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Distributed Energy Resources Flexibility in a Multi-Carrier Energy System Environment

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Distributed Energy Resources Flexibility in a Multi-Carrier Energy System Environment

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Develop methods for aggregated simulation. Investigate methods for classification and aggregation of energy components (DERs), including the network and associated constraints, and express the technologies at more generic, statistical and scalable levels.

Project description

Develop methodologies and ICT solutions for the analysis, operation and development of fully integrated urban energy systems. A holistic research approach will be developed that aims to provide solutions at all levels between the appliance and the total system, and at all time scales between operations and planning.
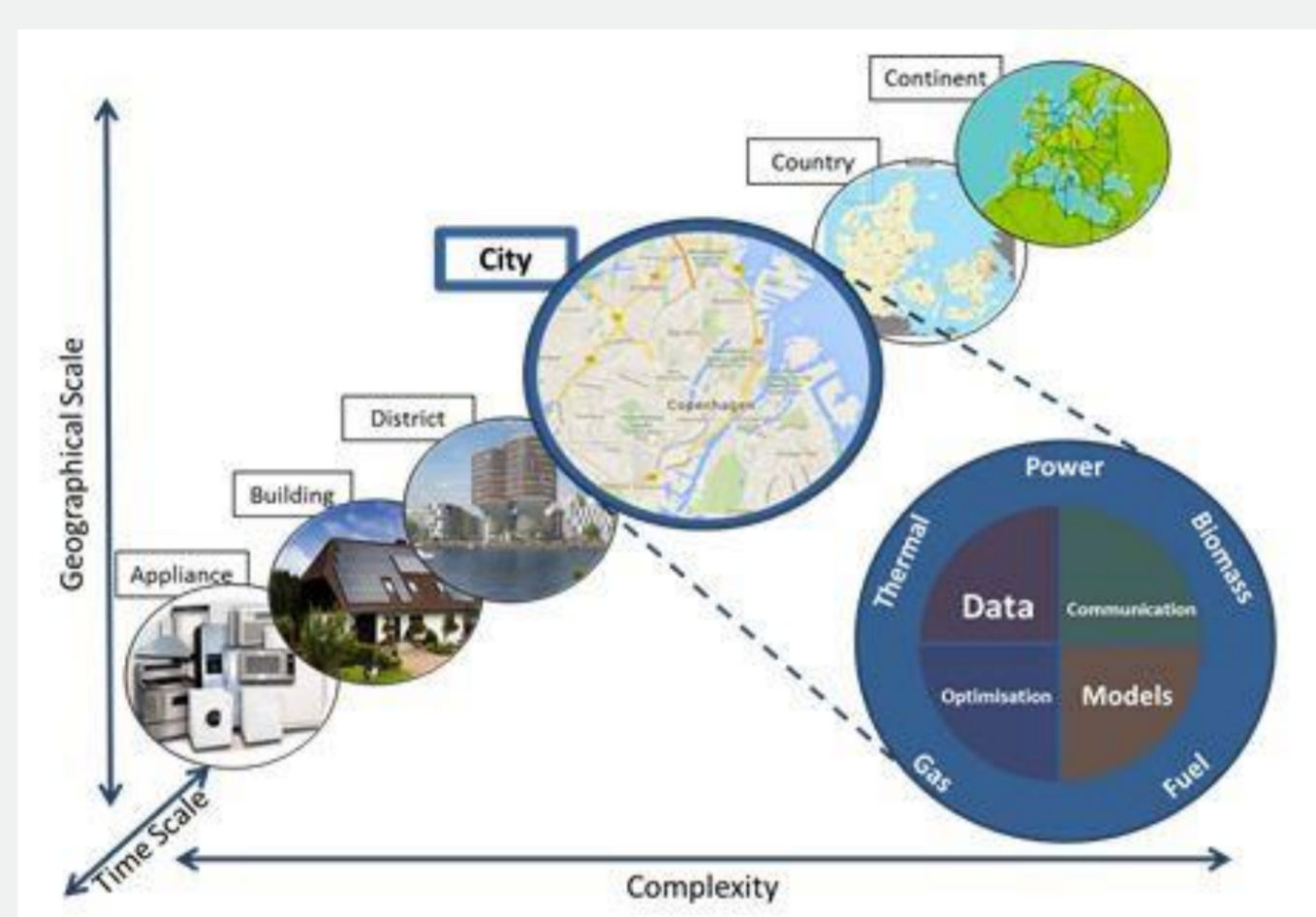

