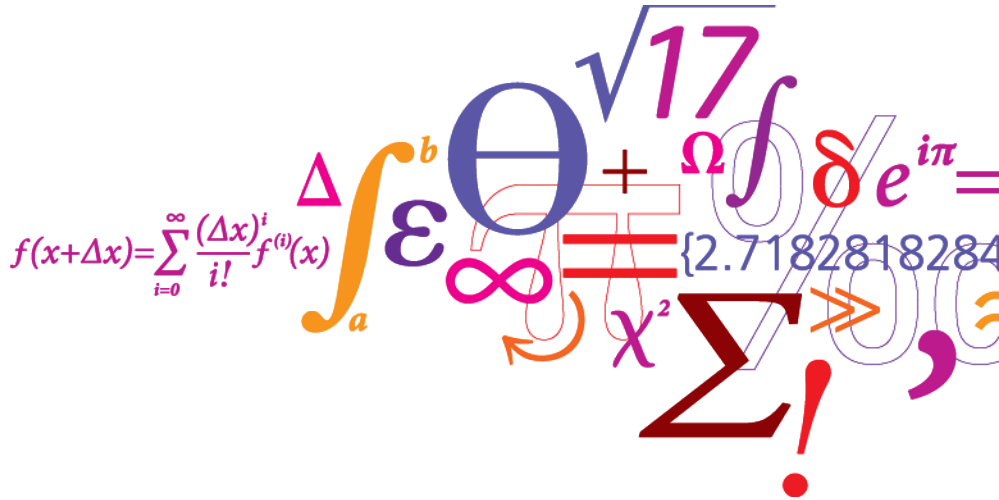
Markets for Demand-Side Flexibility based on the Transactive Energy Approach

CITIES Workshop on "Long-term Ideal Electricity Markets Setup"

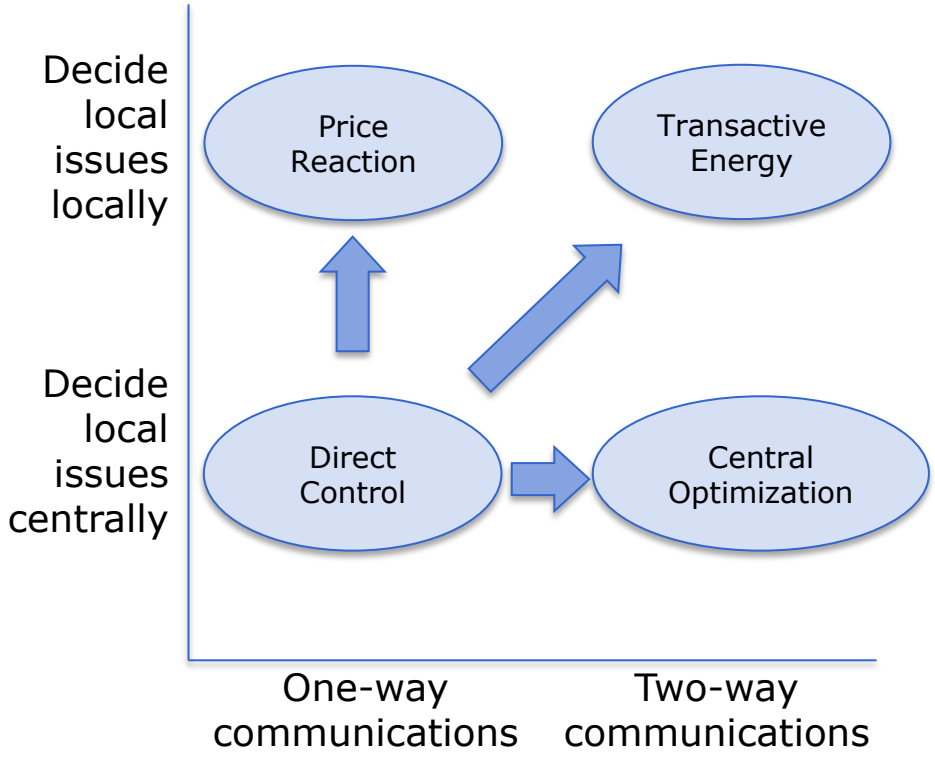
Koen Kok, TNO & DTU



DTU Electrical Engineering
Department of Electrical Engineering

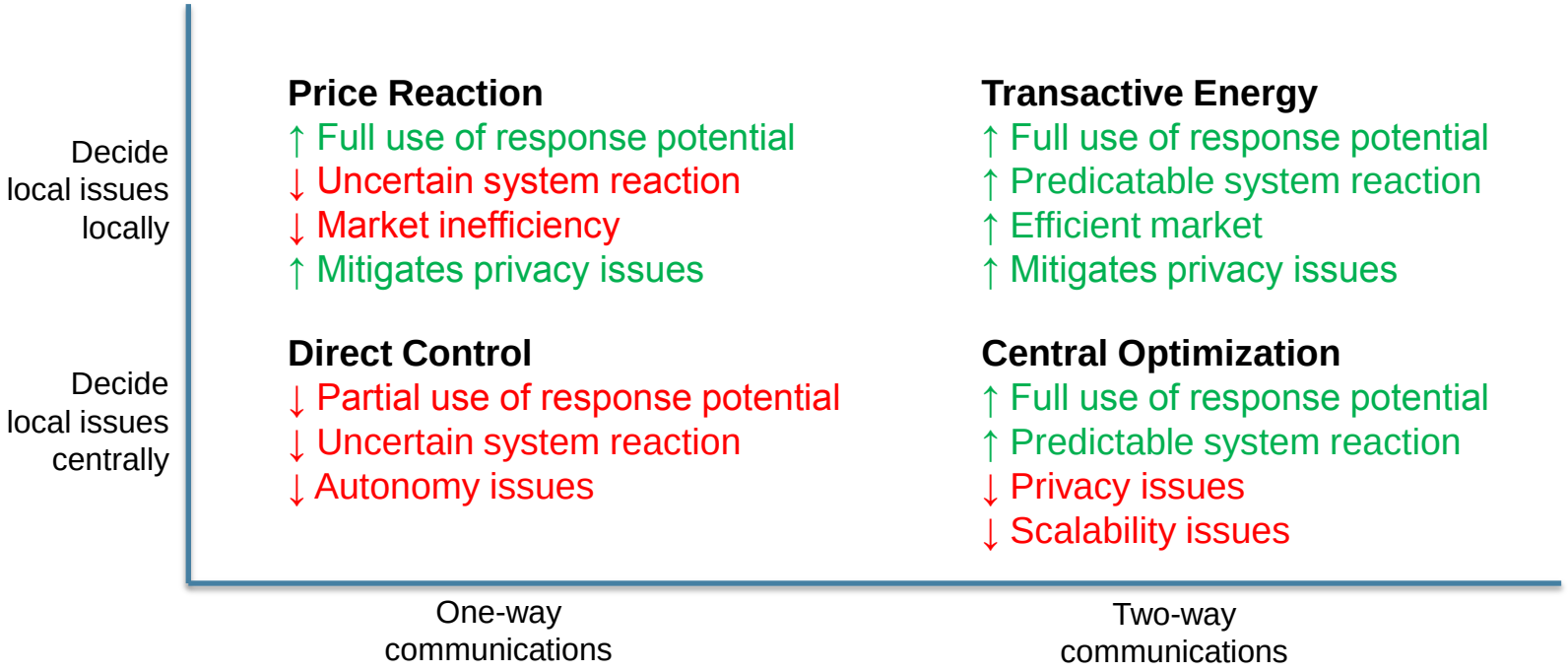
The Smart Grid Coordination Matrix

- **Direct (Top-Down) Control**
  - Utility switches devices on/off remotely
  - No local information considered
- **Central Control/Optimization**
  - Optimization at and control from a central point
  - Relevant local information must be communicated
- **Price Reaction Control**
  - Prices signalled to customers and/or their automated devices
  - No communication of local info
- **Transactive Energy (TE)**
  - Automated devices engage in market interactions
  - Information exchange includes quantity (e.g., power, energy) and price



