October 12, 2011

Vienna, Austria

# 2nd SmartCoDe Expert Cooperation Workshop

organised by

edacentrum

## Welcome to the 2nd SmartCoDe Expert Cooperation Workshop on Energy Efficiency in Buildings 2011!

Events in the year since the last SmartCoDe Expert Cooperation Workshop on Energy Efficiency have further emphasized the urgent need to replace traditional energy with renewable energy. However, the issue is not a purely fossil fuel problem. Certainly, carbon dioxide emissions from fossil fuel power plants remain one of the major problems. But the catastrophic Fukushima incident is a reminder that carbon dioxide is not the only concern – we must prepare for the replacement of nuclear energy. If decisions to eventually discontinue nuclear energy generation are not to lead to even greater consumption of fossil fuels, we must dramatically accelerate our development and deployment of renewable energy sources. Failure is not an option.

The shift to renewable energy sources presents us with two fundamental imperatives:

- We must take measures to manage the volatility and unpredictability inherent to almost all major renewable energy sources.
- We must match our future energy consumption to the available supply of (renewable) energy, and not vice versa as it is today.

In addition, we must enable intelligent ("smart") energy nets that allow distributed energy generation and storage, and we must devise efficient energy storage methods, such as pump storage, power-to-gas, batteries, and so on.

The SmartCoDe project focuses on the two imperatives. Much work has been done already – and is ongoing. This workshop delves into the details and will provide you with an update of the project status.

I hope you will enjoy the event – and audience participation is welcome!

Kind Regards,

Peter Neumann
Project Coordinator

SmartCoDe has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013]) under grant agreement n°247473

# 2nd SmartCoDe Expert Cooperation Workshop 2011

# Agenda

| Time | Modul | Speaker |
|---|---|---|
| 8:30 | Registration / Coffee | edacentrum |
| 9:30 | Welcome | P. Neumann / Dr. C. Pröfrock<br>edacentrum |
| 9:40 | Invited Paper:<br>Energy Management in Households and Built Environments:<br>Assessment of PV and Wind Micro-generation Technologies | Dr. S. Djokic<br>The University of Edinburgh |
| 10:25 | Wind Energy Forecasting for Distributed Generation | Dr. T. Bertényi<br>Quiet Revolution Ltd. |
| **10:55** | **Coffee break** | |
| 11:25 | Invited Paper:<br>Short-term solar energy forecasting for network stability | Prof Dr. H. Hermanns<br>Saarland University |
| 11:55 | Categorizing Energy using Products (EuPs) for partially decentralised Energy Management | M. Damm<br>Vienna University of Technology |
| **12:25** | **Lunch** | |
| 13:45 | The SmartCoDe Node Functional Prototype | E. Holleis<br>Tridonic AG |
| 14:15 | Invited Paper:<br>Sounds for Energy-Efficient Buildings | A. Barona<br>Solintel |
| **14:45** | **Coffee break** | |
| 15:15 | The SmartCoDe Demonstrator -<br>a testbed to evaluate energy management | Prof. Dr. V. Malbasa<br>University of Novi Sad |
| 16:00 | SmartCoDe - System-in-Package Considerations | T. Herndl<br>Infineon Technologies Austria AG |
| 16:30 | Closing words | Dr. C. Pröfrock<br>edacentrum |
| **16:40** | **End** | |

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## Invited Paper:
## Energy Management in Households and Built Environments: Assessment of PV and Wind Micro-generation Technologie
Dr. S. Djokic (The University of Edinburgh)

Dr Sasa Djokic is a Senior Lecturer in Electrical Power Systems, Programme Director for MSc Studies in Sustainable Energy Systems and Leader of the Power Systems Group in the School of Engineering at the University of Edinburgh, UK.

He received Dipl-Ing and MSc degrees in electrical engineering from the University of Nis, Serbia, and PhD degree in the same area from the University of Manchester, UK. From 1993 to 2001 he was with the Faculty of Electronic Eng. of the University of Nis. From 2001 to 2005 he was with the School of Electrical and Electronic Engineering at the University of Manchester. He joined the University of Edinburgh in October 2005.

In the general area of Power System analysis, Dr Djokic's research focuses on the assessment of reliability and power quality performance of networks with distributed energy generation/storage resources, including highly dispersed micro-generation systems, as well as on the development of improved system load models, fully incorporating demand-side management and responsive demand functionalities.

Dr Djokic is a Senior Member of IEEE, Member of IET, Associate Member of IESNA and SaRS, and also actively participates in a number of IEEE, CIGRE, CIRED, IES, UIE and BSI/IEC international Committees and Working Groups.

