Centre of Research Excellence
for Advanced Cooperative Systems

From Smart Buildings to Smart Grids – Integration Concepts for Smart Cities

Mario Vašak and Mato Baotić

ACROSS team – Optimal Control Group

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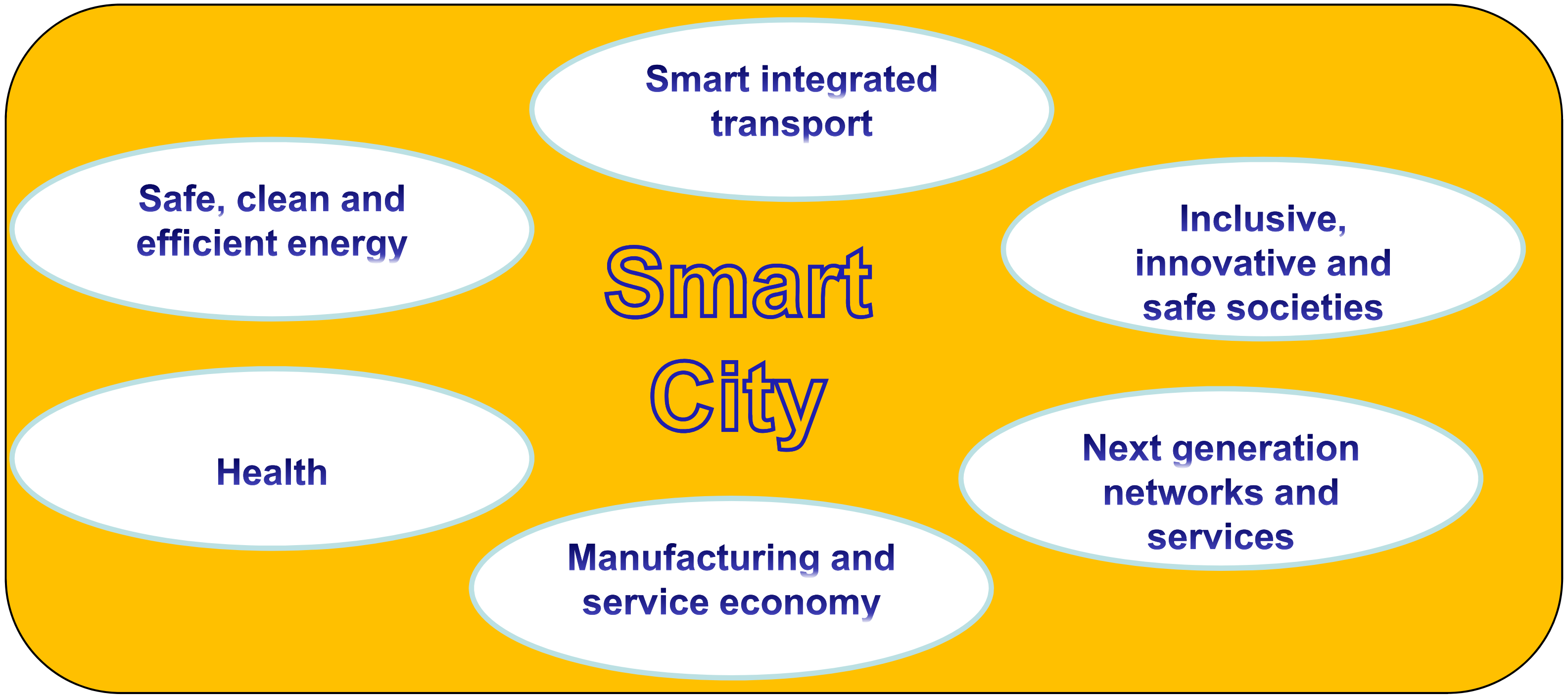
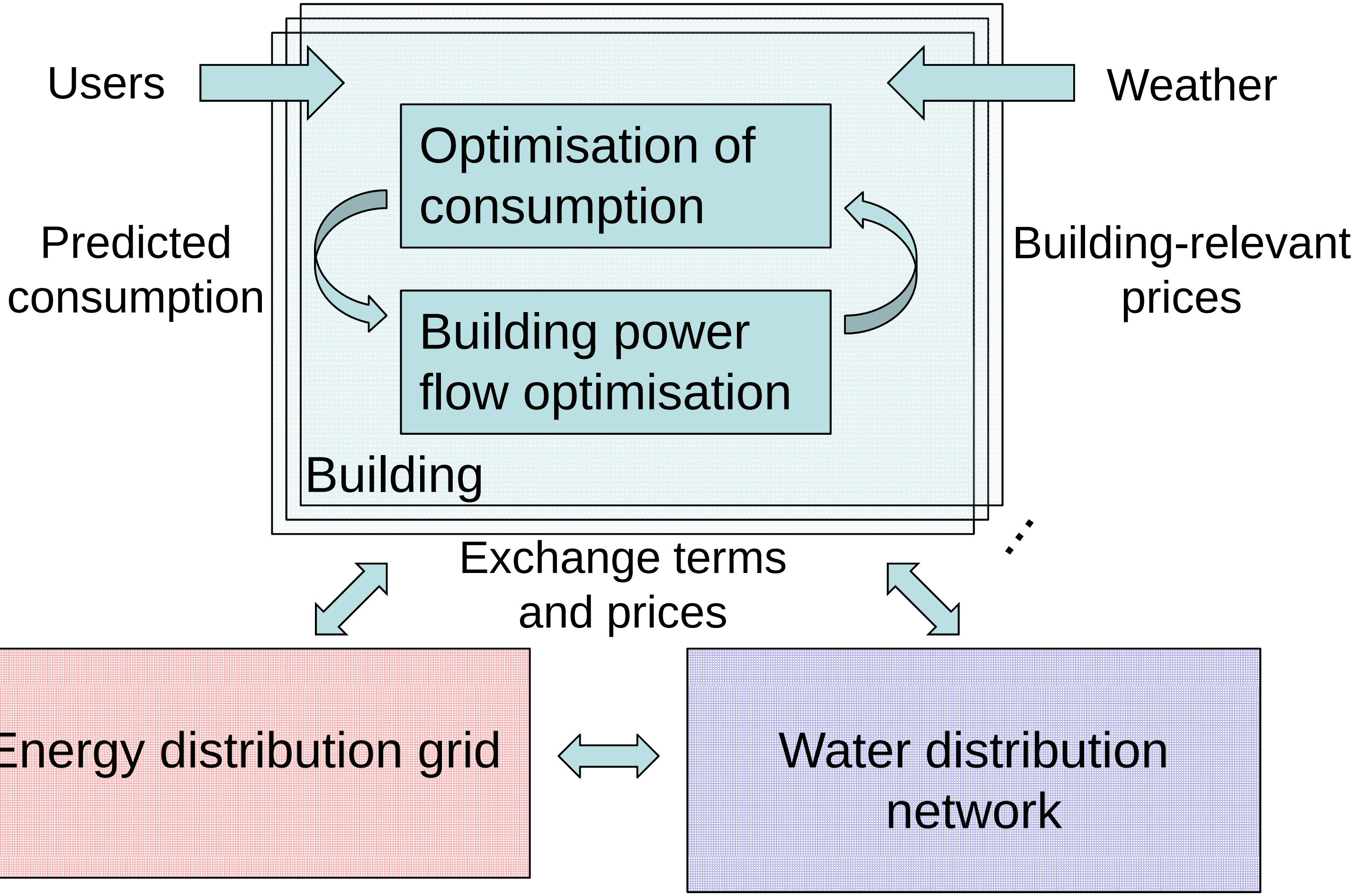
Smart City