Source: The PowerMatcher Smart Coordination for the Smart Electricity Grid, published by TNO, The Netherlands, 2013. www.tinyurl.com/PowerMatcherBook

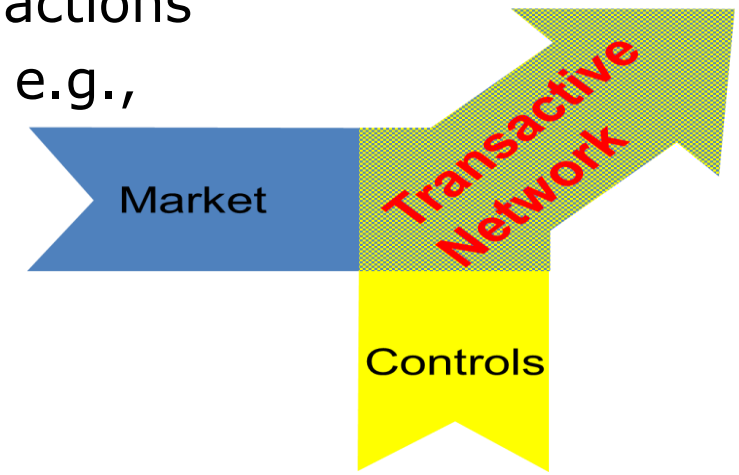
The Smart Grid Coordination Matrix



Source: The PowerMatcher Smart Coordination for the Smart Electricity Grid, published by TNO, The Netherlands, 2013. www.tinyurl.com/PowerMatcherBook

Transactive Energy

- Use market mechanisms to perform distributed optimization
  - Reflect value in exchangeable terms (price)
  - Effectively allocate available resources and services in real-time
  - Provide incentive for investment on longer time horizon
- Use communications and automation of devices and systems as real-time agents for market interaction
  - Agents convey preferences and perform local control actions
  - Engage in one or more markets to trade for services, e.g.,
    - Real-time energy, peak-shaving
    - System reserves



[Slide from Steve Widergren, Transactive Energy Tutorial, IEEE PES 2015]

Proven Approach & Technology

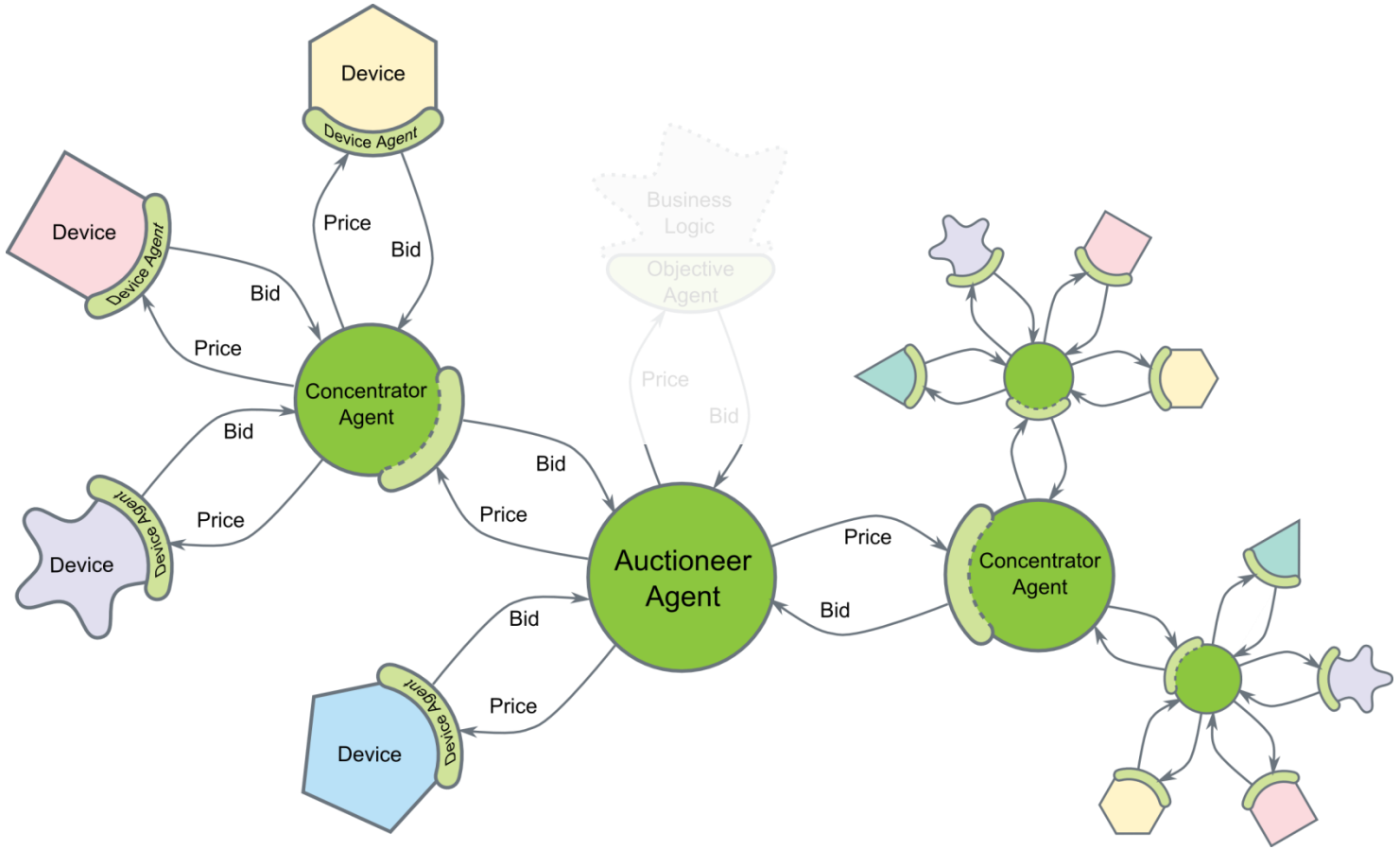
- USA: Work of Pacific North-West Laboratories (PNNL)
  - Olympic Peninsula Demonstrator
  - GridSMART Ohio Demoinstrator
  - Pacific North-West Smart Grid Demonstrator
- Europe:
  - PowerMatcher
    - Several field demos
    - Open-source implementation
    - Commercialization by several parties
  - Intelligator
    - Combination with Intelligent business agents and flexibility modelling

How does/can it work?

- Principles of real-time dispatch using Myopic Bidding
- Island case:
  - Balancing
  - Balancing & network management
- Single Aggregator (Virtual Power Plant) Case
- Multiple Aggregators plus Network Mgmt by a Distribution System Operator

