AALBORG UNIVERSITET

Flex-Offers: Unified handling of Flexibility in Electricity Consumption and Production

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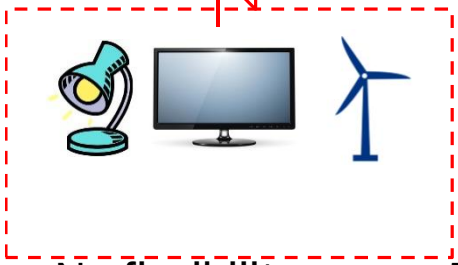
Nov 4, 2016

THE FLEX-OFFER CONCEPT

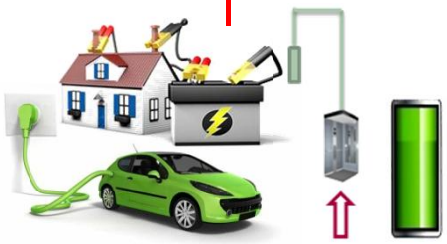
> Flexible Electricity Consumers and Producers

No or simple flexibility patterns — Complex flexibility patterns

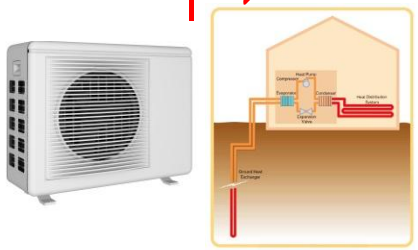


- No flexibility

- *Time-shift* flexibility

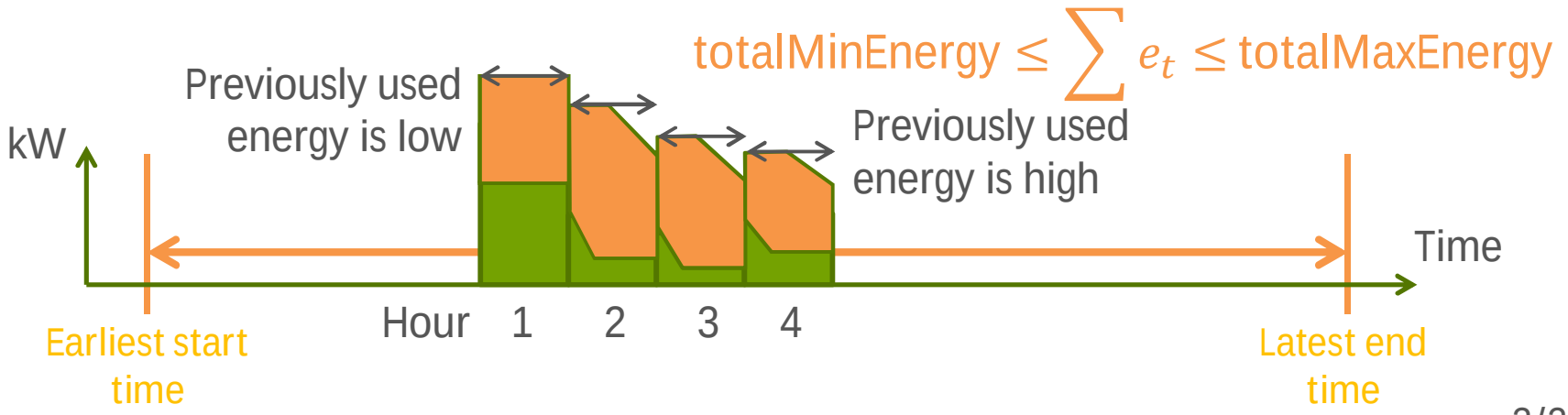


- *Time-shift* flexibility
- *Amount* flexibility
- [*Total Amount* requirement]



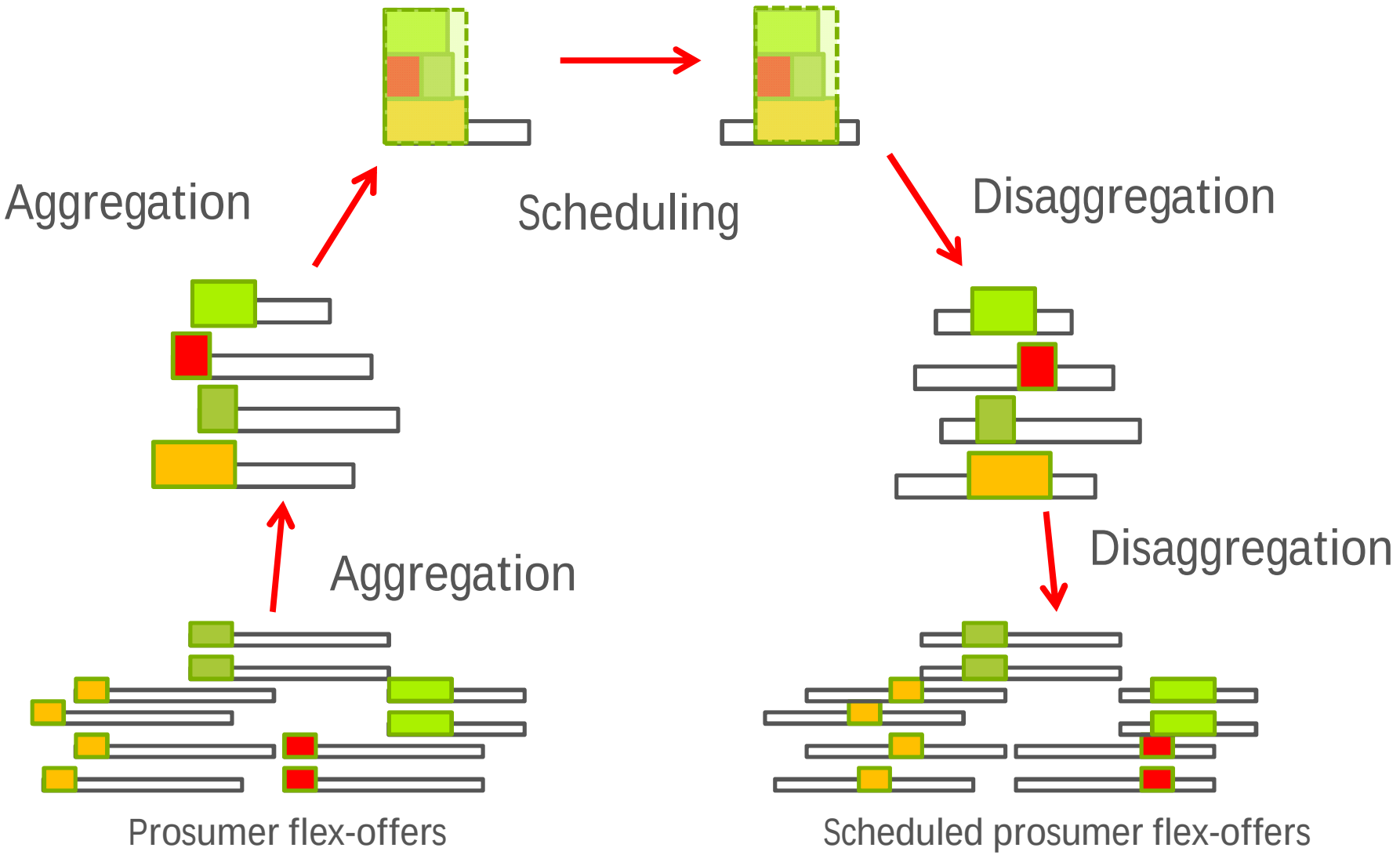
- Amount flexibility with intra-time unit dependencies

Flexible Offer (flex-offer) allows unified modelling of a flexible consumer/producer in ALL these cases

