

# Why the Smart Grid should not underestimate your refrigerator

Demand-side self-stabilization of energy consumption

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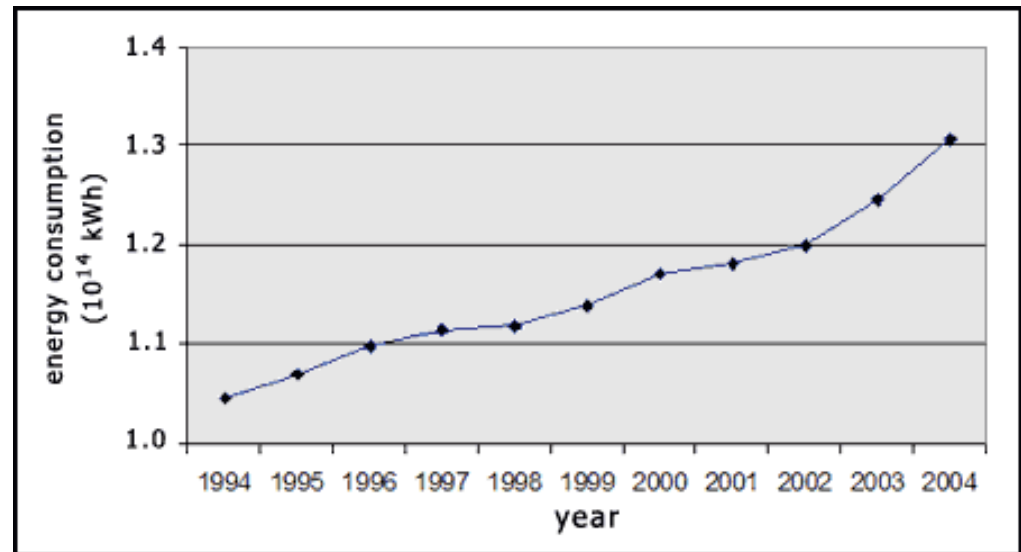
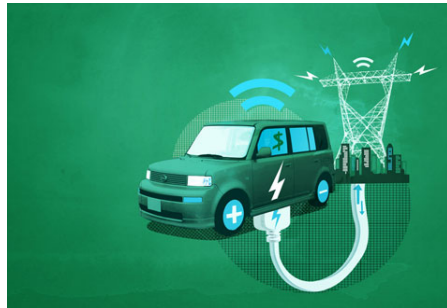
# Problem Description



## Matching energy production to energy consumption



New emerging challenges



Source: US Department of Energy Information Administration

# Problem Description (Cont.)

Expensive

Complex

## **Production-side matching**

Inflexible

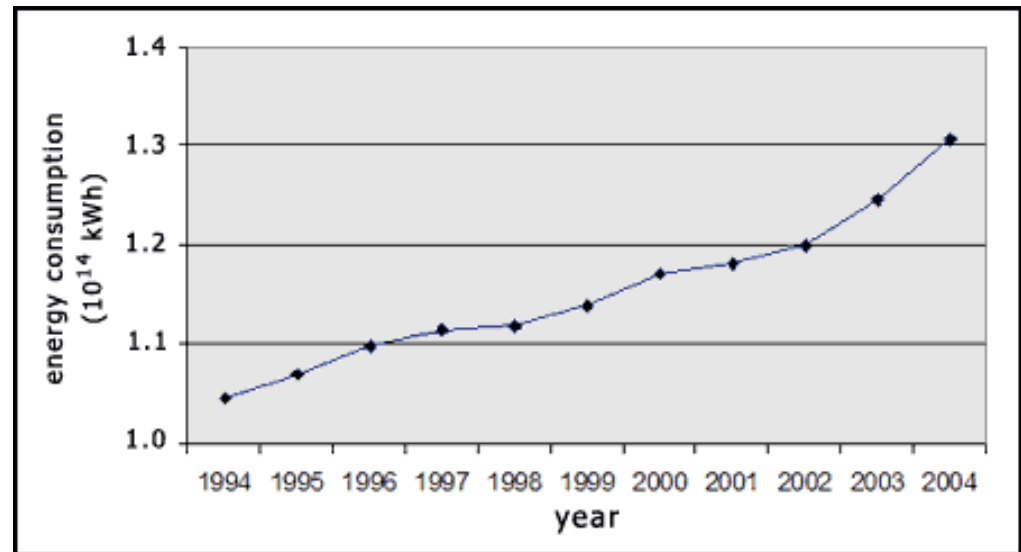
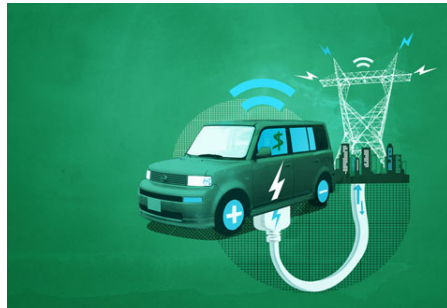
# Problem Description (Cont.)