Island Balancing

- PowerMatcher Agent Topology



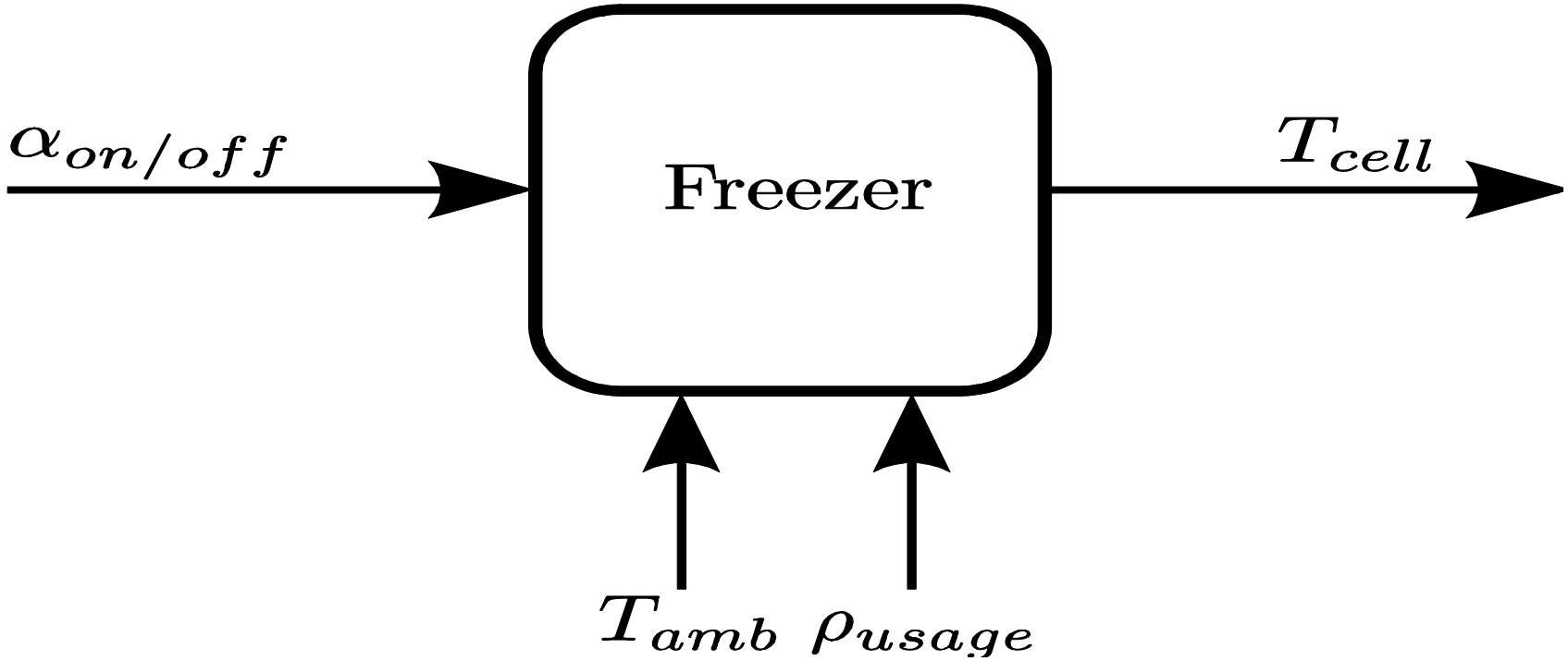
Bids and prices

PowerMatcher agents operate in a **real-time market:**

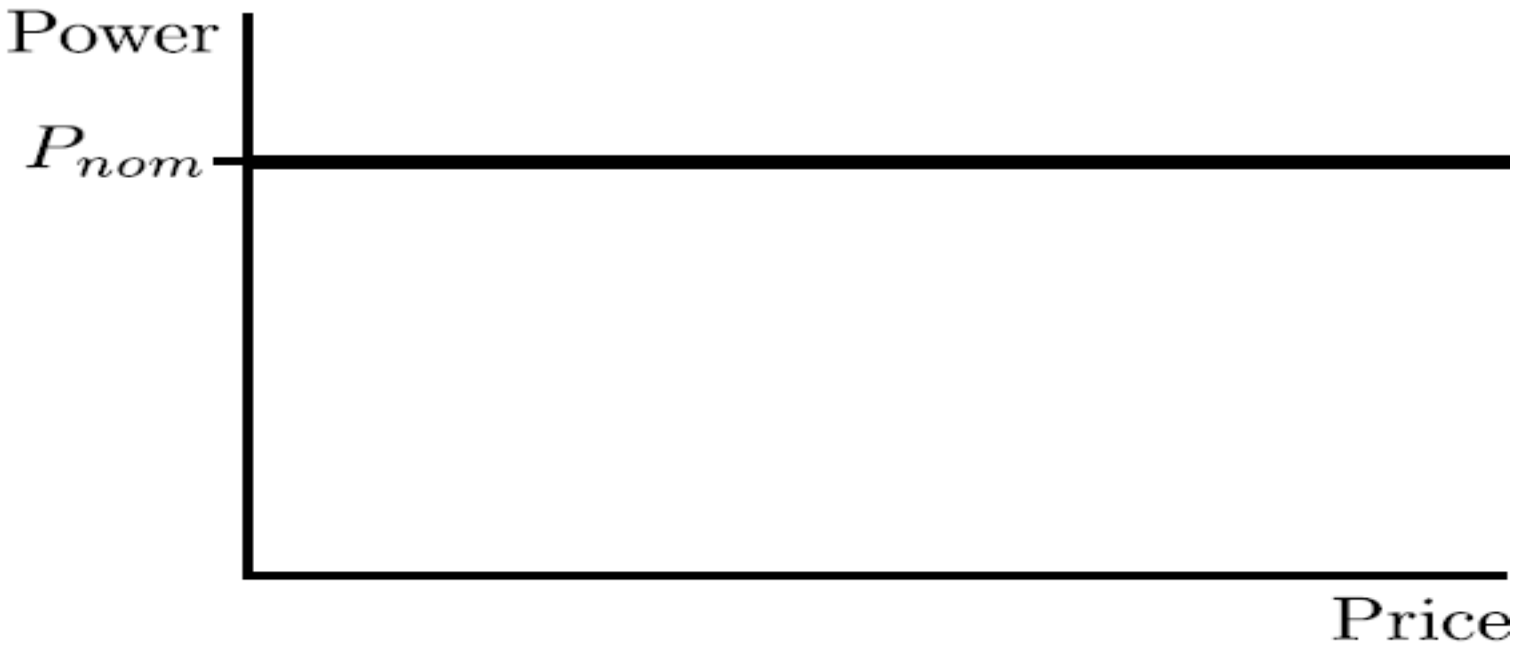
- Bids express the *instant* **willingness** (flexibility) to **consume** and/or **produce**
- A price is the **price for demand / supply**

→ **Myopic Bidding**

Freezer Block Model



Freezer Basic Bid Shapes: “Must run”

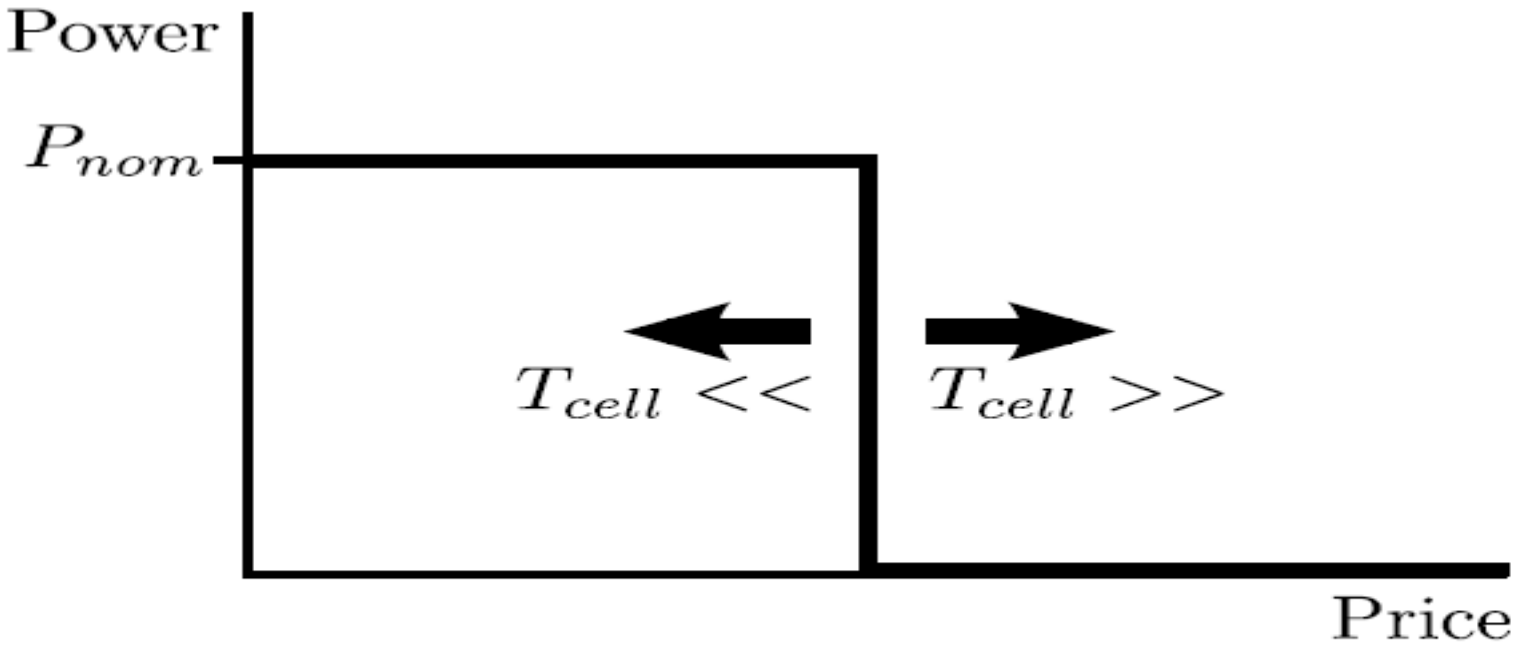


$T_{cell} > T_{max}$
“Must run”