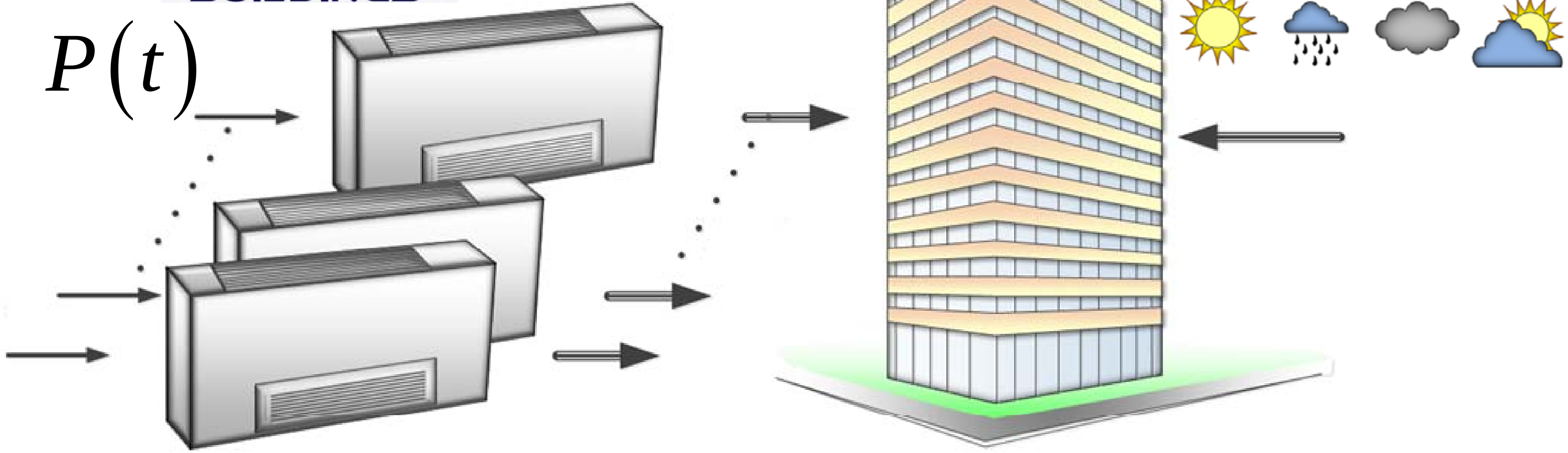
- **A multifaceted concept of integration and interoperation**