## Matching energy production to energy consumption



New emerging challenges



Source: US Department of Energy Information Administration



# Problem Description (Cont.)

Large-scale coordination

Heterogeneous environment

## **Consumption-side matching** (Demand-side management)

Communication

Integration

# Research Question

Can we achieve decentralized stabilization of energy consumption with a minimum user involvement?

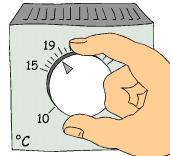


# EPOS

Energy Plan Overlay Self-stabilization

# The Means of Stabilization

Simple



≈30% of total energy consumption

Source: U.S. Department of Energy, Core Data Book, 1997

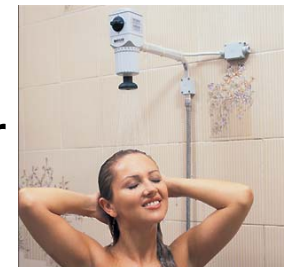
## Thermostatically controlled appliances



No critical operation

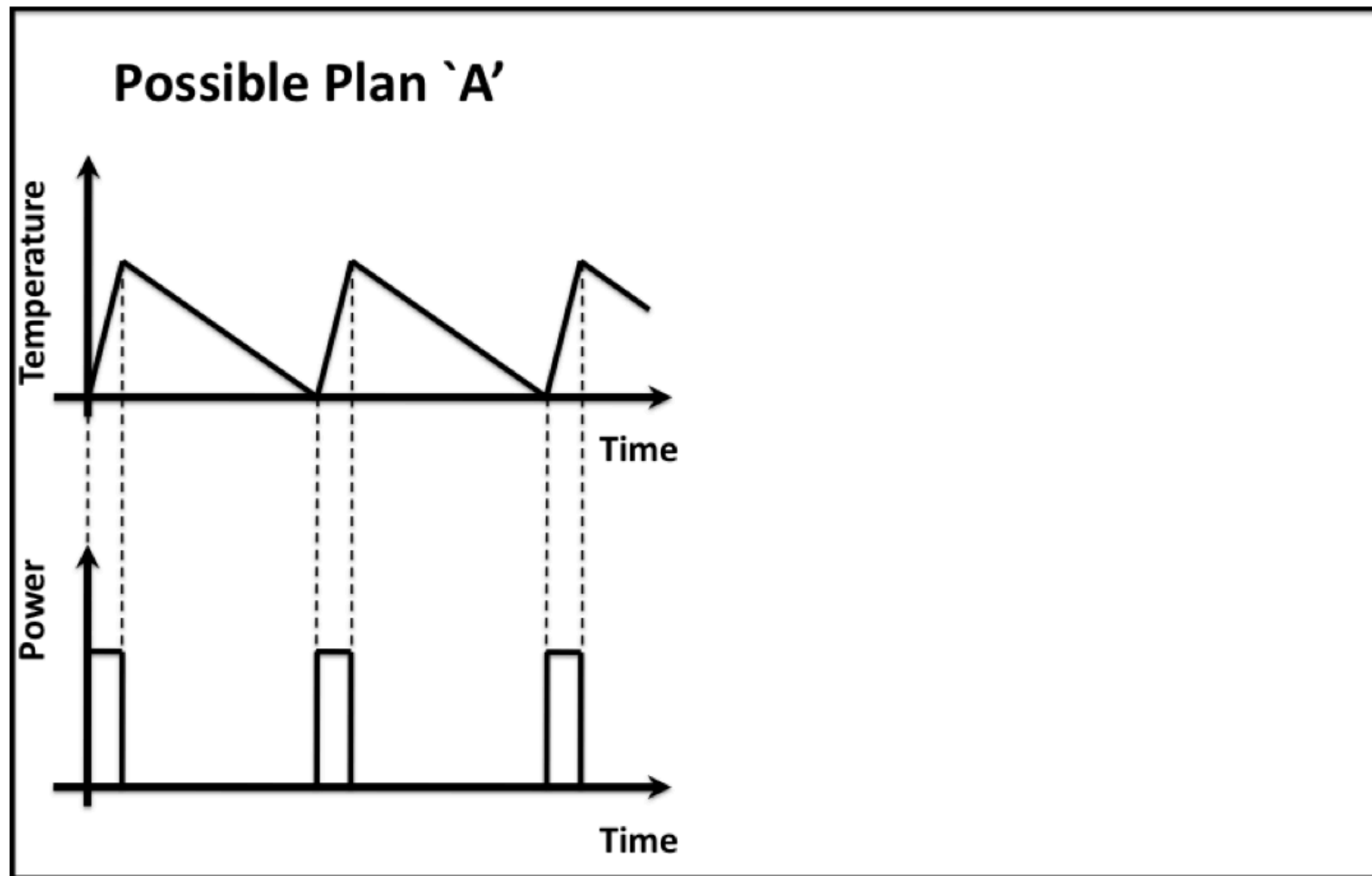


'Easy' to model user

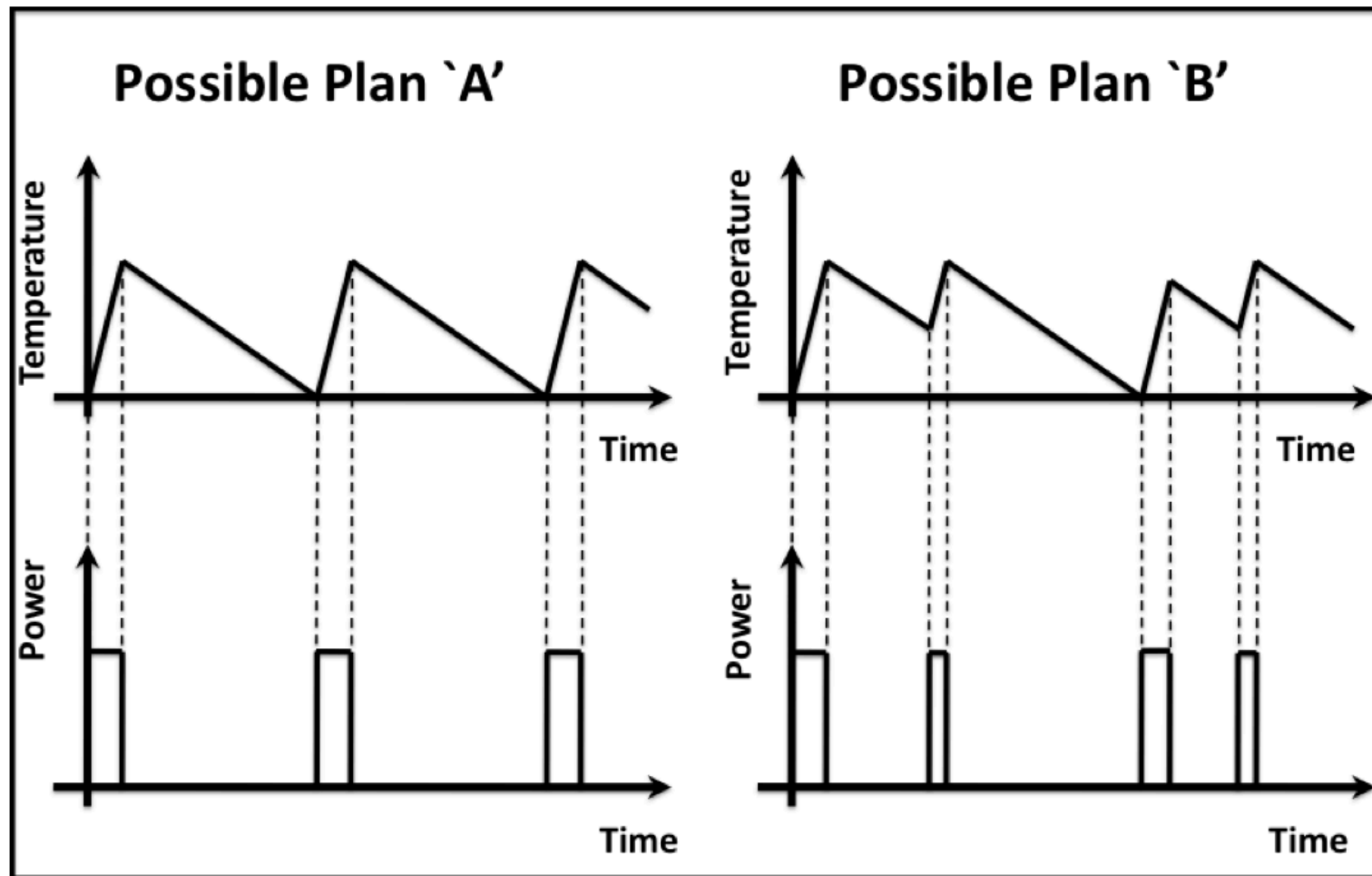




# Operational Flexibility




# Operational Flexibility



# Operational Flexibility (Cont.)

**LG introduces its first Smart Grid-Ready Refrigerator the DIOS**

Category: Environment Household - Tags: Household, Lg, Lge, Smart Adapt, Smart Grid, Wi-fi, Wifi




Barely 24 hours Samsung's Smart Grid Ready fridge, LG is now announcing its very own connected Smart Grid-Ready DIOS Fridge in Korea. The new smart refrigerator offers updates and information that can be accessed via smartphones and tablets. It offers three powerful smart savings options: late night saving, preferable time saving and the Smart Grid-ready.

