Sustainable Energy Policy and Strategies for Europe

October 28-31, 2014 in Rome, Italy
LUISS University of Rome

ABSTRACT SUBMISSION DEADLINE **JUNE 1st, 2014**

The Conference Objectives

As Europe strives to overcome the economic crisis, energy stands out both as a conditioning factor and as an opportunity. The energy situation is evolving in Europe as well as in the rest of the world, where new actors, the emerging economies, are taking the leading role. Political developments in several areas of the globe (North Africa and Middle East, the Caspian region, ASEAN countries) are reshaping the geopolitical situation, generating some worries about the security of supply in the EU countries.

The crisis has somewhat released the pressure on energy demand and allowed to reach objectives in the reduction of greenhouse gas emissions that seemed out of reach, but as the European Energy Roadmap to 2050 makes clear the objectives for 2020 and beyond are likely to require a renewed, powerful effort as soon as the economy is back on the track.

Important steps towards the establishment of a really open and competitive energy market in Europe have been achieved, but much remains to be done. Energy technologies (as evidenced in the SET-Plan) have evolved and contributed new solutions, as in the case of non-conventional hydrocarbon resources, but this has happened more as gradual step-by-step improvements than by real breakthroughs. The evolution of these technologies has been influenced by the instruments adopted by governments to promote new sources or new solutions rather than directly by market demand. The use of "market instruments" to steer the energy choices in the direction of sustainability is the subject of animated discussions, based on the analysis of diverse case studies. The hope of obtaining reductions of energy costs by these means has been often frustrated.

Some sectors show difficulties in moving in the right direction (in terms of economy as well as sustainability): the outstanding example is the transport sector, where, apart from the improvement of the efficiency of vehicles, there is little sign of moving from the present paradigm (with private prevailing over public transport, road over track and waterways,) and sporadic attempts are done to reduce the need of displacements (both of people and of goods). Another sector which is meeting institutional rather than technical difficulties is the building sector, especially as concerns distribution of costs and revenues among the different actors.

The first (dual) plenary session of the Conference will be devoted to the European Energy Road Map to 2050, and to the response to environmental challenges.

The next plenary sessions will deal with the specific energy aspects of transportation, and to the efficiency of energy utilisation in buildings. The last two plenary sessions will be devoted to energy geopolitics and emerging countries, and to the regulation of energy markets.

The 14th IAEE Conference will try to discuss all the issues related to European policy and its new perspectives in 8 plenary and 40 concurrent sessions that will be organized by the **AIEE- Italian Association of Energy Economists and IAEE - The International Association for Energy Economics**, in cooperation with the **Guido Carli Free International University for Social Studies - LUISS**, that will host this conference.

LUISS

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(see map)

Designing Business Models for different market participants in a hybrid retail energy market

Tariff Design Options for Residential Customers

Daniel Schwabeneder

October 31, 2014

Outline

The OrPHEuS FP7-Project

- **Hybrid poit-of-view:** Consider different energy networks (Electricity, Gas & Heat) as a hybrid energy network via coupling technologies (CHP, heat pumps, ...).
- **Cooperative concept:** Develop cooperative hybrid control strategies and corresponding business models among different market participants aiming to create win-win situations.

$\Longrightarrow$ Create optimization models for different market participants (**Customers**, **Supply Companies** & **Distribution System Operators (DSO)**) for validation.

This presentation will focus on the model for **Customers**.
Research Question:

Influence of different **tariff types** on the **residual loads** of residential customers?

The model should

- consider multiple energy domains simultaneously and
- be flexibly adaptable to different technology portfolios.

Notation

- The **demand** is exogenously given and denoted by $\mathbf{d}(t)$.
- The **prices** are are chosen by the supply company and the distribution system operator, respectively, and denoted by $\mathbf{p}(t)$.
- The **purchased energy** or **residual load** is a decision variable and denoted by $\mathbf{q}(t)$.

All quantities (kWh/h) and prices (c/kWh) are written as 3-dimensional vectors:

$$\mathbf{d}(t) := \begin{pmatrix} d^{El}(t) \\ d^{Gas}(t) \\ d^{Heat}(t) \end{pmatrix}, \quad \mathbf{q}(t) := \begin{pmatrix} q^{El}(t) \\ q^{Gas}(t) \\ q^{Heat}(t) \end{pmatrix}, \quad \mathbf{p}(t) := \begin{pmatrix} p^{El}(t) \\ p^{Gas}(t) \\ p^{Heat}(t) \end{pmatrix}.$$

The considered time frame is a planning period of N years and the customer's personal interest rate is denoted by r.