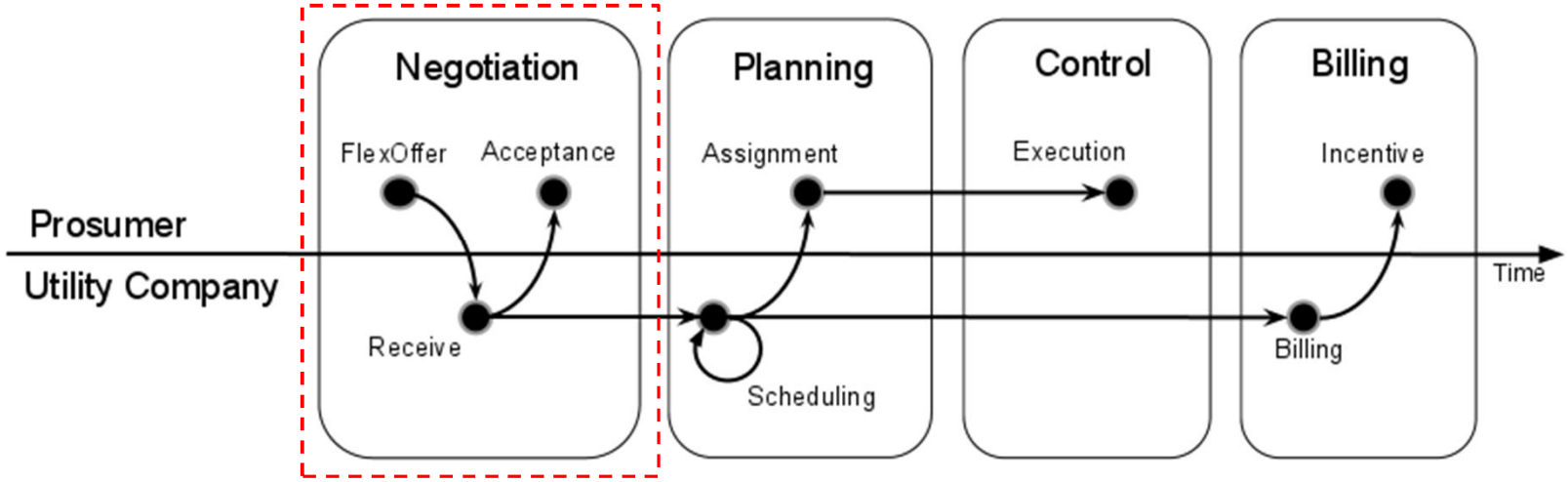


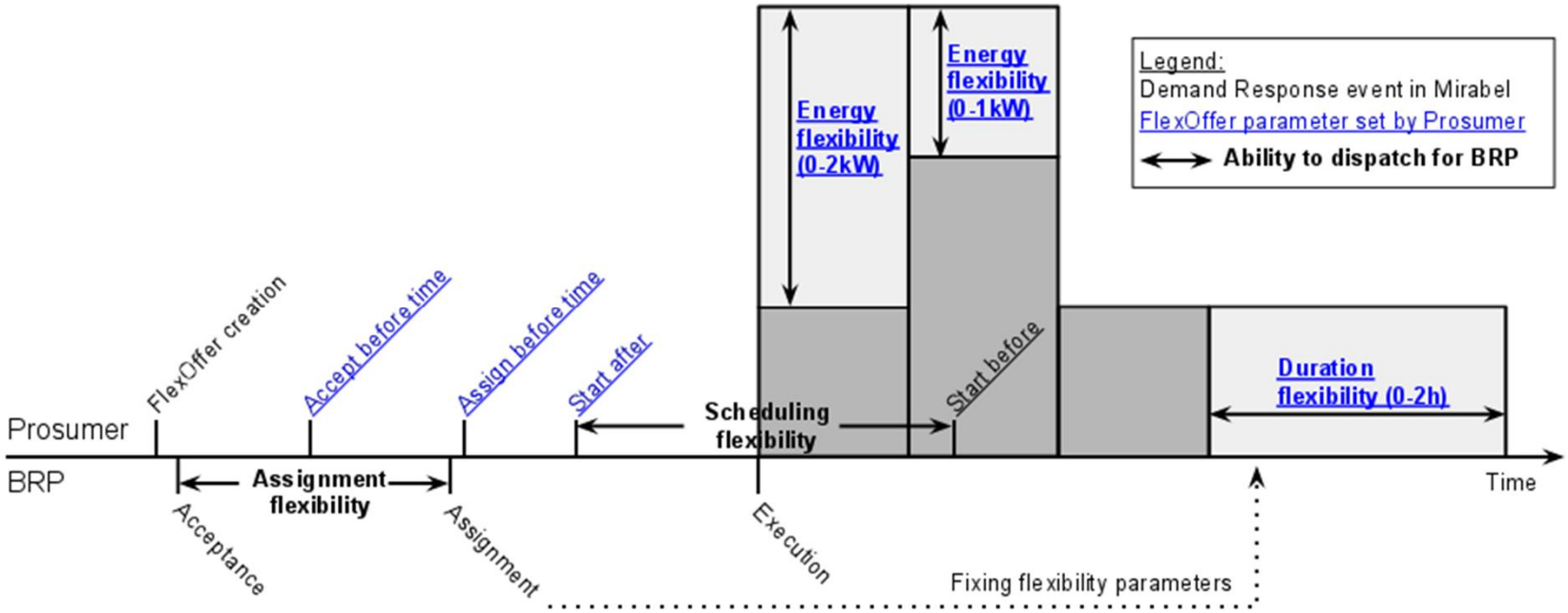
TBP1 all the examples are from households, perhaps you could add a few for the industrial/commercial cases we have eg in Arrowhead
Torben Bach Pedersen; 1.11.2016