IT for Smart Cities – A Fraction on Energy&Water



Building as energy consumer



Fixed energy price *c*:

$$c \min_{P(t)} \int P(t)\,\mathrm{d}t$$

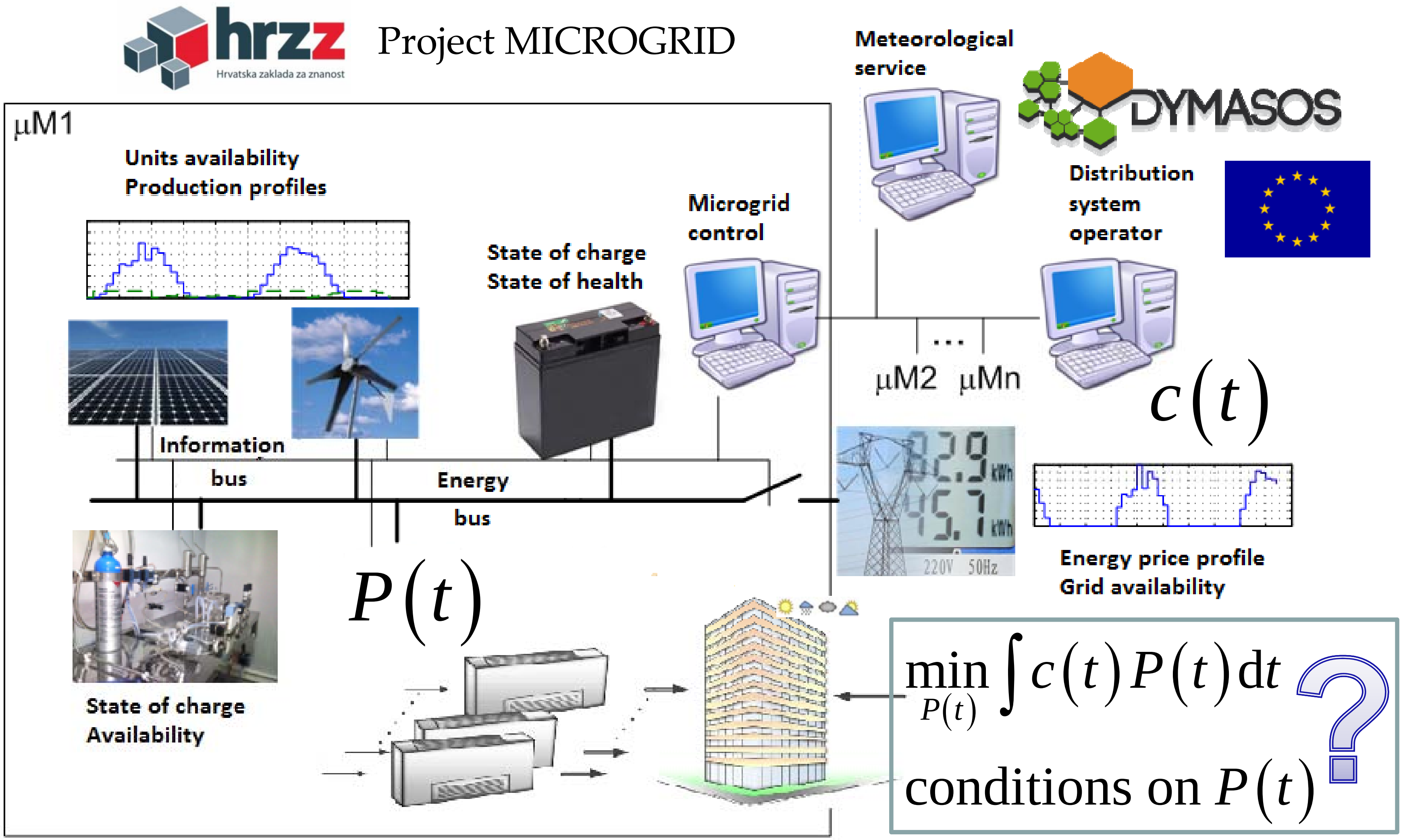
comfort conditions on $P(t)$

Time-varying energy price *c(t)*:

$$\min_{P(t)} \int c(t)\,P(t)\,\mathrm{d}t$$

comfort conditions on $P(t)$

Building as energy producer, storage and consumer (1)



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Building as energy producer, storage and consumer (2)

- For an arbitrary $P(t)$ there is the optimal microgrid control policy which results in a minimum energy cost for the building: $J(P(t))$
- Therefore, in the optimization of consumption it is cost-optimal to choose

$$\min_{P(t)} J\left(P\left(t\right)\right)$$

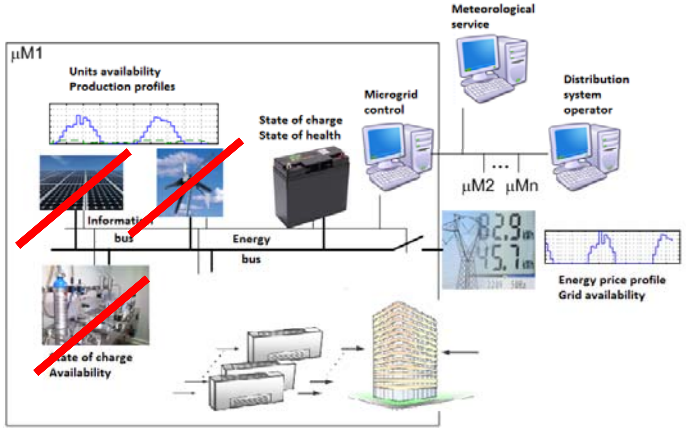
conditions on $P\left(t\right)$

Input-disturbance decomposition of hierarchical systems (P is disturbance for the microgrid and input for consumption)

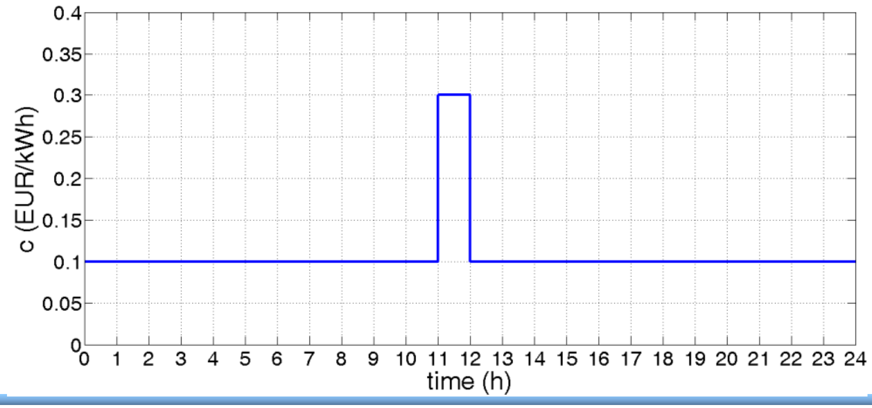
- ... and to declare the computed optimal consumption profile $P^*(t)$ to the microgrid control level

Building as energy producer, storage and consumer – A simple example (1)

- **Microgrid consists solely of a battery storage**
  - no battery losses
  - infinite capacity of connection with the distribution grid