The smart fridge also comes with Smart Adapt, which allows owners to keep their refrigerator software up-to-date with the latest upgrades, features and options. The smart fridge is also a source of useful information as it keeps track of daily schedules and dispenses regular weather reports. And instead of having to jot notes on sticky memos, family members can turn the fridge's LCD screen into a note pad to leave messages for each another.

Via LGE

Category **ENVIRONMENT HOUSEHOLD**

4 Comments



Agents can know when  
to change the  
temperature setpoints

**Is this possible?**

Agents can know when to  
pre/post cool or heat

## Available Technologies

### Grid Friendly Appliance™ Controller

Battelle Number(s): 12782-E, 13538-B  
Patent(s) Issued  
Available for licensing in all fields

Awards Won:  
R&D 100 Award - 2008  
FLC Award - 2007

#### Summary

The Grid Friendly Appliance controller developed at PNNL senses grid conditions by monitoring the frequency of the system and provides automatic demand response in times of disruption.



(click on image for full size)

Within the North American power grid a disturbance of 60-Hz frequency is an indicator of serious imbalance between supply and demand that, if unarrested, leads to a blackout. This simple computer chip can be installed in household appliances and turn them off for a few minutes or even a few seconds to allow the grid to stabilize. The controllers can be programmed to autonomously react in fractions of a second when a disturbance is detected, whereas power plants take minutes to come up to speed. They can even be programmed to delay restart instead of all coming on at once after a power outage to ease power restoration.

#### Advantages

- More reliable power grids are less costly to run
- Smaller electricity bills for consumers
- More efficient power plant use
- Inexpensive
- A foundation for future grid management