> Flex-Offer Aggregation and Disaggregation

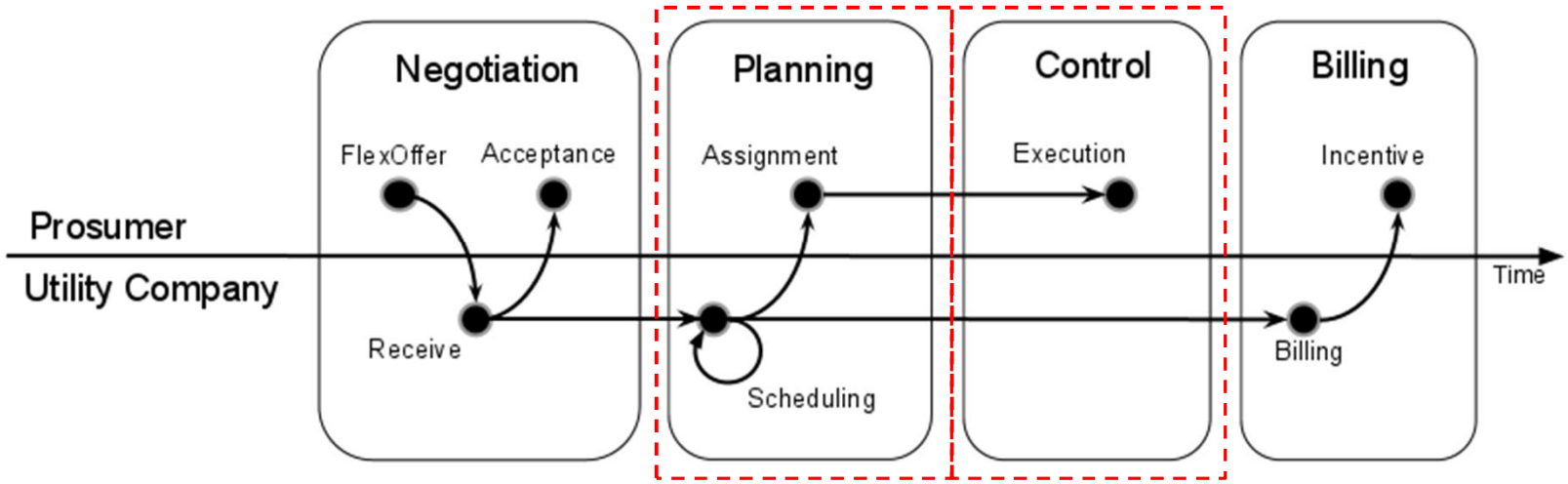


> (Simple or Aggregated) Flex-Offer Lifecycle





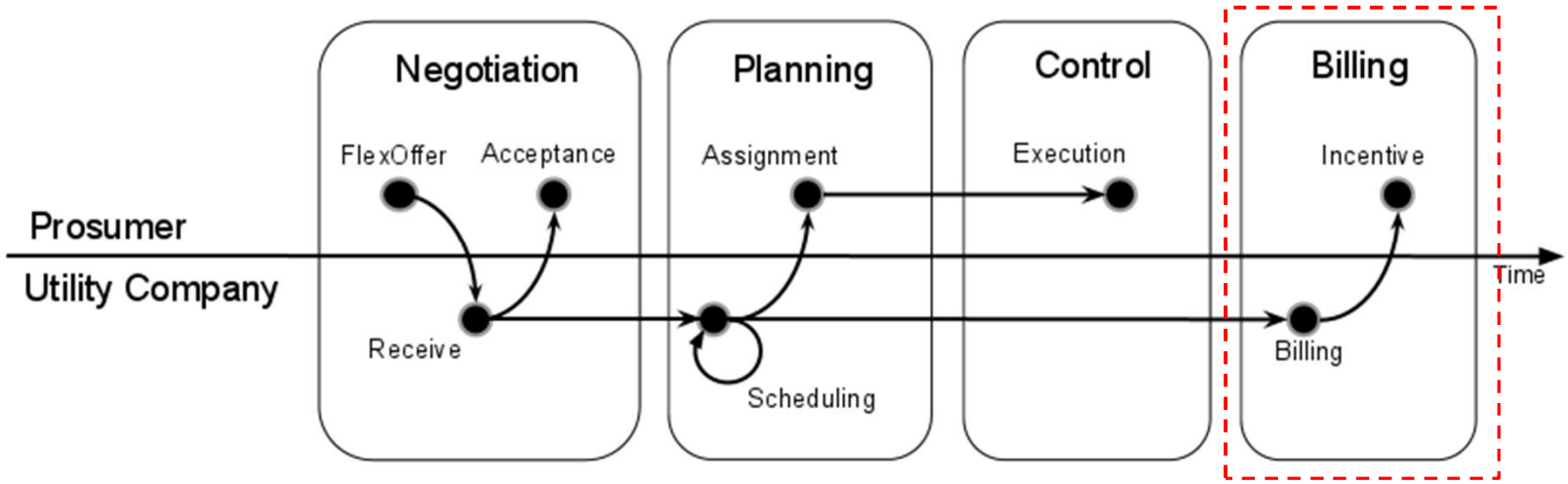
> (Simple or Aggregated) Flex-Offer Lifecycle



(One feasible)
Flex-Offer Schedule

Generate ON/OFF signals to fulfil the schedule

> (Simple or Aggregated) Flex-Offer Lifecycle



Customer: arrowhead_lift

Item	Value	Price
Number of flexoffers	2	
Fixed reward for all flexoffers		10.00 DKK
Total Time Flexibility	0 time units (15 min)	0.00 DKK
Total Energy Flexibility	68.83 kWh	6.88 DKK
Number of default schedule deviations	0	0.00 DKK
The sum of stat time scheduling deviations with respect to the default schedule	0 time units (15 min)	0.00 DKK
The sum of energy deviations with respect to the default schedule	0.00 kWh	0.00 DKK
Total Reward		16.88 DKK

Summary

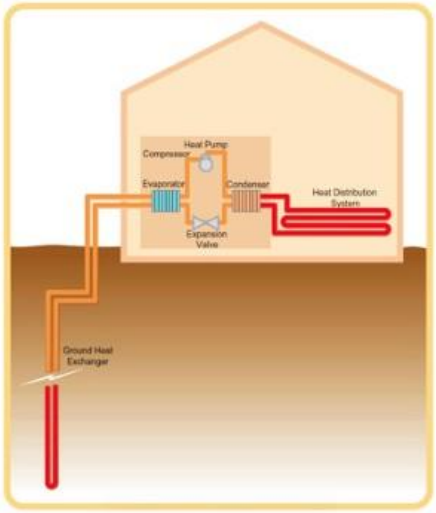
- Flex-Offers: A Powerful Concept applicable in many Smart-Grid applications:
  - Demand supply balancing
  - Electricity trading
  - Congestion management
  - ...

USING FLEX-OFFERS BOTH FOR ELECTRICITY AND DISTRICT HEATING

Flex-Offers for electricity and heating

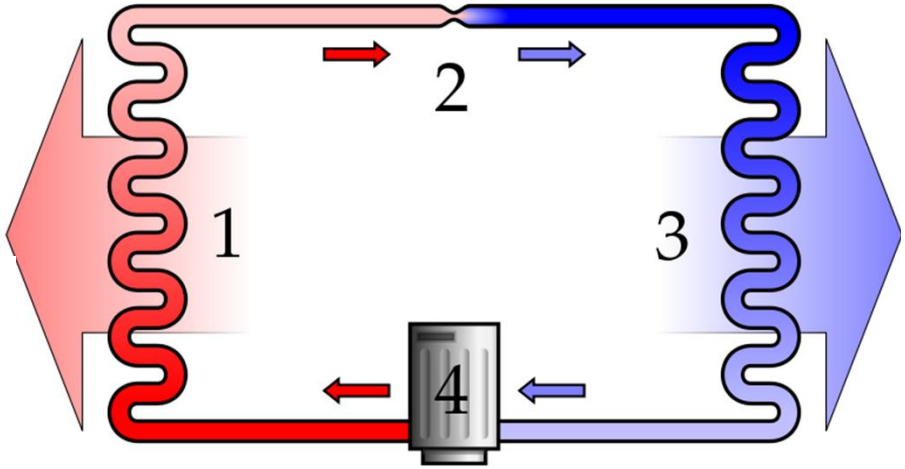
- OBSERVATION 1: kW and kWh can be used for both electrical and thermal energy, and so can Flex-Offers
- OBSERVATION 2: Flex-Offers for different types of energy should be treated separately
- OBSERVATION 3: For interplay, energy conversion needs to be modelled as a flex-offer

E.g., A house heated with a heat-pump and comfort constraints



Temperature x(t),

$$\theta_r - \delta \leq \mathbf{x}(t) \leq \theta_r + \delta$$



Heater power u(t), $0 \leq \mathbf{u}(t) \leq P$

> Example of modelling energy conversion

1. Linear Time Invariant State Space Model

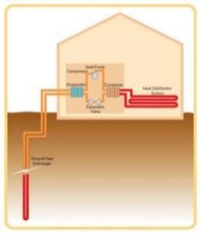
$$\mathbf{x}(t) = \left(1 - \frac{1}{R \cdot C}\right) \cdot \mathbf{x}(t-1) + \left(\frac{\eta}{C}\right) \cdot \mathbf{u}(t) + \left(\frac{\theta_a}{R \cdot C}\right)$$