Freezer Basic Bid Shapes: “Must off”

$T_{cell} < T_{min}$
“Must off”

Freezer Basic Bid Shapes: “May run”

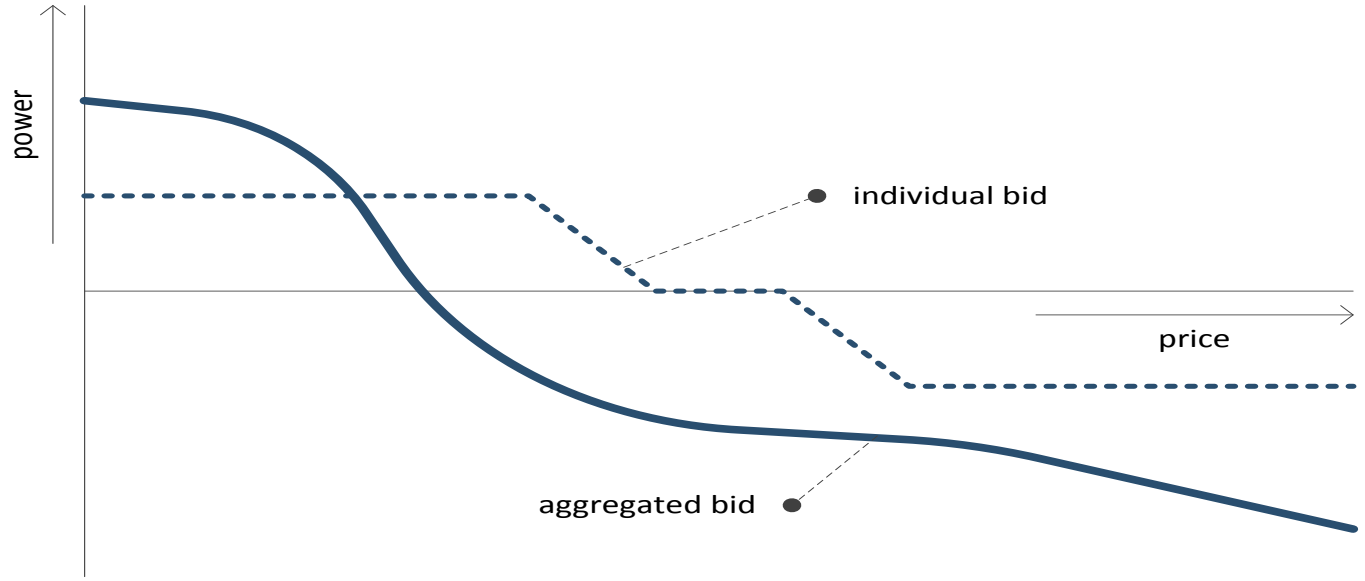


$$T_{min} \leq T_{cell} \leq T_{max}$$

“May run”

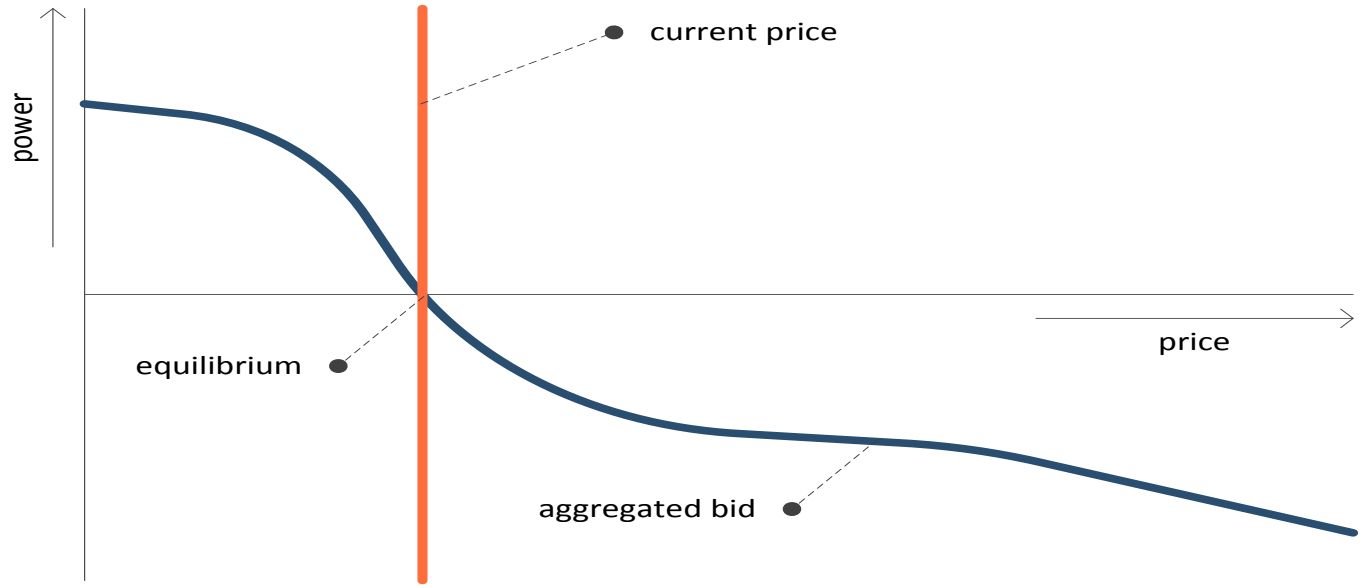
Bid aggregation

- **Bids** can be **summed** (aggregated) to represent the **total supply** / **demand** as **function** of **price**



