers/prosumers (for energy and flex trading)
  - Modelling and Forecasting, Flex Characterization, Optimal Planning
- Communal consensus reaching approach and platform
  - Privacy and Complexity
  - Decentralized or Distributed
  - Middle-man ? Trust ?
- Location (grid) awareness: importance of DSO role
  - Reactive ⇔ Proactive (aDSM → ADSM ?)
  - Avoid/solve problem ⇔ Optimal use of grid and flex resources



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# CONTACT INFORMATION

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