Constraints on input and state

$$0 \le \mathbf{u}(t) \le P$$

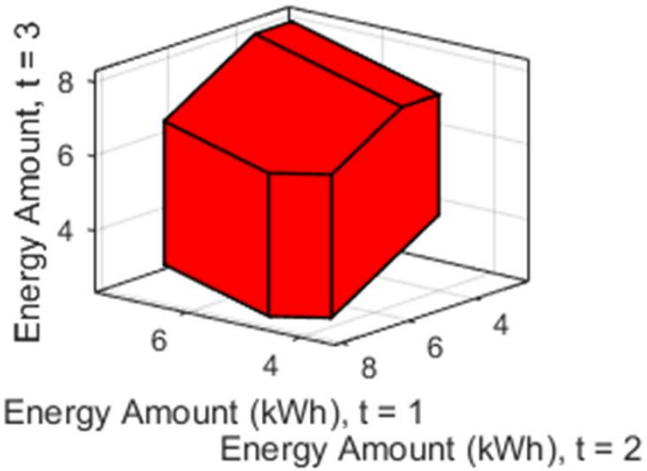
$$\theta_r - \delta \le \mathbf{x}(t) \le \theta_r + \delta$$

$$t = 1..T$$

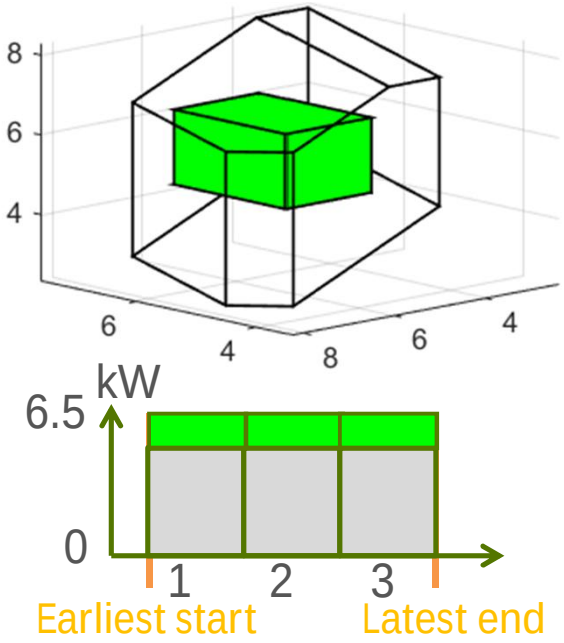


R – thermal resistance (°C/kW);
C – thermal capacitance (kWh/ °C);
η – coefficient of performance
θ_a – ambient temperature (°C)
θ_r – required temperature (°C)
δ – user temperature band (°C)

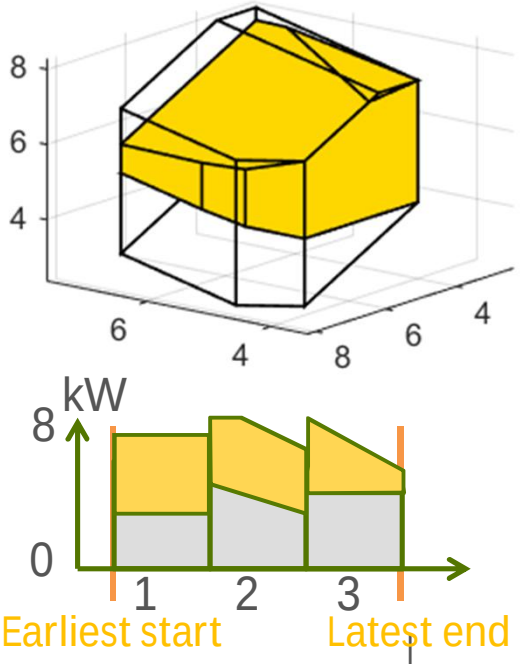
2. Exact polyhedrons



3. FO with Energy Flexibility



4. FO with Energy Flexibility and Dependencies



FLEX-OFFER RELATED PROJECTS AND MAJOR ACHIEVEMENTS

> Related Projects/Initiatives

2010-2013

MIRABEL energy

Balancing energy supply and demand

www.mirabel-project.eu

- Scalable ICT system for:
  - Higher RES integration
  - Demand-supply balancing
  - Flex-offer management

TotalFlex 2012-2016

www.totalflex.dk

- Develops and demonstrates a market-based system for flexibility trading and congestion management

2013-2017

ARROWHEAD

www.arrowhead.eu

- Largest European auto-mation project of all time
- Collaborative automation and interoperability of networked devices in (1) production, (2) end-user services, (3) smart buildings and infrastructure, (4) electro-mobility, and (5) markets of energy.

Flex-Offers

DiCyPS 2015-2021

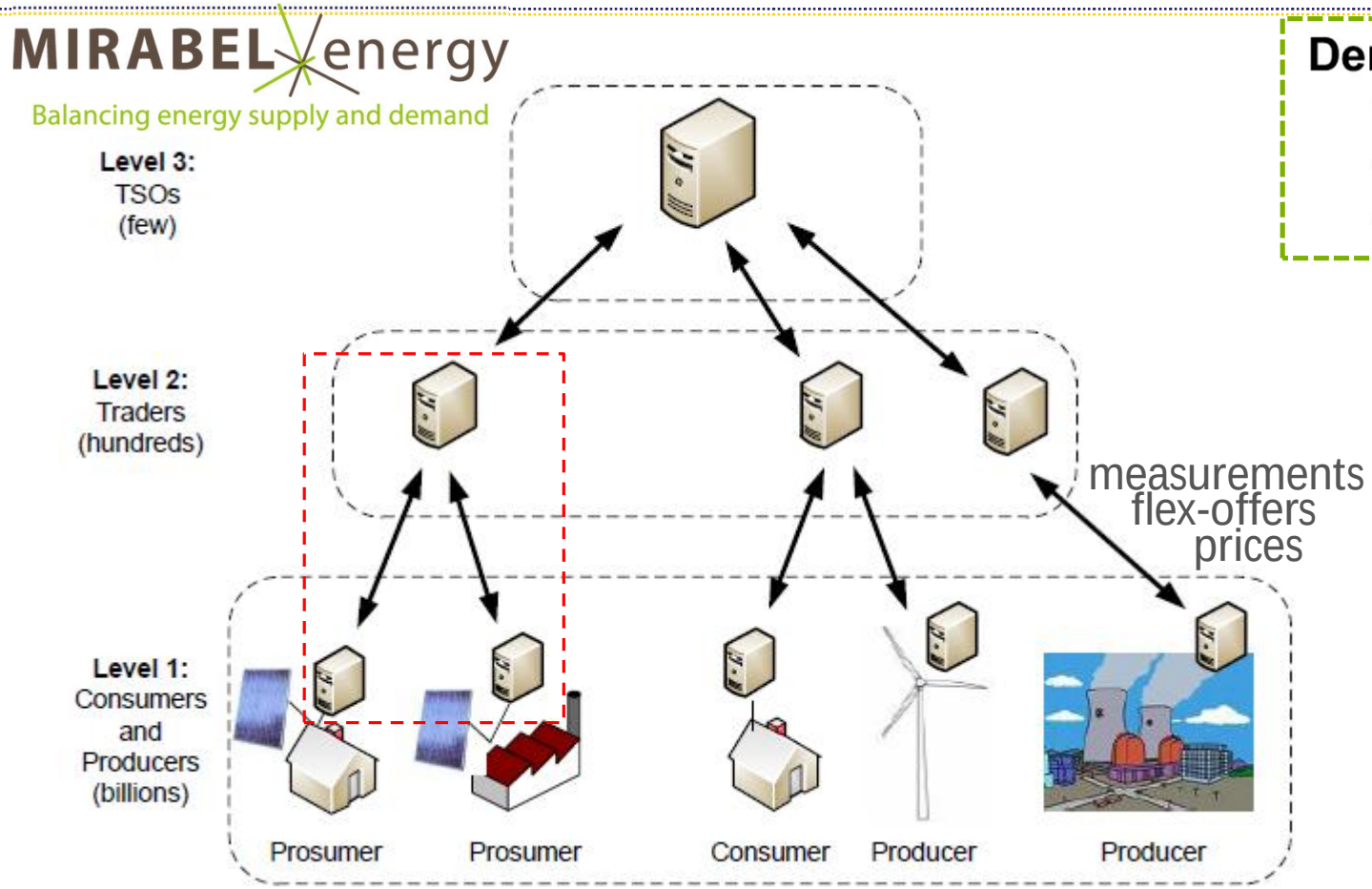
CENTER FOR DATA-INTENSIVE CYBER-PHYSICAL SYSTEMS