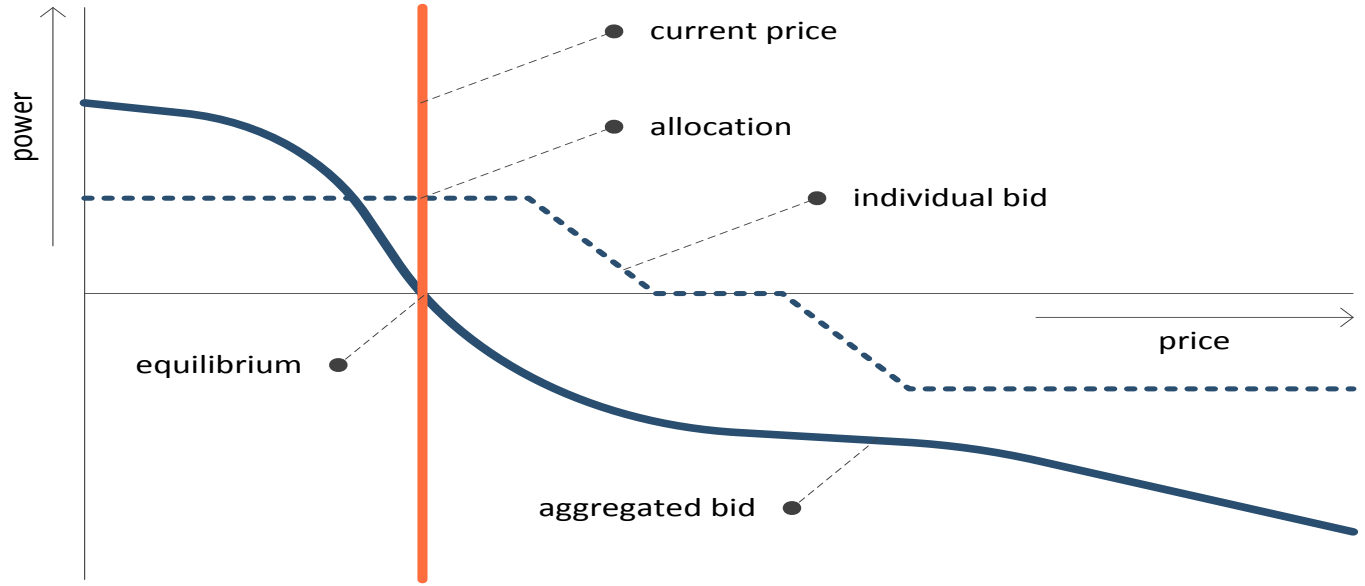
Equilibrium pricing

- The **basic pricing mechanism** is to determine the **balance supply and demand**

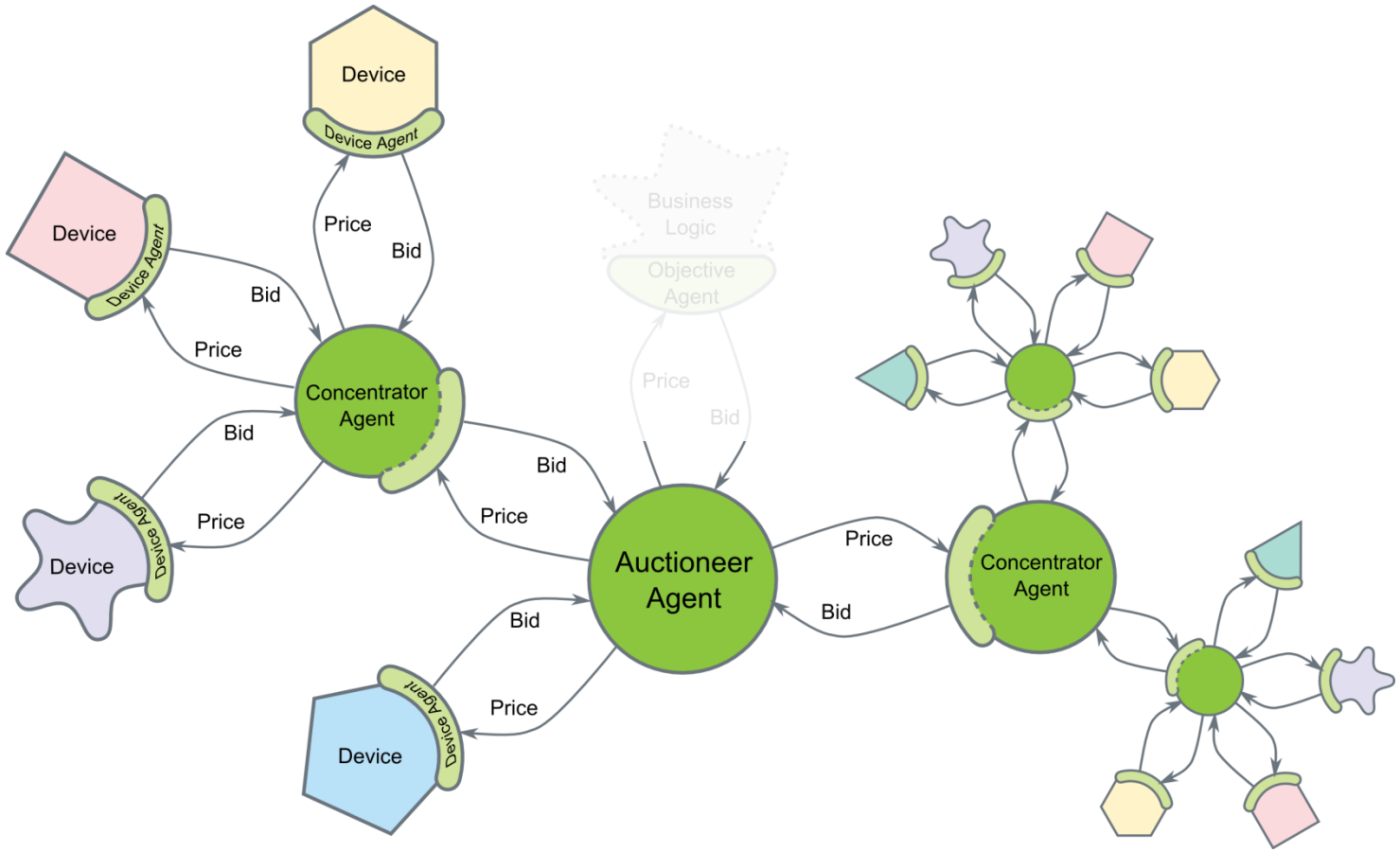


Allocation

- The **price** – together with their **bids** – **determines** the **allocation** for agents.