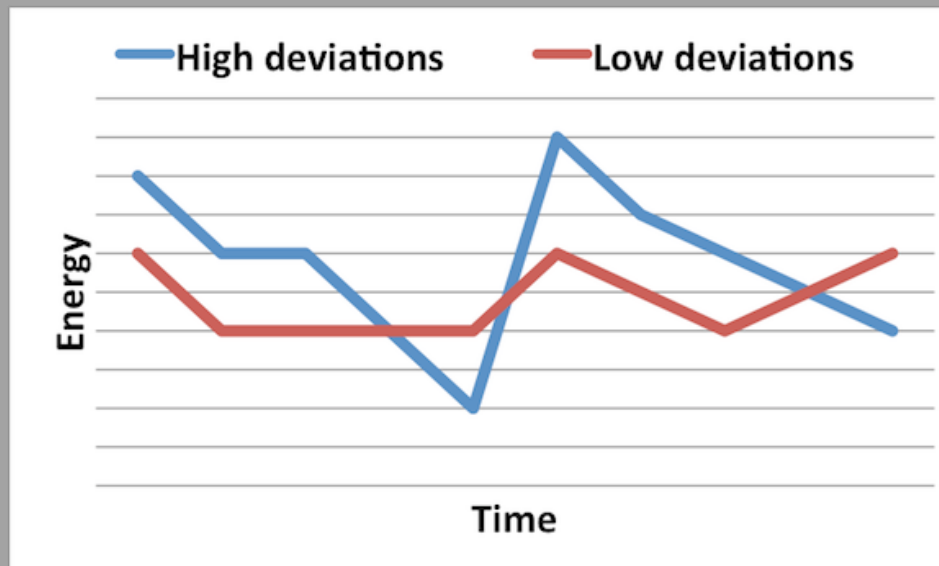


# Coordination

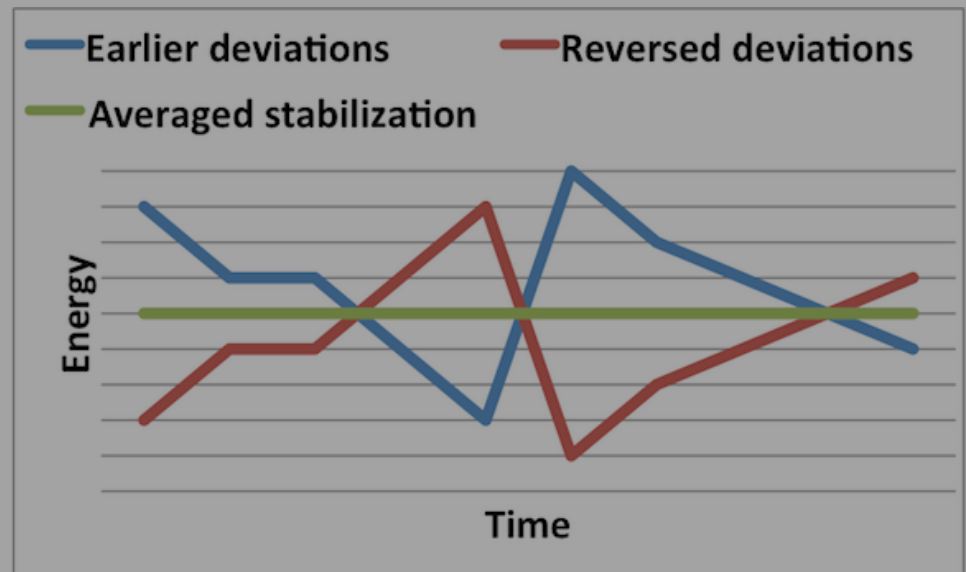
Every agent should execute the possible plan that stabilizes the global energy consumption