- Research on how to utilize software and data for smarter solutions in heath, traffic, energy, and community service domains

GOFlex 2016-

- Will integrate, and demonstrate a group of smart-grid technologies for the cost effective use of demand response in distribution grids

Major results: Hierarchical ICT infrastructure



Denmark
1 TSO
~100 traders (BRPs)
$\sim 3 \cdot 10^6$ households

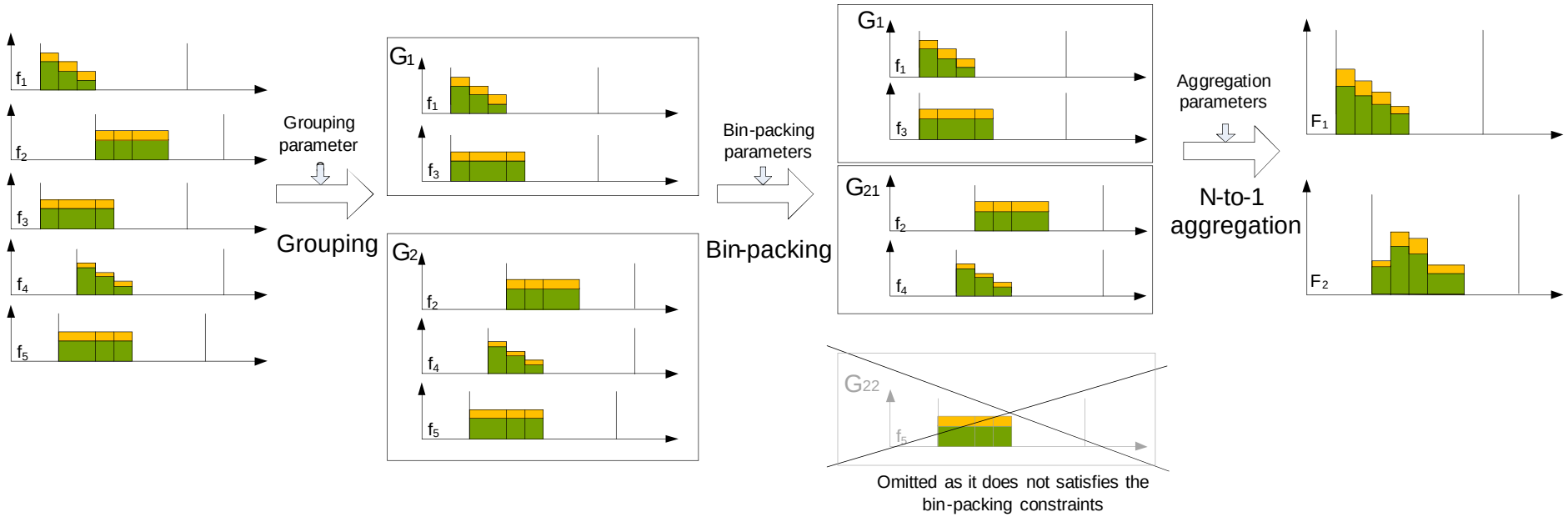
- Flexible demand and supply can lead to 7-13% cost reduction for BRPs.
- Flexible demand and supply improves RES integration significantly: 70% of the negative impact of fluctuating renewables can be neutralized if 15% of the energy consumption is flexible and intelligently controlled by the BRP.
- Households can reduce energy bills by 10-20%

> Major results: Flex-Offer Aggregation

MIRABEL energy
Balancing energy supply and demand

TotalFlex

For all forms of flex-offers, a number of flex-offer (dis-) aggregation techniques were developed: *simple*, *incremental*, with *bin-packing*, with *balancing.*



Major results: Flex-Offer Aggregation

MIRABEL energy
Balancing energy supply and demand

TotalFlex

- Millions of flex-offers can be aggregated and disaggregated in seconds
- *Aggregation+Scheduling+Disaggregation* is BETTER AND FASTER than just *Scheduling*
- Aggregated flex-offers of the desired form can be generated:
  - "More flexibility NOW"
  - "More flexibility LATER"
  - "Keep balance conditions"

Major results: Flex-Offer Market

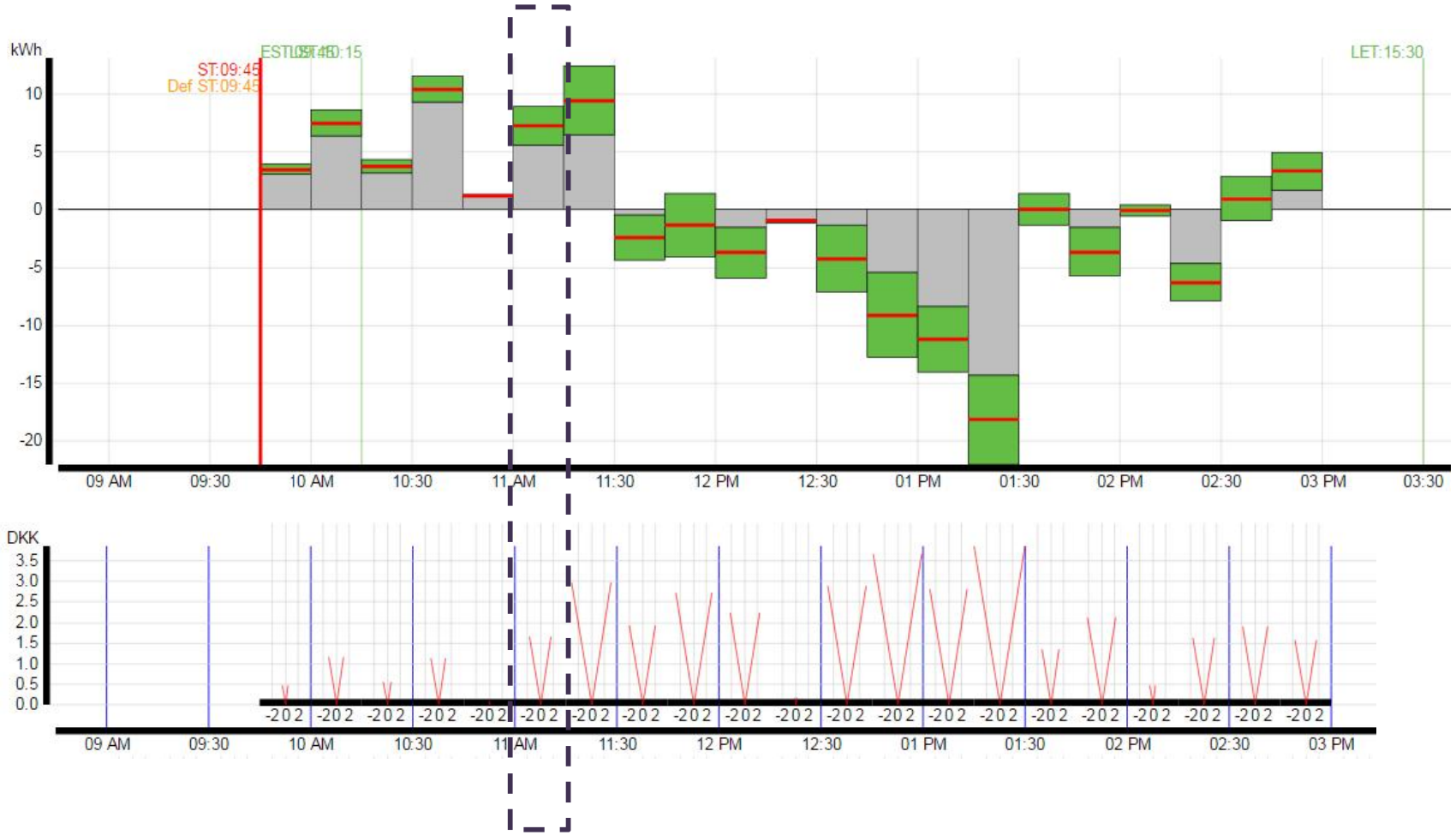
TotalFlex

- PERFORMED AN ANALYTICAL AND EXPERIMENTAL VALIDATION OF FLEXIBILITY IN THE DANISH REGULATION AND SPOT MARKETS:
  - On average, 50% of the energy demand from a household is flexible.
  - BRPs/Aggregators can achieve 49% reduction in the regulation cost with just 3.5% of energy demand being flexible
- CONSIDERED FLEXIBILITY PRICING AND DEVELOPED A MARKET FOR FLEXIBILITY (FLEX-OFFERS)