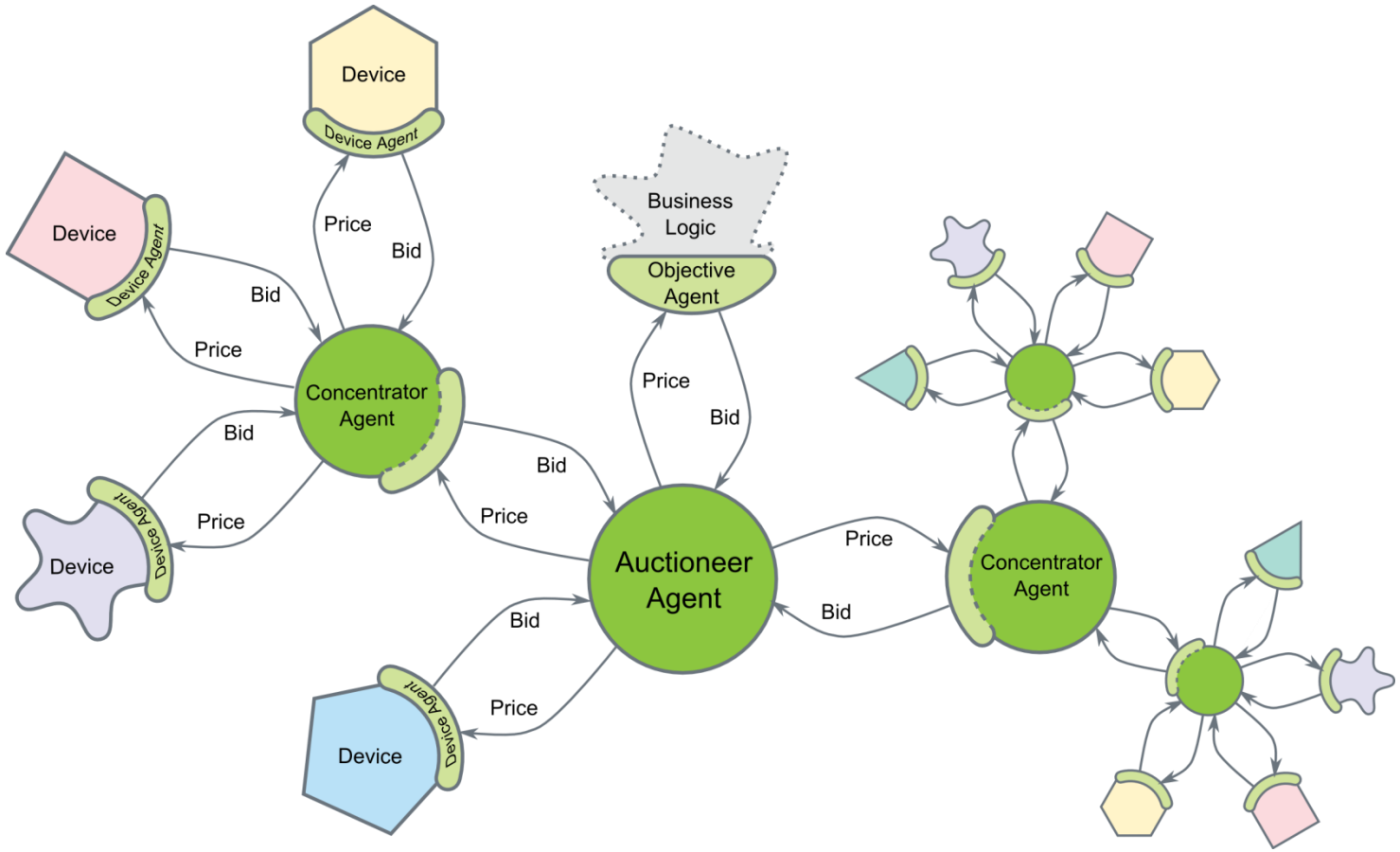


Island Balancing



- Automatic Balancing on minute to hours scale
- Primary reserve needed
  - Fast reaction device
  - Relieve system through bidding
- Network agnostic (in this set-up)

Virtual Power Plant Aggregation

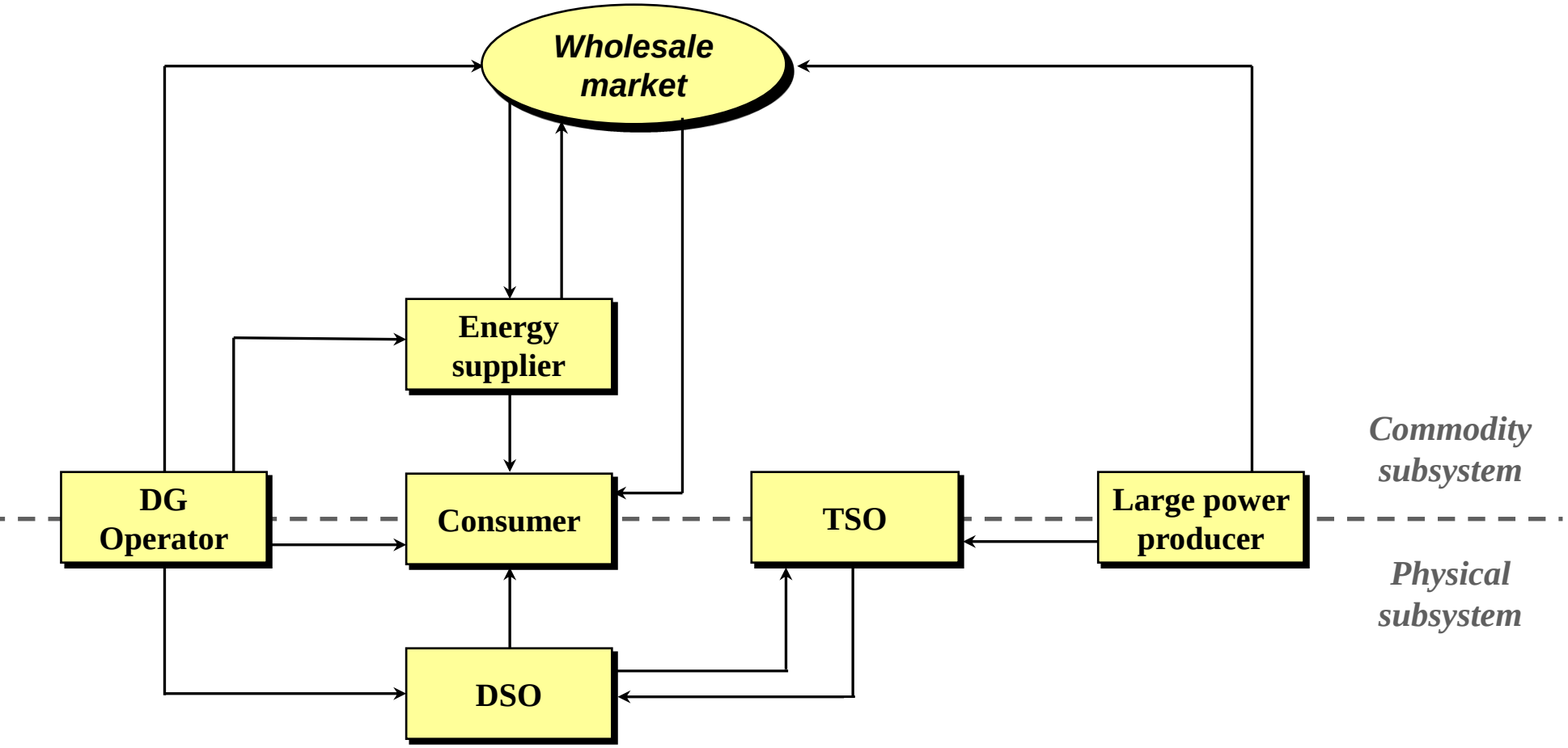


- Introduce an *Objective Agent*
  - Places bids for production or consumption
  - Controlled deficit or surplus
  - Automatic internal balancing still in place

Features

- Dispatch of aggregated demand-side response
  - Fast & Scalable
  - Communication based on Myopic Bids
  - Planning and Model-based Predictive Control intelligence possible at Agent level:
    - Business Agents & Smart Device Agent
    - Slower Info Exchange possible (forecasts, flexibility modelling)