# Stabilization

## Two system objectives

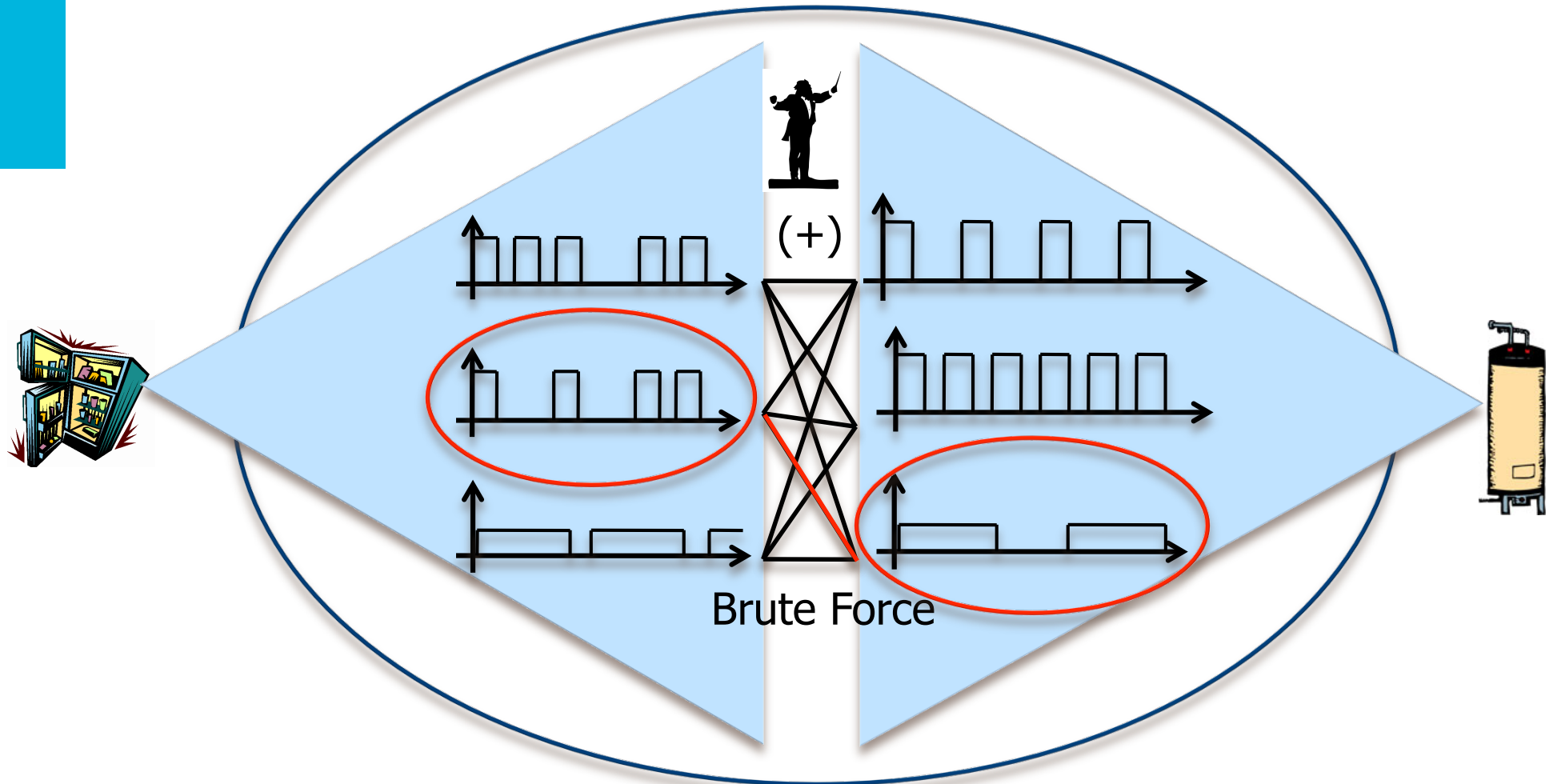


Minimizing deviations



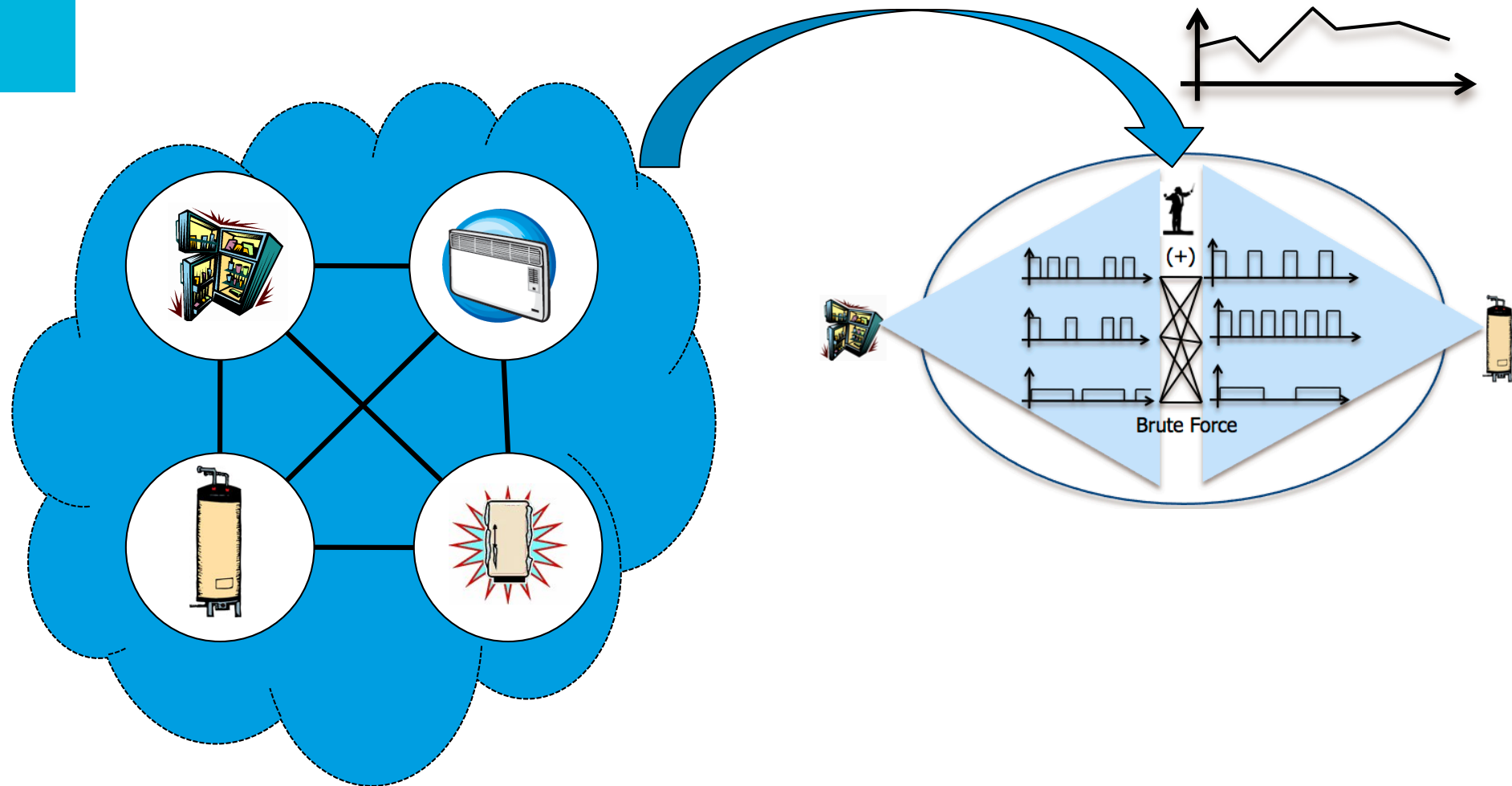
Reversing deviations