Major results: Flex-Offer Market

TotalFlex

Default Schedule and Prices for ΔkWh:

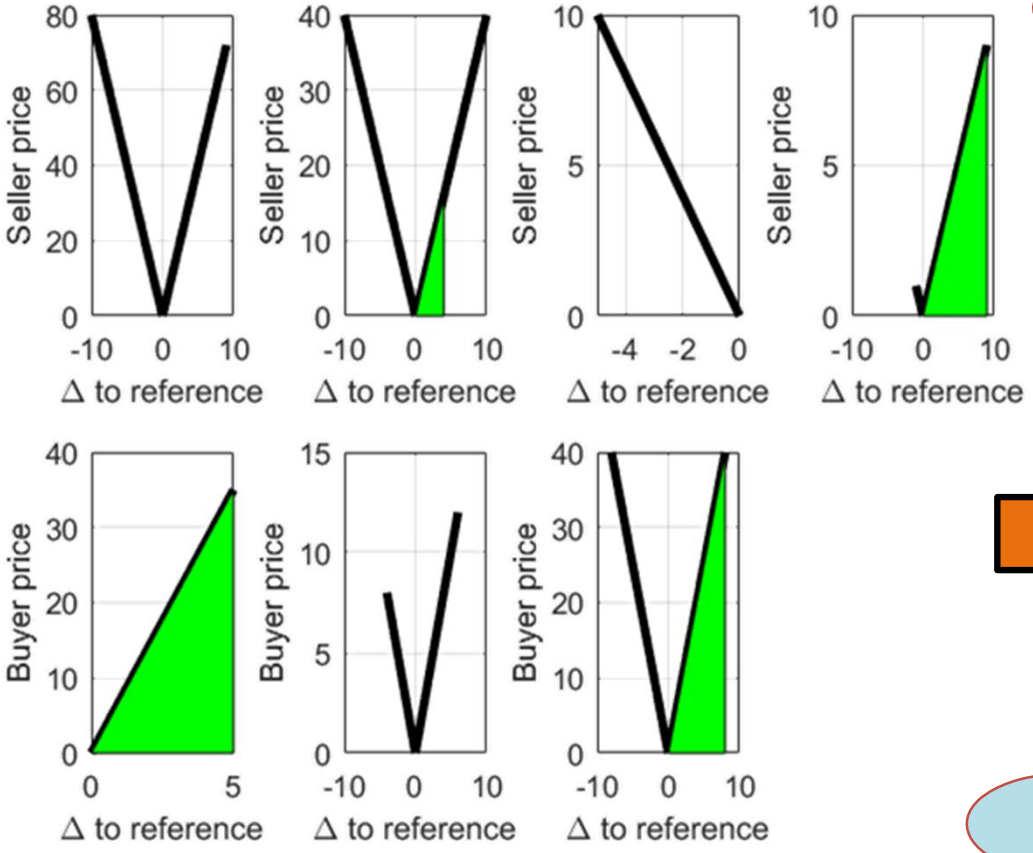


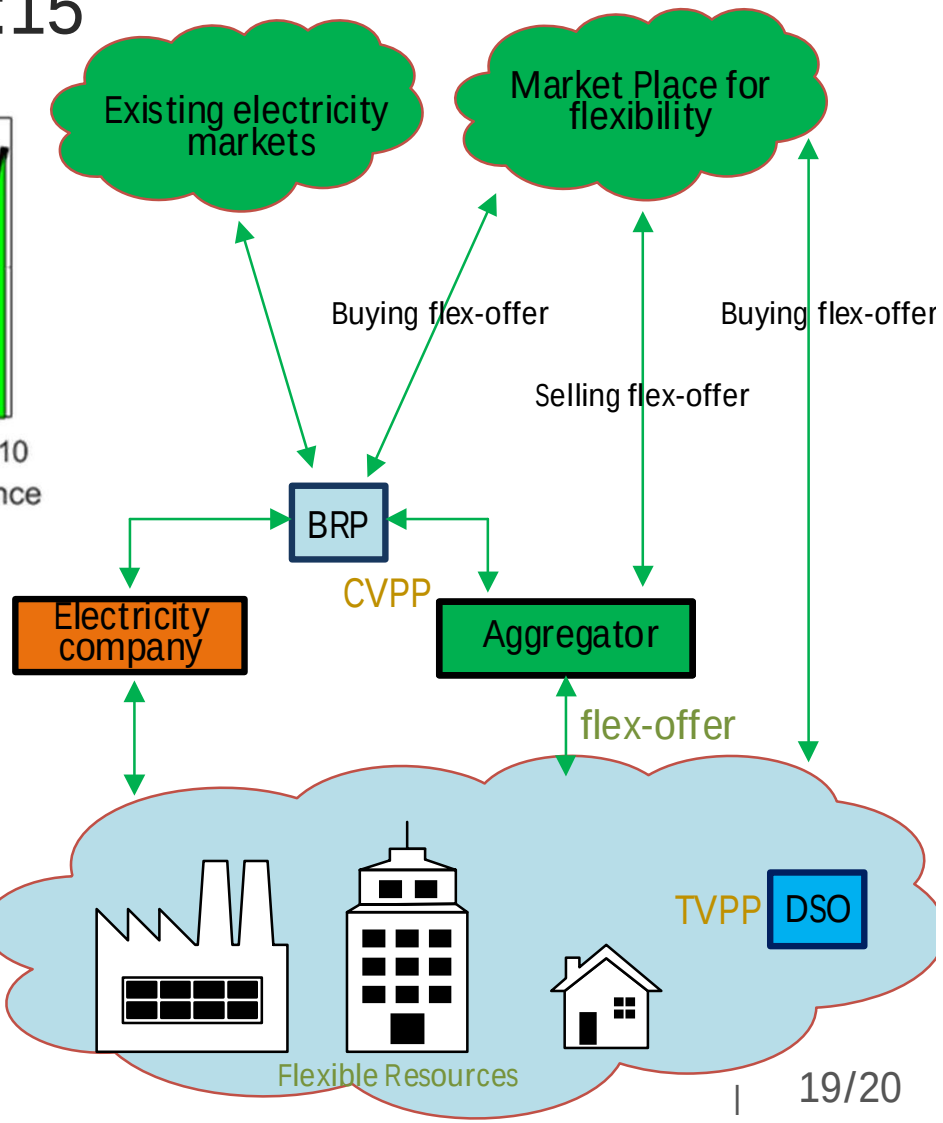
Time interval 11:00-11:15

Major results: Flex-Offer Market

TotalFlex

FLEXIBILITY TRADING: 11:00-11:15





> Summary

➢ FLEX-OFFERS

- Powerful concept for unified modelling of flexibility
- Suitable for *negotiation*, *planning/trading*, *control*, and *billing*
- Validated in a number of Danish and EU projects