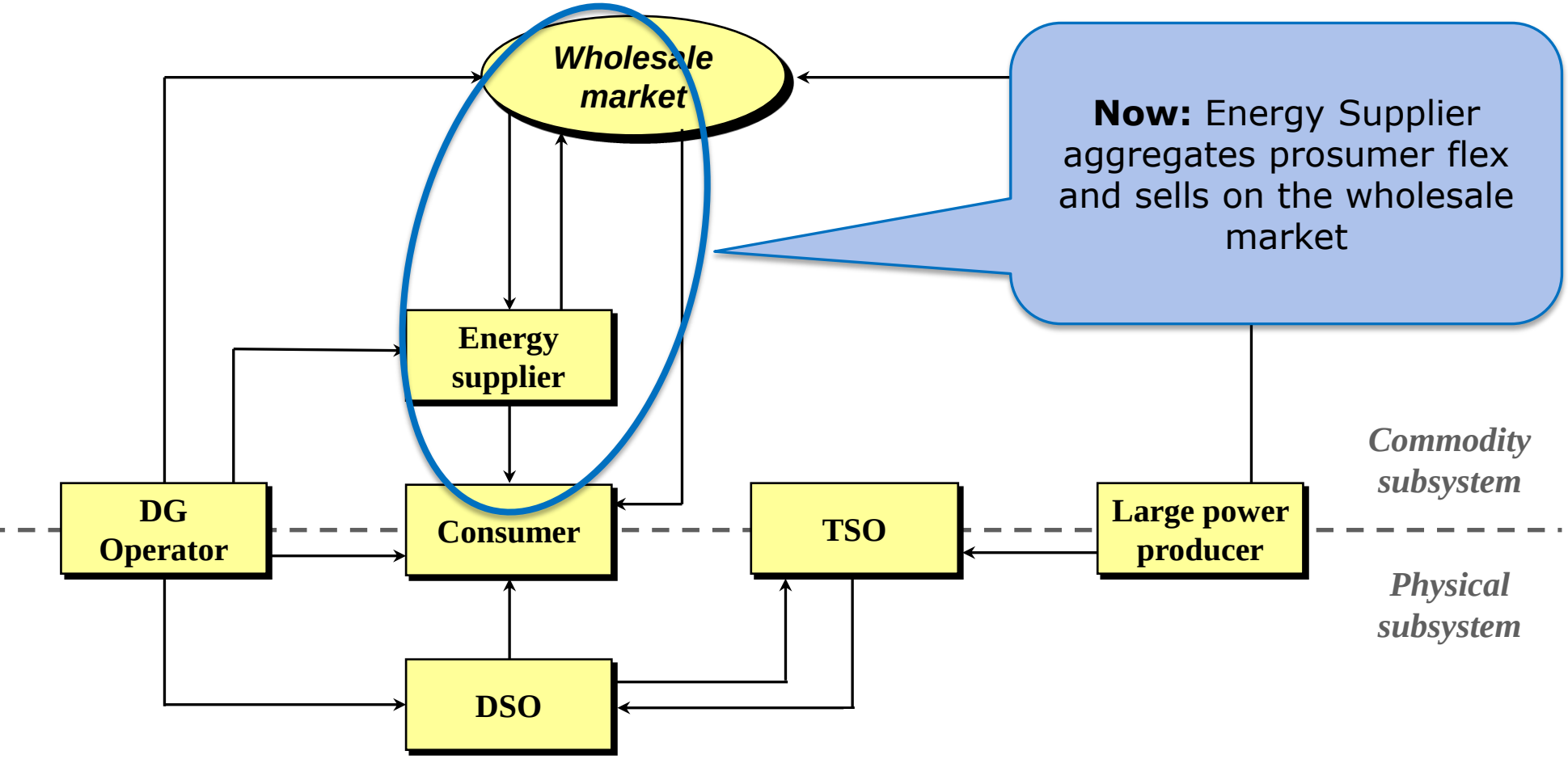
The European Market Model



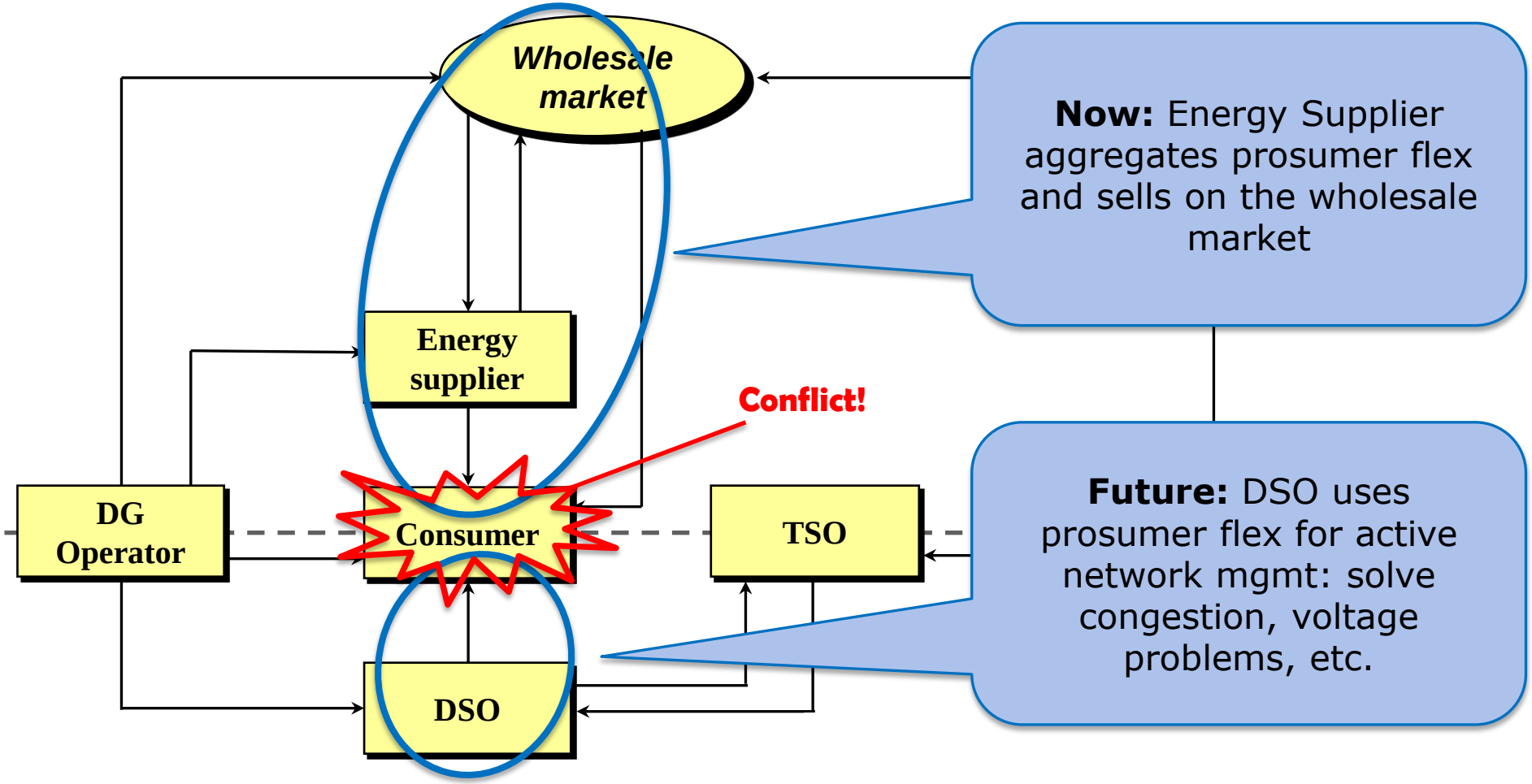
- Unbundling of commodity trade and network functions
- TSO: Transmission System Operator
- DSO: Distribution System Operator
- DG: Distributed Generation