CITIES, aims at tackling the deficiencies related to Smart Grid. Its research activities supports the Danish target of a 100% renewable energy system by establishing an **integrated research** center covering all aspects of the energy system, **including gas, power, district heating/cooling and biomass**, and most importantly methods to forecast, control and optimize their interactions through the use of advanced ICT solutions.

Centralized   Distributed   Decentralized
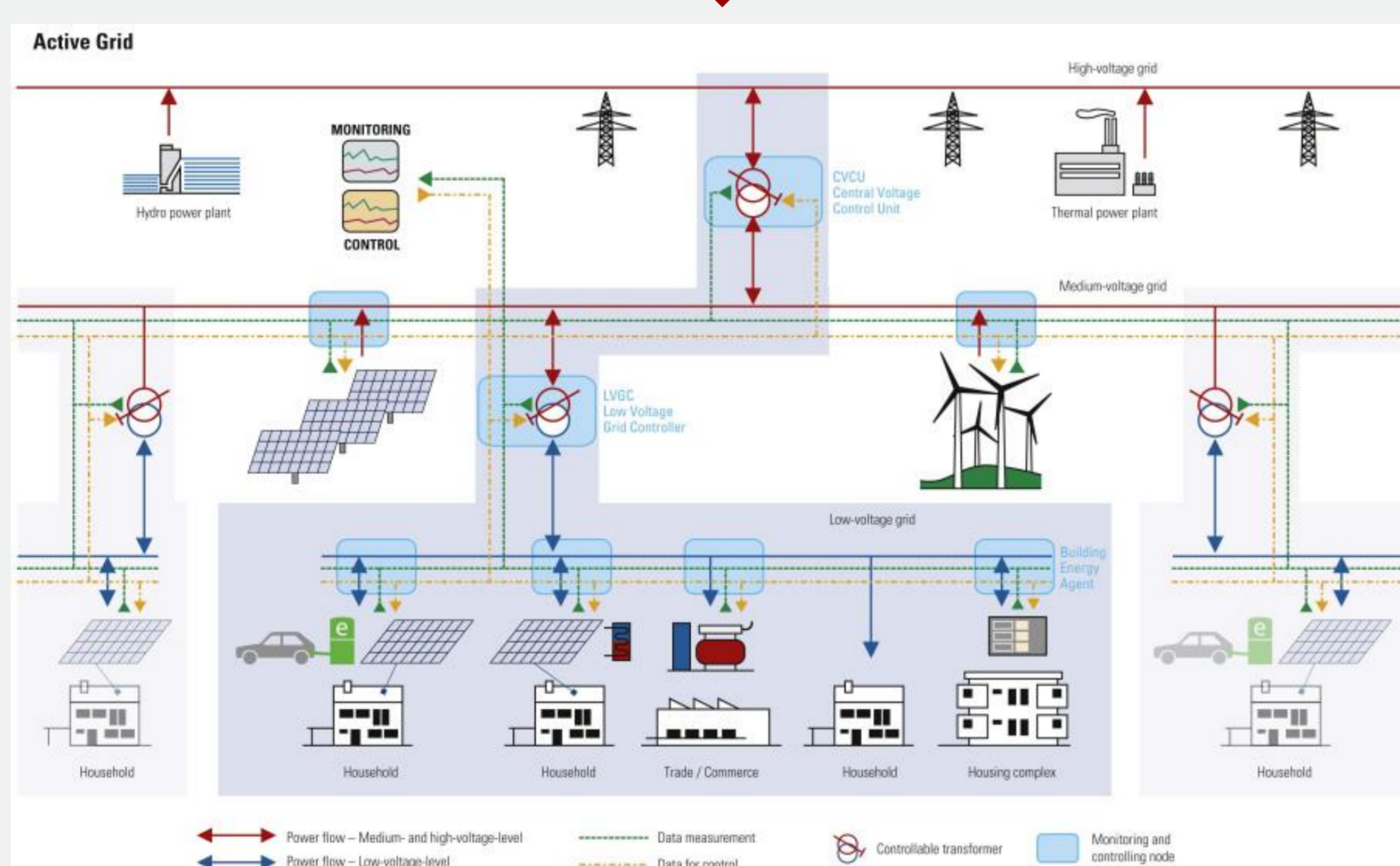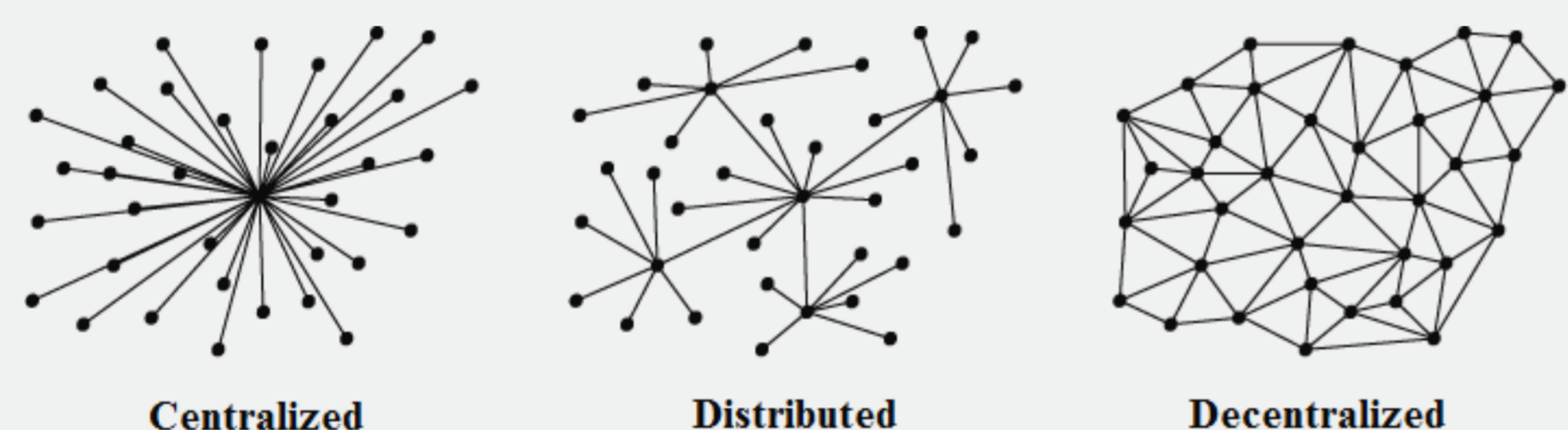
The current energy system evolves towards more and more decentralized energy generation with the diversification of distributed energy resource (DERs) at individual buildings level. The system as a whole becomes highly inter-connected with the heat and gas network coming more into play since heat pumps and micro CHP units have become popular. DERs could provide flexibility (and other services) to TSOs and DSOs. However, in this new highly collaborative energy system where different energy carrier interact with each other, flexibility definition needs to be reshaped. Conflict of interests might occur between different actors regarding the control of distributed energy assets. Moreover, flexibility is constrained by more than one dimension (mostly electrical so far) and needs to be redefined to account for the multi-carrier environment in which DERs are evolving.