- **Price profile from the distribution grid *c*(*t*)**



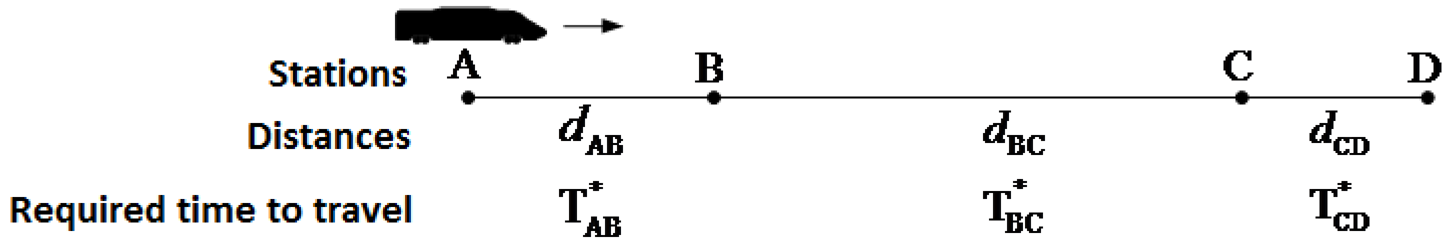
Building as energy producer, storage and consumer – A simple example (2)

- **Cases:**
  - Comfort-required $P(t)$ can be served in full from the battery between 11:00 and 12:00
    - J equals to $0.1\int_{0}^{24} P(t)\,\mathrm{d}t$
    - Micorgrid **transforms** the price of energy with a spike to a constant lower-level price for final consumption
  - Comfort-required $P(t)$ cannot be in full served from the battery between 11:00 and 12:00
    - The price of energy for final consumption **depends on time of use** (within or outside 11-12) **and quantity of use** (depends how much is $\int_{11}^{12} P(t)\,\mathrm{d}t$ higher than battery capacity)
- **Microgrid transforms the energy price for consumption (optimally if optimally controlled)**

Research in progress on the topic

- **Croatian Science Foundation project:**
  - CONtrol-based Hierarchical CONsolidation of Large CONsumers for their Integration in Smart Grids (3CON, 2014-2017)
  - parametric representation of J (explicit) – possible if the framework of hybrid systems control is applied to power flow optimisation problem in micorgrids
  - sensitivity analysis of J around $P^*(t)$ and iterations between the hierarchical levels in the general case
  - <u>first publication on the topic planned for ECC 2015</u>

Train on the route



Fixed energy price *c*:

$$c \min_{F(t)} \int F(t) v(t) \mathrm{d}t$$

conditions on $F(t)$

Variable energy price *c(t)*:

$$\min_{F(t)} \int c(t) F(t) v(t) \mathrm{d}t$$

conditions on $F(t)$

Coordination of trains on the route

Without microgrid infrastructure:

$$\min_{F_1(t),\dots,F_i(t),\dots} \int c(t)\sum_i F_i(t)\,v_i(t)\,\mathrm{d}t$$

conditions on $F_i(t)$

With microgrid infrastructure:

$$\min_{F_1(t),\dots,F_i(t),\dots} J\left(\sum_i F_i(t)\,v_i(t)\right)$$

conditions on $F_i(t)$

Water distribution system

- **Preparation and delivery (distribution tanks pumping) of fresh water requires energy**
- **Pressure regulation along the water network:**
  - energy generation for pressure decrease
  - energy consumption for pressure increase
  - distributed microgrid case!
- **A great potential for interconnection between electricity and water distribution systems**
- **Project UrbanWater enables penetration of ICT into water distribution networks (open platform)**
  - seed to tackle these issues

Microgrids coordination on the distribution grid

- **Price profiles $c_{P,k}(t)$ and $c_{Q,k}(t)$ declared to microgrids through the distribution grid**
  - influence the resultant energy $P_{e,\mu Gk}(t)$ and $Q_{e,\mu Gk}(t)$ exchanged between the microgrid k and the distribution network in the connection point
  - $P_{e,\mu Gk}(t)$ and $Q_{e,\mu Gk}(t)$ affect voltages and currents across the network, and thus losses
- **Challenge:**
  - Compute prices resulting in minimal expected losses
  - Using also other controls like tap changers, switches, capacitor banks etc. ensure reliable grid operation

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Info on all projects through: http://act.rasip.fer.hr/

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