Drawing by Scheepers & Van Werven

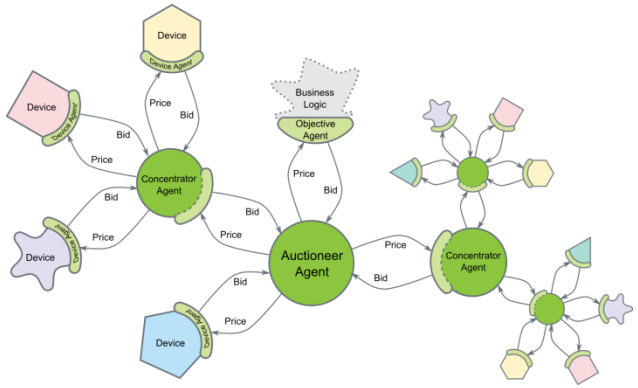
Demand-side Flex (DSF): Status Quo



Demand-side Flex (DSF): Future

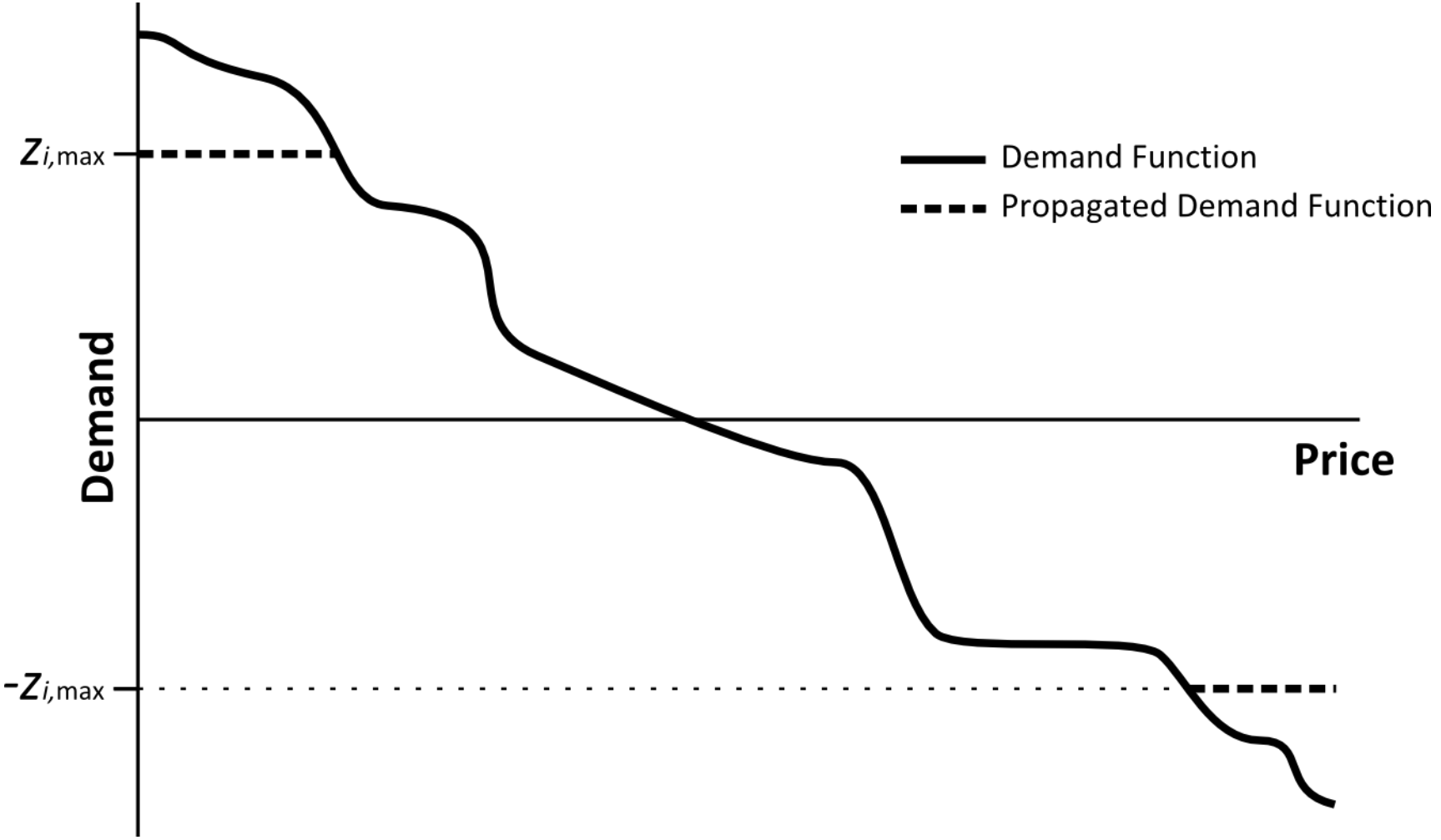


Adding Network Management: Congestion Mgmt

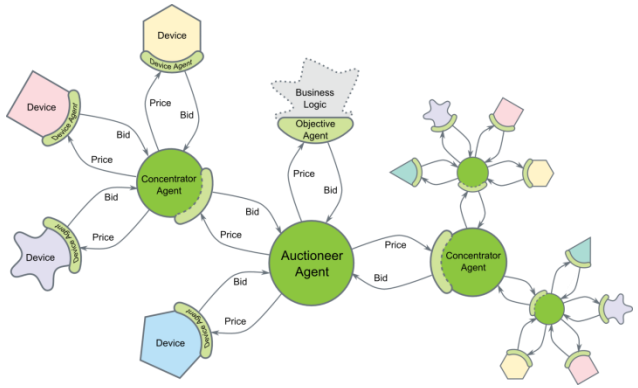


Bidding phase communication:

- Concentrator keeps local bids *network feasible*.

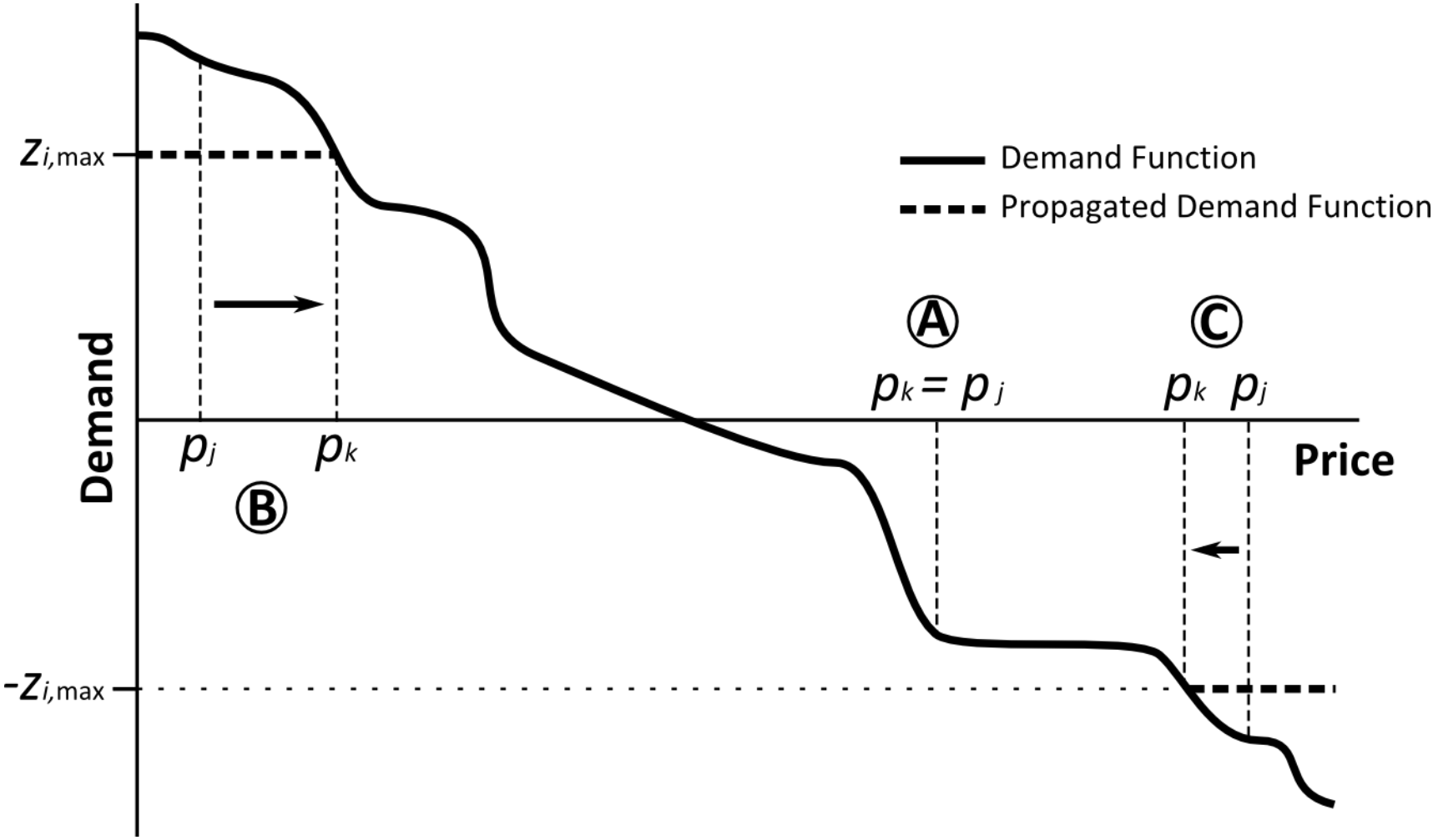


Adding Network Management: Congestion Mgmt



Price communication:

- Concentrator creates local price difference if needed.



Adding Network Management

- Bid curve transformation
  - Transactive algorithm for combining aggregation and network management
  - Fast computing if the network is radial: distribution grid
  - Example gives congestion management case
  - Also possible for Accounting of losses, Self-consumption optimisation, etc.

- Next step: Local Flexibility Market-layer for the Distribution/Retail Level of the Smart Grid.

Multiple Aggregators and Distribution Network Mgmt

- GA: Grid agents
- PA: VPP Portfolio Agents

- GAs spawn when a network problem is eminent
- VPPs then create corresponding PAs.