# Coordination (Cont.)

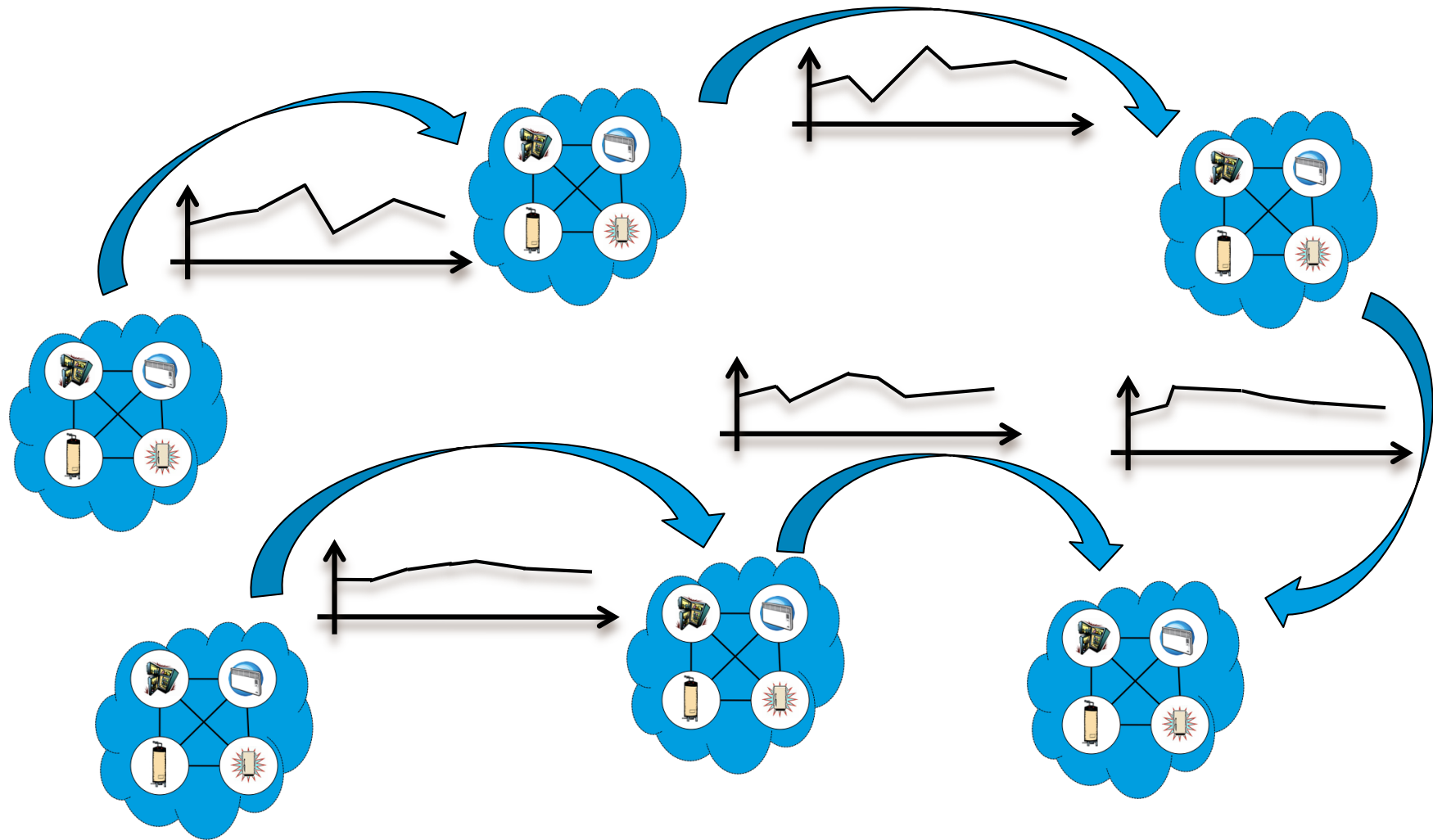


**Complexity = # of possible plans<sup># of devices</sup>**

# Adaptation



# Adaptation (Cont.)







# Overlay Communication

Tree topologies (structured)