Multi-carrier energy system and flexibility - aggregation
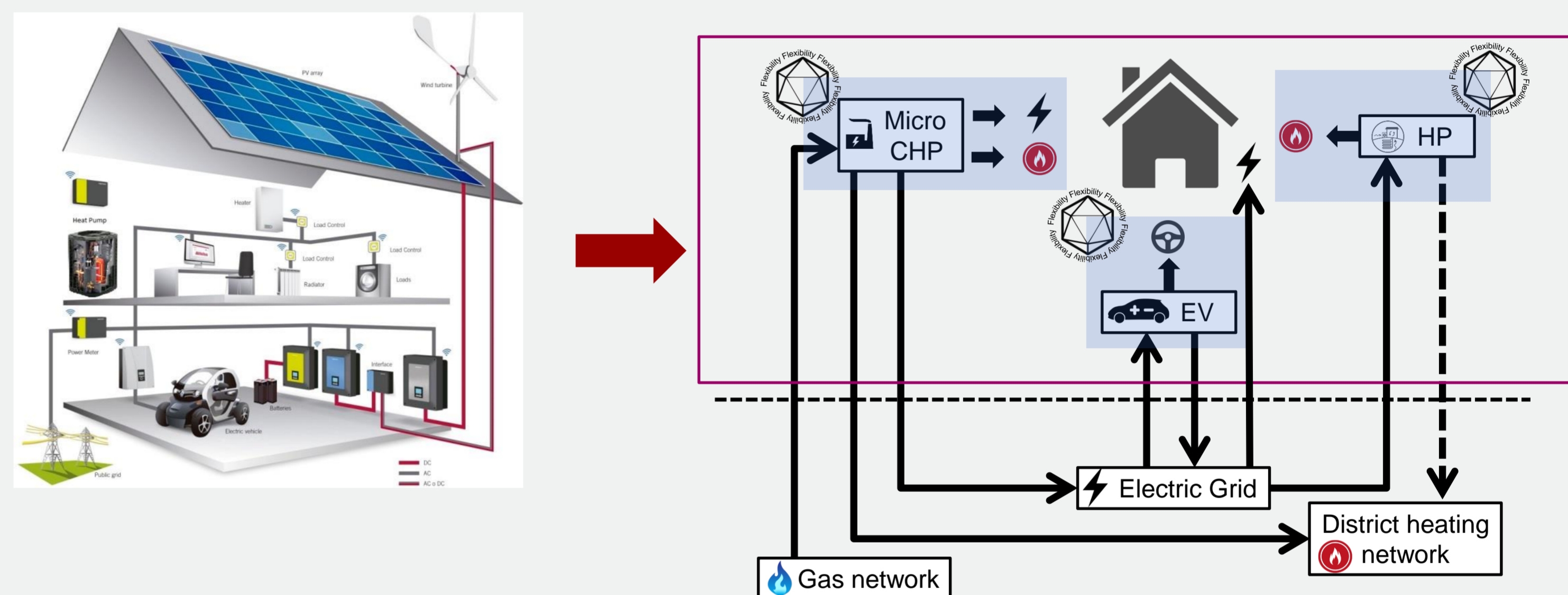
Flexibility is first defined at a unit level (lowest level of the system) in form of a capability zone. This flexibility is multi-dimensional and its "shape" is more or less complex depending on the number of constraints under which the resource is operated. Electric Vehicles are only subject to electrical constraints for instance, while Heat Pumps have limitations from both the electrical and the heat side (CHP are even more complex with gas as an additional constraint). Once this flexibility is defined for the different DERs, polyhedron aggregation (multi-dimensional flexibility summation) allows to aggregate at different levels. Aggregation can be performed by unit type, service type etc… and later on dispatched in an optimal fashion using resource allocation and optimization methods.