**Abstract**
Due to the space limitations and lower levels of primary energy resources, renewable-based generation technologies implemented in built environments are usually realised as micro and small-scale systems, commonly known as micro-generation (MG) technologies. Although the individual MG units are highly dispersed and small in sizes, their total numbers are expected to increase significantly in the future, when their aggregate effects and provided benefits (e.g. in a large urban area) are, in essence, similar to those of medium to large-scale generation systems. Additionally, MG will provide residential customers with an attractive option for reducing overall electricity consumption and energy bills, particularly when appropriate incentives and subsidies are incorporated in their installation grants and when they can negotiate suitable tariffs for generated and grid-exported electricity. Despite the fact that the selection of optimal MG technology is usually determined by locally available renewable energy resources, PV and wind-based MG systems are currently the two most common types of MG in the majority of European countries, requiring, therefore, improved and more accurate aggregate models for their analysis.

The correct analysis and representation of MG systems requires detailed assessment of input energy resources and accurate modelling of applied generation technologies. Using Midlothian region in Scotland, UK (around the city of Edinburgh) as an example, a new methodology for assessing performance of PV/wind MG technologies and analysing their aggregate effects on the operation of typical LV/MV distribution networks will be introduced and discussed. The presented analysis takes into account relatively high levels of temporal and spatial variations of input solar/wind energy resources in urban areas, which typically change on a both short-term scale (e.g. minute-by-minute, or hourly variations) and long-term scale (e.g. daily, weekly, or seasonal variations), as well as from one (geographic or network) location to another. Based on the estimated ranges of these variations, the outputs of aggregate PV and wind MG will be calculated and correlated with the corresponding variations in load demands, allowing to obtain improved and more accurate aggregate system load models, capable of correctly representing not just the connected loads, but also all supply network components and all MG units connected downstream the point of aggregation. As the proposed aggregation methodology allows to identify demand-manageable portion of the load in the total demand, implementation of specific demand-side management schemes in networks with different penetration levels of MG will be discussed and illustrated on a number of selected practical cases and scenarios for energy management in households and built environments in future “smart grids”.

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## SmartCoDe Expert Cooperation Workshop

**ENERGY MANAGEMENT IN HOUSEHOLDS & BUILT ENVIRONMENTS:**

# Assessment of PV and Wind Micro-generation

**Dr Sasa Djokic**
**The University of Edinburgh**
**sasa.djokic@ed.ac.uk**

**12th October 2011, Vienna**

# Renewable Generation in Built Environment (I)

## General Characteristics:

- highly variable (spatially and temporally)
- micro/small systems – Micro-generation
- highly dispersed (e.g. in a large urban area)
- mix of different technologies (wind, PV…)

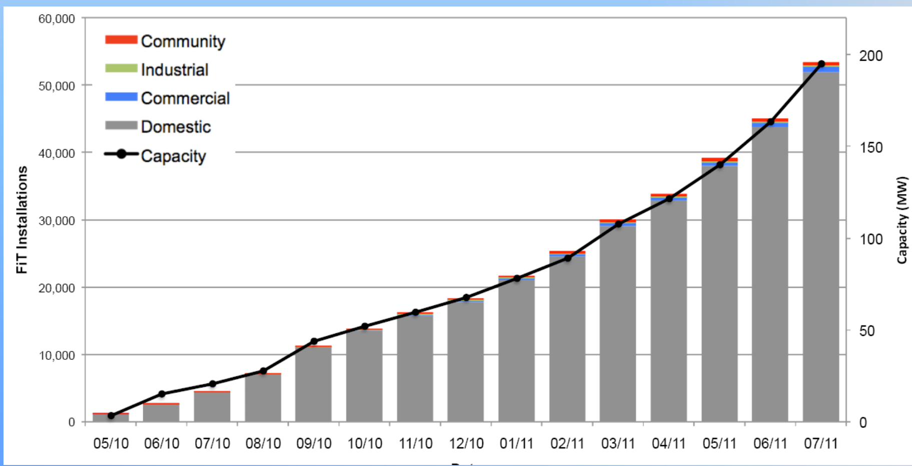
Similarity with Load Analysis, e.g. Demand Side Management (DSM) (both are Energy Management functionalities in future "Smart Grids")

Large number of small in size and highly dispersed individual units, connected in parallel to LV networks, exhibiting short, medium and long-term variations, as well as large changes from one geographic or network location to another

# Renewable Generation in Built Environment (2)

The analysis of MG is connected with uncertainties and requires assessment of stochastic variations

When present in high numbers, aggregate effects of MG & DSM (e.g. at bulk supply points at MV) can be significant…




After introducing Feed-in Tariffs in the UK…

[Ofgem data]