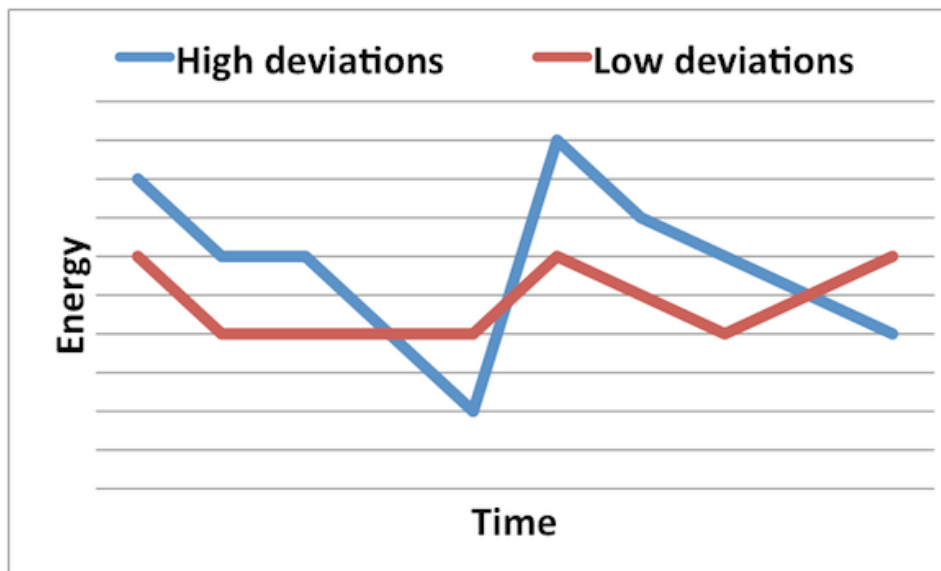
## **Challenge**

Duplicate-free aggregation

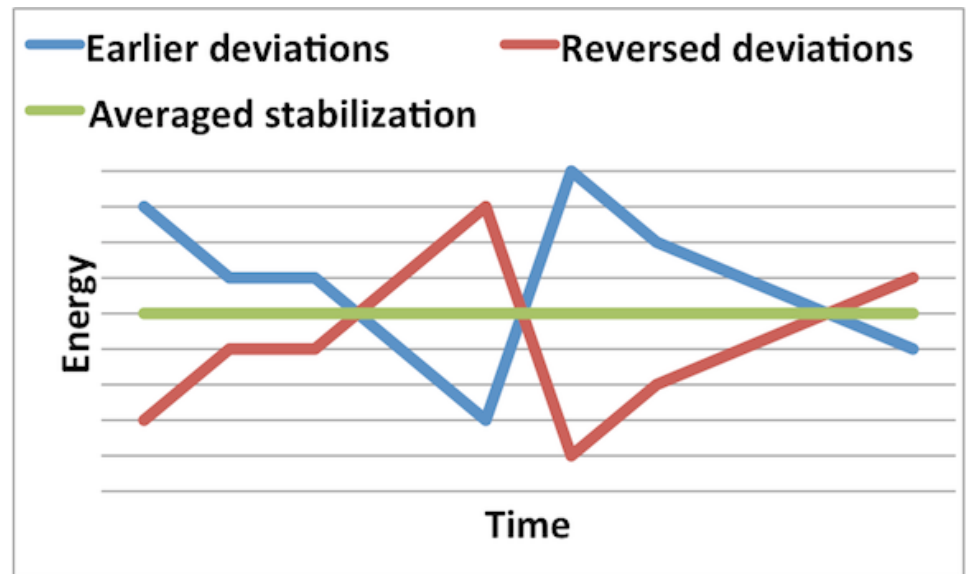
Duplicate-aware topologies (unstructured)

# Stabilization

## Two system objectives



Minimizing Deviations



Reversing Deviations

# Experimental Results

Minimization of deviations  $\approx 63\%$

Reverse of deviations  $> 90\%$

**Settings:** Tree coordination, 3280 agents, 5 possible plans/agent

**Comparison:** Random plan execution & locally optimum plan execution

More possible plans, more children/agent=Higher stabilization, higher cost

**Source:** Evangelos Pournaras, Martijn Warnier and Frances M.T. Brazier, Local Agent-based Self-stabilisation in Global Resource Utilisation, International

Journal of Autonomic Computing, Vol. 1, Nr. 4, 350-373, 2010

# Answers

Minimum deviations

Demand-side stabilization

Matching deviations

Reversed deviations

Ongoing work

**Can we achieve decentralized stabilization of energy consumption with a minimum user involvement?**

Unstructured topologies

Ongoing work

Decentralization

No involvement

Minimum user involvement

Self-organization of trees

Incentives

**Source:** Warnier and Frances M.T. Brazier, Adaptation Strategies for Self-management of Tree Overlay Networks, in the proceedings of the International Conference on Grid Computing-Grid 2010, pages 401-409, Brussels, Belgium, October 2010



# Conclusions

Extreme cases

Non-extreme cases

## **EPOS: flexible energy consumption in the Smart Grid**

Simple intervention

New business opportunities



# Questions?

## **More information**

<http://evangelospournaras.com/project/epos/>

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