UNIT LEVEL	BUILDING	NEIGHBORHOOD - CITY	RESULTING FLEXIBILITY AT AGGREGATOR LEVEL
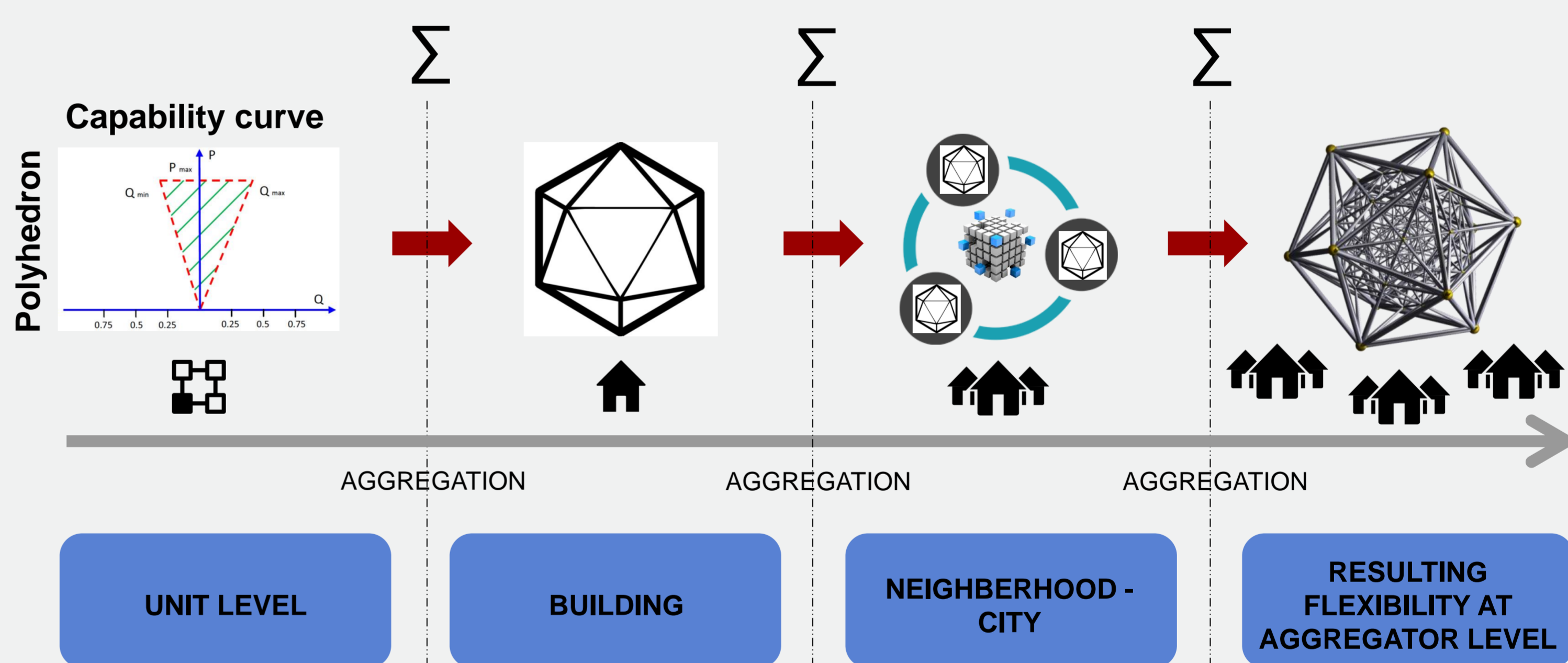
Control of DERs

Defining the available flexibility of an energy asset aims at controlling its operation in an optimal manner via an aggregator. Control is performed under network constraints (DH, Electrical grid, gas network), unit constraints (ramping, lock on/off, thermal limits …etc), comfort constraints (defined with the resource owner). Multidimensional constraints need to be properly evaluated and their associated information and communication technologies (ICTs) must be consistent to harvest the potential flexibility while not violating the constraints. Model predictive control theory offers interesting possibilities to address the aforementioned challenges.

$$\dot{x}(t) = A(t)x(t) + B(t)u(t)$$
$$y(t) = C(t)x(t) + D(t)u(t)$$

where:

$x(\cdot)$ "state vector"

$y(\cdot)$ "output vector"

$u(\cdot)$ "input (or control) vector"

$A(\cdot)$ is the "state (or system) matrix", $\dim[A(\cdot)] = n \times n$,

$B(\cdot)$ is the "input matrix", $\dim[B(\cdot)] = n \times p$,

$C(\cdot)$ is the "output matrix", $\dim[C(\cdot)] = q \times n$,

$D(\cdot)$ is the "feedthrough (or feedforward) matrix"

Block diagram representation of the linear state-space equations

Linear Time Invariant (LTI) Systems

Matrices A, B, C and D are not time dependent

State space model	→	Lumped parameter equivalent
Optimization	→	Update and repeat

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