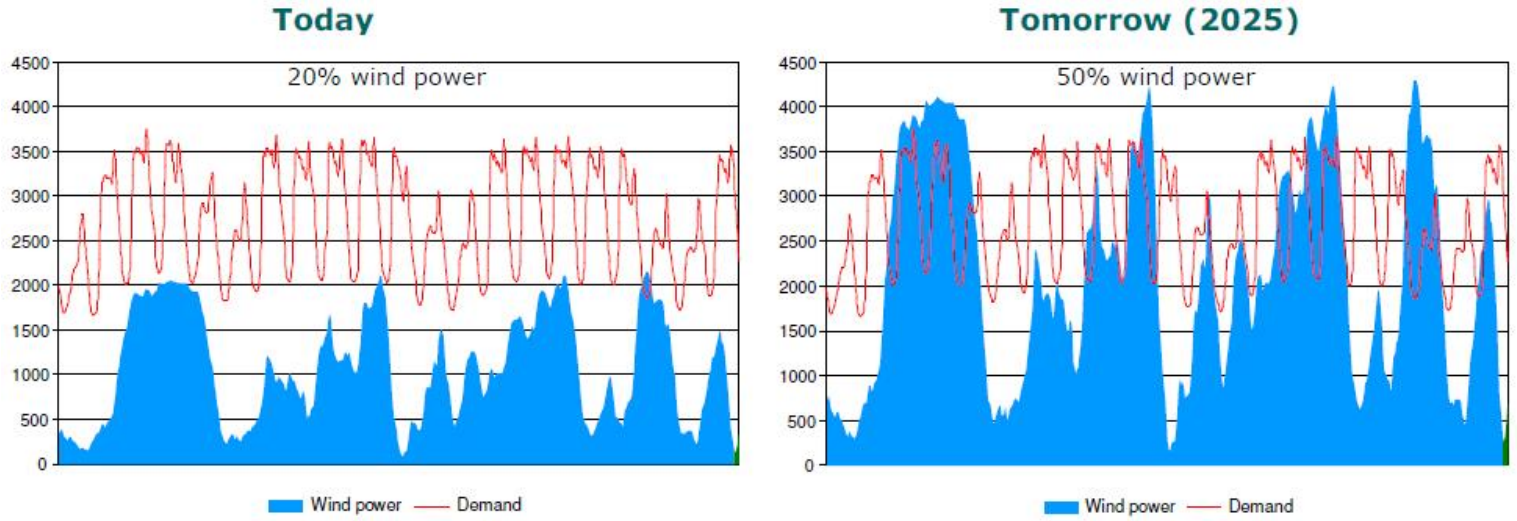
➢ KEY REFERENCES

- Matthias Böhm, Lars Dannecker, Andreas Doms, Erik Dovgan, Bogdan Filipic, Ulrike Fischer, Wolfgang Lehner, Torben Bach Pedersen, Yoann Pitarch, Laurynas Siksnys, Tea Tusar: *Data management in the MIRABEL smart grid system*. EDBT/ICDT Workshops 2012: 95-102
- Luis Lino Ferreira, Laurynas Siksnys, Per Pedersen, Petr Stluka, Christos Chrysoulas, Thibaut Le Guilly, Michele Albano, Arne Skou, César Teixeira, Torben Bach Pedersen: *Arrowhead compliant virtual market of energy.* ETFA 2014: 1-8
- Laurynas Siksnys, Emmanouil Valsomatzis, Katja Hose, Torben Bach Pedersen: *Aggregating and Disaggregating Flexibility Objects*. IEEE Trans. Knowl. Data Eng. 27(11): 2893-2906 (2015)
- Laurynas Siksnys, Torben Bach Pedersen*: Dependency-based FlexOffers: scalable management of flexible loads with dependencies*. e-Energy 2016: 11:1-11:13

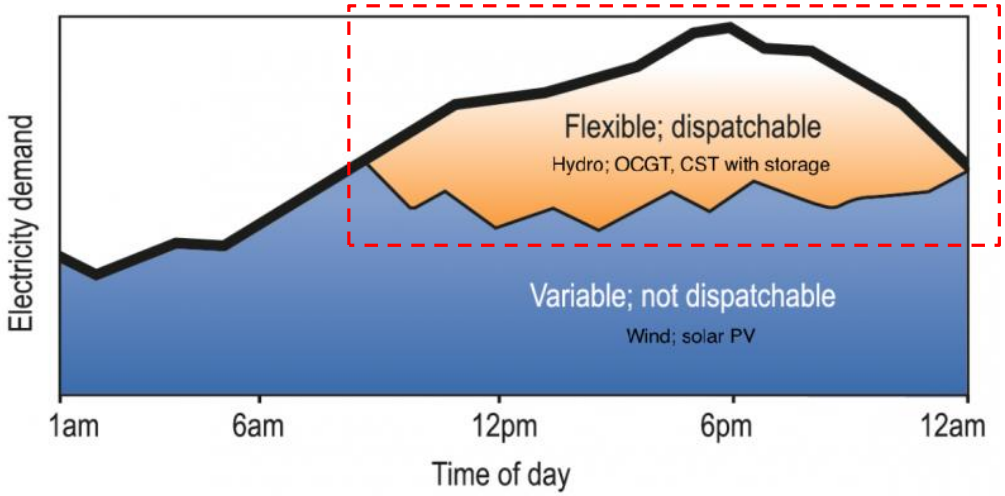
THANK YOU!

AALBORG UNIVERSITET daisy Center for Data-intensive Systems

RENEWABLE ENERGY IS CHALLENGING:

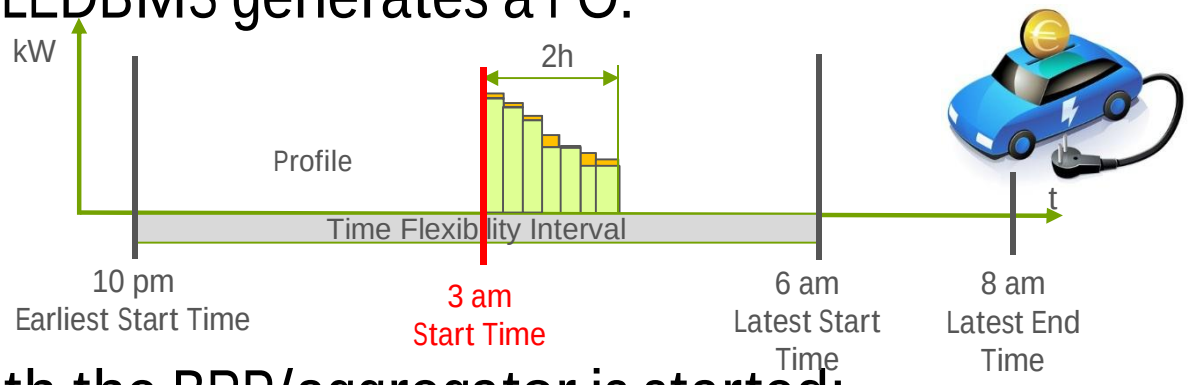


SOLUTION: MAKE DEMAND AND SUPPLY FLEXIBLE

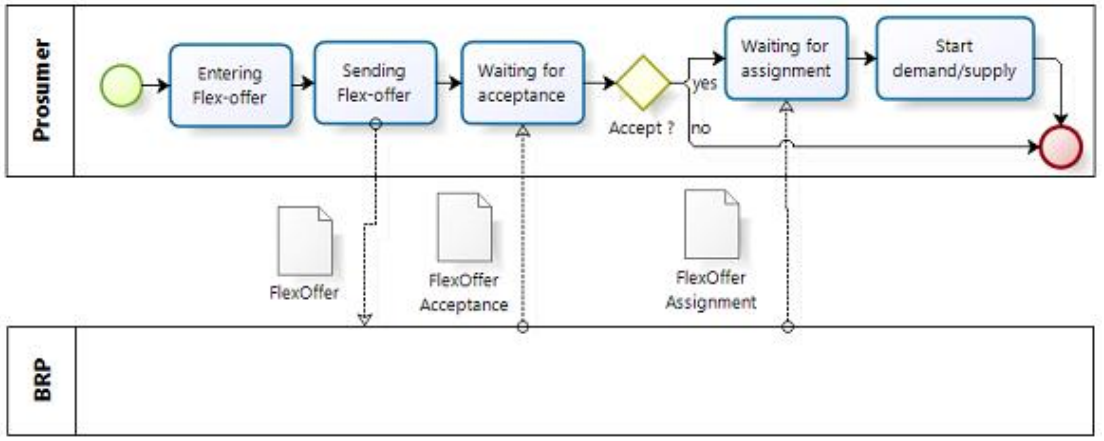


> Use-case Example

1. A consumer arrives home at 10pm and wants to rechange the electric vehicle‘s battery at the lowest possible price by the next morning
2. The consumer‘s LEDBMS generates a FO:

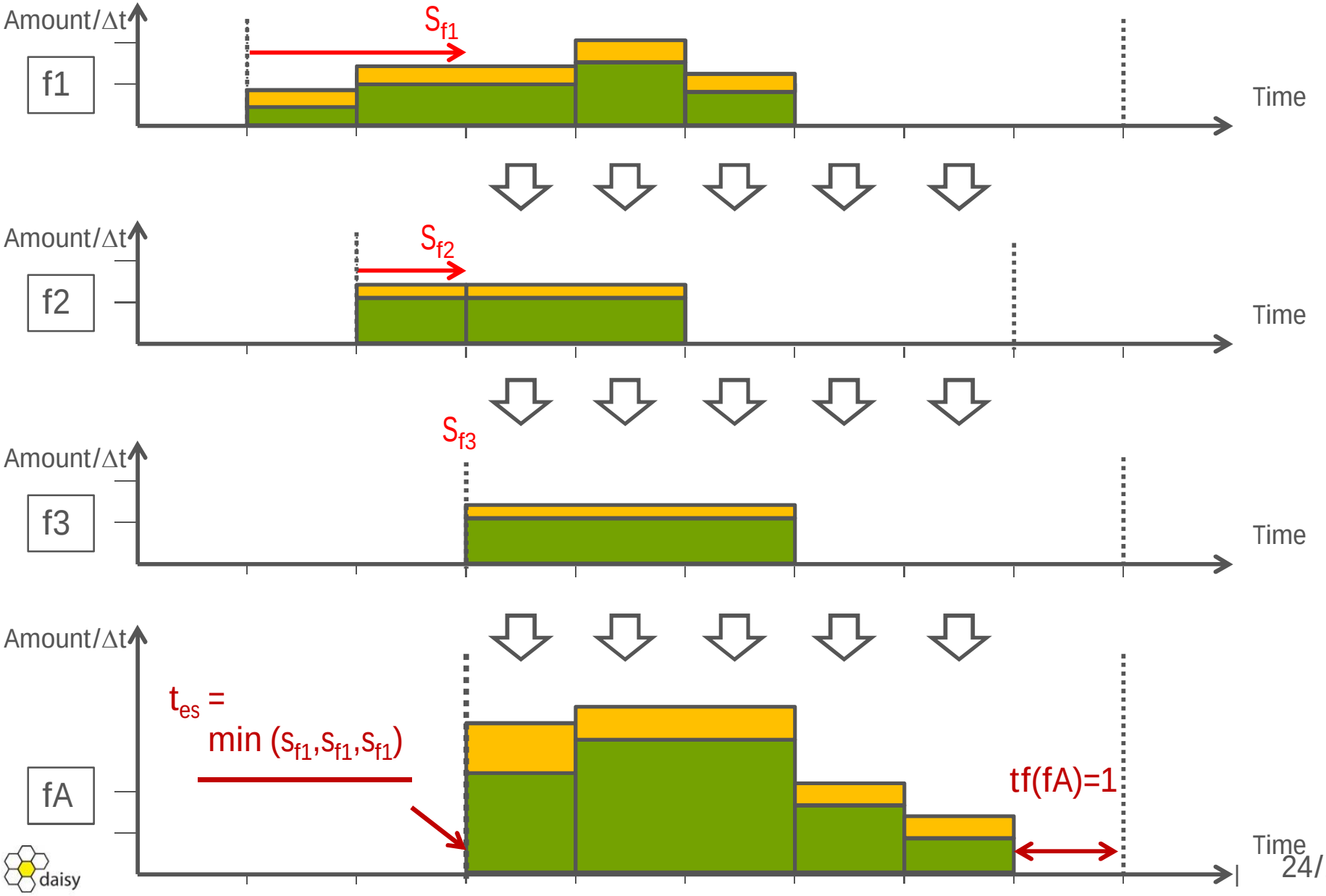


3. A negotiation with the BRP/aggregator is started:

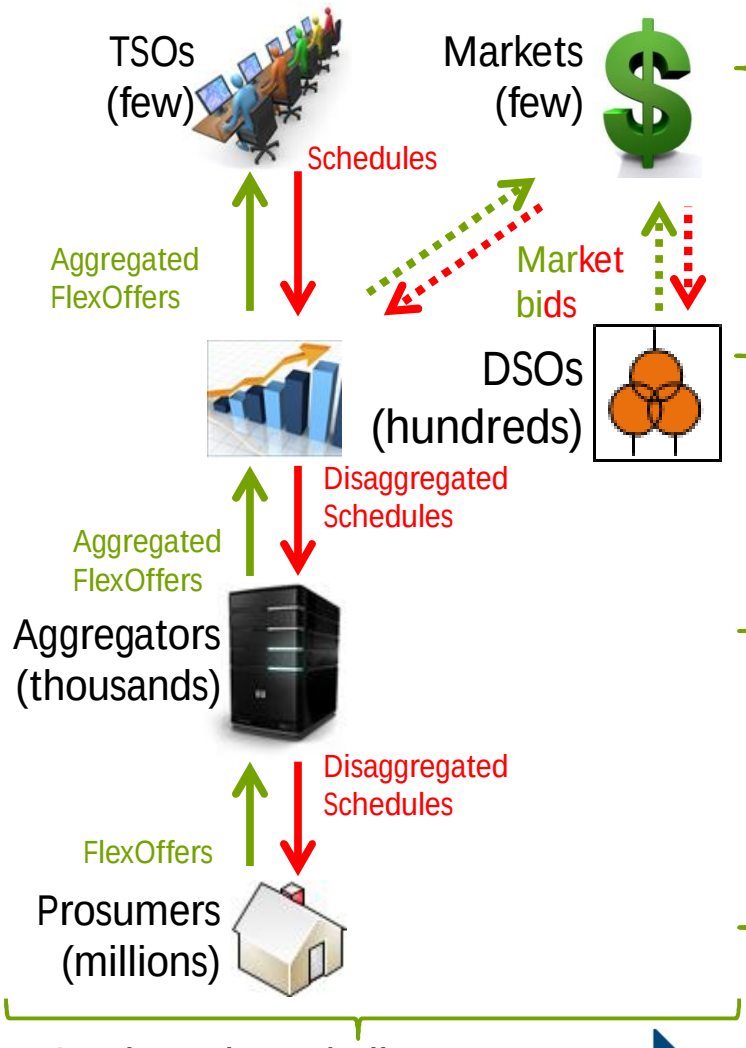


4. The consumer is rewarded for its offered flexibility

> Major results: Flex-Offer Aggregation



FlexOffer Management Platform



- Flexibility market approach — TotalFlex
- Evaluation of flexibility value in energy regulation markets — TotalFlex
- Cost-effective FlexOffer scheduling techniques for energy balancing — MIRABEL energy
- Integrated system for FlexOffer data prescriptive analytics and management — TotalFlex
- Algorithms for predicting grid congestions — TotalFlex
- Scalable techniques for aggregating FlexOffers and disaggregating FlexOffer schedules — MIRABEL energy
- Techniques for balancing energy and avoiding grid congestions during FlexOffer aggregation — TotalFlex
- Techniques for flexibility extraction from the smart-meter measurements — MIRABEL energy
- Techniques for flexibility detection and extraction at the appliance levels — TotalFlex

- Service-oriented pilot demonstration

ARROWHEAD

www.arrowhead.eu