Basic objectives

Standard Customer:

$$\min\ C \overset{!}{=} \sum_{k=1}^{N} \frac{1}{(1+r)^k} \cdot \sum_{t=1}^{8760} \mathbf{p}(t)^T \cdot \mathbf{q}(t)$$
$$\text{s.t.}\ \ \mathbf{q}(t) = \mathbf{d}(t)$$

Adding a generation technology:

$$\min\ C \overset{!}{=} \mathbf{I}_{gen} + \sum_{k=1}^{N} \frac{1}{(1+r)^k} \cdot \sum_{t=1}^{8760} \Big(\mathbf{p}(t)^T \cdot \mathbf{q}(t) + \mathbf{c}_{gen}(t)^T \cdot \mathbf{q}_{gen}(t) - \mathbf{p}_{feed}(t)^T \cdot \mathbf{q}_{feed}(t)\Big)$$
$$\text{s.t.}\ \ \mathbf{q}(t) + \mathbf{q}_{gen}(t) = \mathbf{d}(t) + \mathbf{q}_{feed}(t)$$
$$\mathbf{q}_{gen}(t) \leq \bar{\mathbf{q}}_{gen},$$
$$\mathbf{q}(t), \mathbf{q}_{gen}(t), \mathbf{q}_{feed}(t) \geq 0$$

Similarly other technologies like energy storages can be added.

Preliminary remarks

Research Question:

Influence of different **tariff types** on the **residual loads** of residential customers?

- No flexible behaviour of customers has been assumed.
  $\Longrightarrow$ Only the operation of different technologies can influence the residual load profile.
- No investment costs for customers' technologies have been considered.
- Only one year has been simulated.

Household Customer types

Demand: Synthetic electric load profile scaled to 4000 kWh/a and heat load profile scaled to 12000 kWh/a.

Type Passive

- Electricity grid connection
- District Heating grid connection

Type μCHP

- Electricity grid connection
- Gas grid connection
- Gas-fired μCHP ($P_{\max}$: 4.7 kW_{el}, 12 kW_{th}, η_{el}: 25%, η_{th}: 65%)
- Thermal energy Storage (Capacity: 12 kWh, η: 90% Hourly stand-by loss: 2%)

Type PV

- Electricity grid connection
- PV system ($P_{\max}$: 2 kWp)
- Heat pump ($P_{\max}$: 9 kW_{th}, CoP: 341%)
- Thermal energy Storage
- Electric energy Storage (Capacity: 2kWh, η: 90% Hourly stand-by loss: 1%)

Tariff types

Assumed "Standard Tariffs"

The assumed "Standard Tariffs" consist of a fix annual lump sum and a flat energy price:

	Annual lump sum	Energy price
Electricity	48 EUR	18 c/kWh
Gas	70 EUR	7 c/kWh
District Heating	216 EUR	5 c/kWh

Furthermore, electricity customers with generation technologies are granted a feed-in tariff of 7 c/kWh.

Investigated modified Tariffs

- **Electricity time-of-use (TOU) tariff:**

$$18\ \text{c/kWh} \mapsto \begin{cases} 26\ \text{c/kWh} & \text{from 8AM to 8PM on working days} \\ 13\ \text{c/kWh} & \text{else} \end{cases}$$

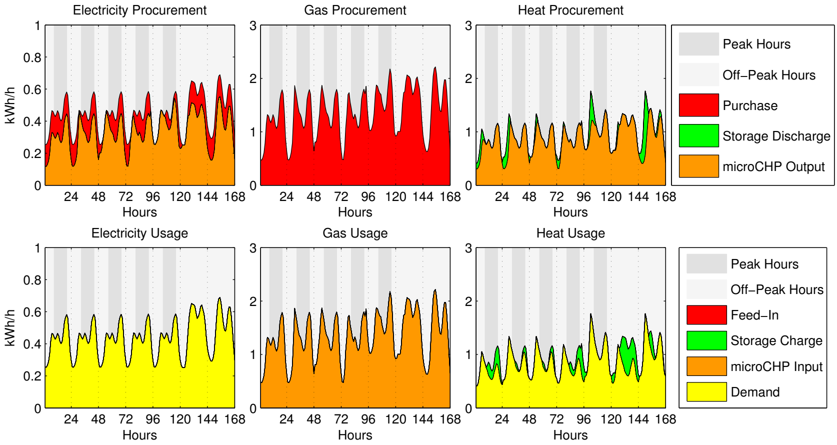
- **Peak load pricing:** Replace the annual lump sum with a monthly charged EUR/kW$_{max}$ component for the highest peak load during a month:

Electricity	48 EUR per year		5.35 EUR/kW$_{max}$ per month
Gas	70 EUR per year	$\mapsto$	1.74 EUR/kW$_{max}$ per month
District Heating	216 EUR per year		5.48 EUR/kW$_{max}$ per month

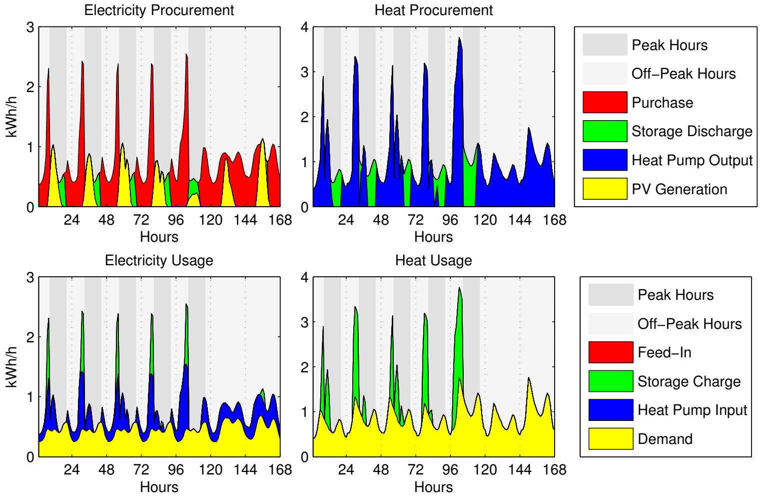
The modified tariffs have been chosen in a way that the passive customer type would have the same or slightly lower annual cost than with the "standard tariffs".

Exemplary Results

Operation of the μCHP customer type with peak load pricing



Operation of the PV customer type with an electricity TOU tariff



Residual loads of the μCHP customer type

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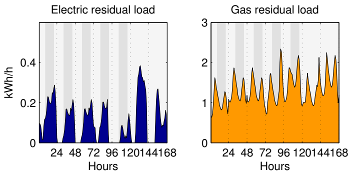
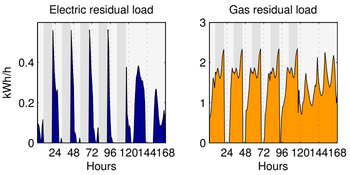
<tr><th></th><th>Flat Tariff</th><th>TOU Tariff</th></tr>
<tr><th>Annual lump sum</th><td>
</td><td>
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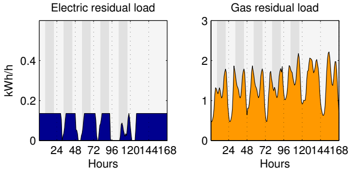
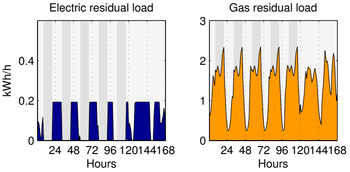
<tr><th>Peak load pricing</th><td>
</td><td>
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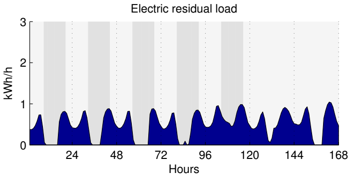
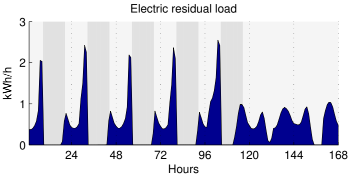
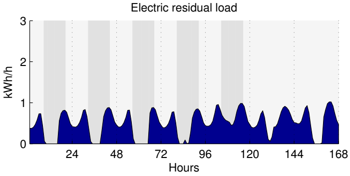
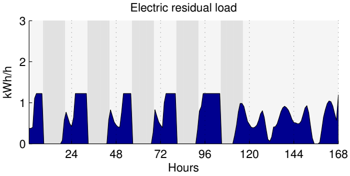
Residual loads of the PV customer type

	Flat Tariff	TOU Tariff
Annual lump sum		
Peak load pricing		

Conclusions

- A TOU tariff provides incentives to shift most of the residual load to Off-Peak hours.
- A EUR/kW$_{max}$ price provides incentives to reduce the maximal peak loads.

Outlook

- Consider investment costs of additional technologies and create long-term investment planning model.
- Create models for supply companies and distribution system operators (DSOs).
- Analyse further tariff design alternatives (real time pricing (RTP), tariffs considering meteorological forecasts, ...).

Thank you for your attention!