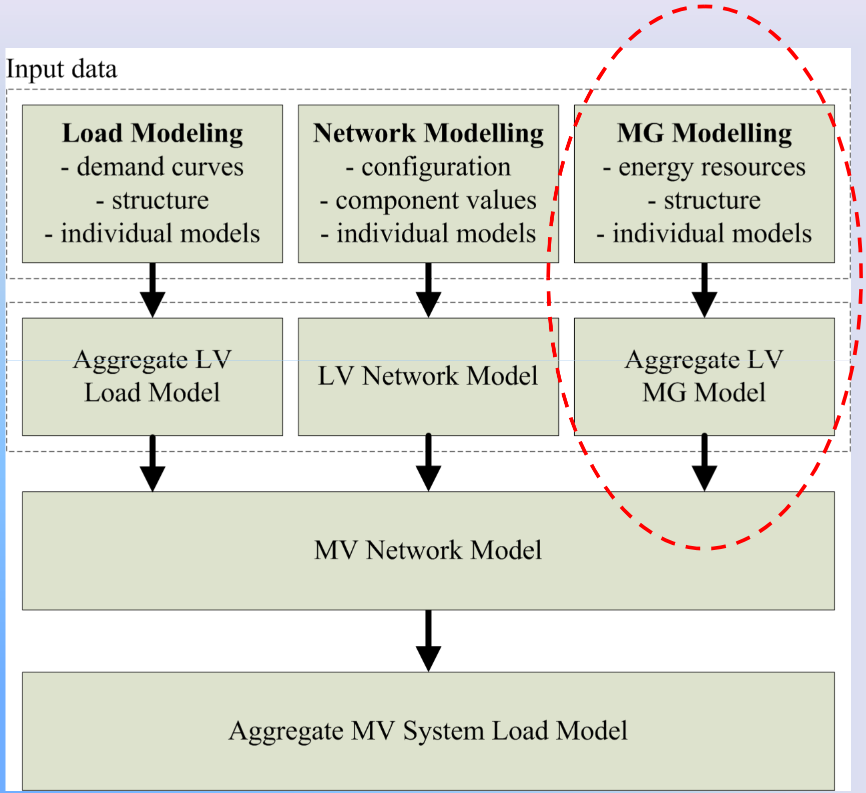
# Lecture Overview

## Energy Management in Households/Built Environments: Assessment of PV and Wind Micro-generation (and Demand Side Management)

Effects of MG & DSM (individual/combined) on network operation/performance:

- Detailed network model (typical LV/MV residential distrib. network)
- Two renewable MG technologies: µPV and µWind
- Assessment of input solar and wind energy resources
- Description of residential load mixes and daily load curves
- Aggregate residential load model (with identified DSM-portion)
- Correlation of µPV and µWind outputs with loads/demands
- Illustrated using Midlothian region in Scotland, UK (around the city of Edinburgh)

# Aggregation Methodology

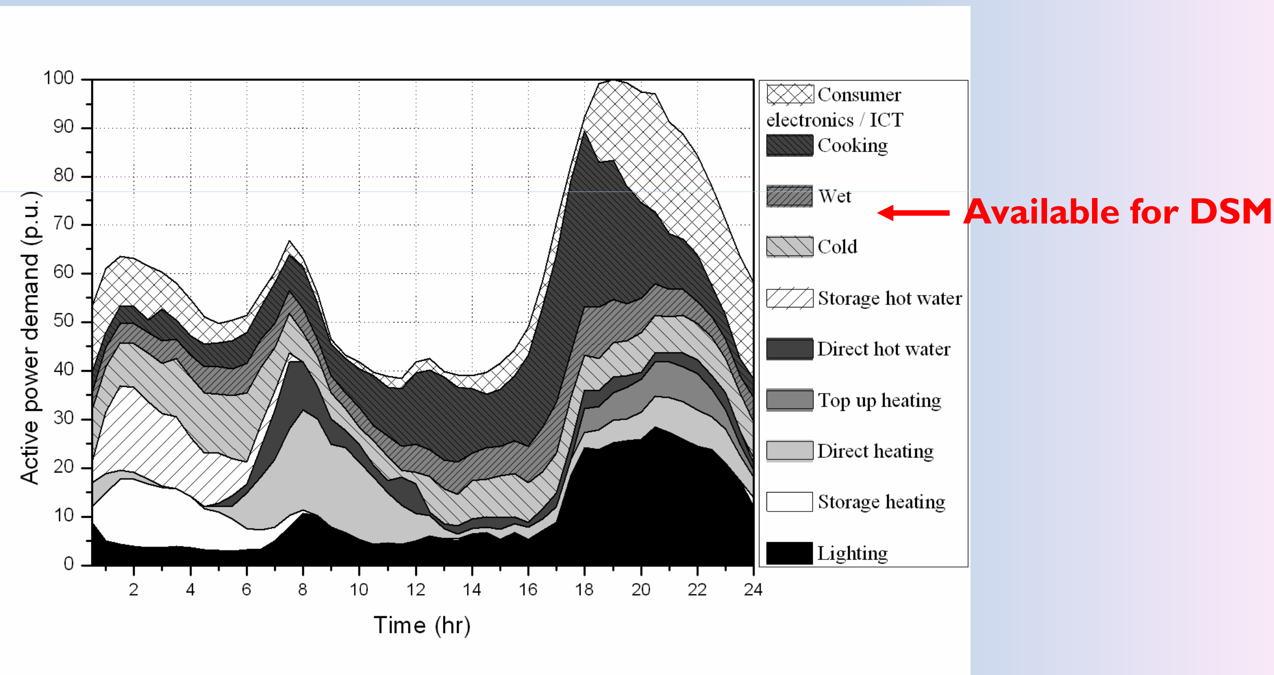





# Aggregate LV Load Model (1)

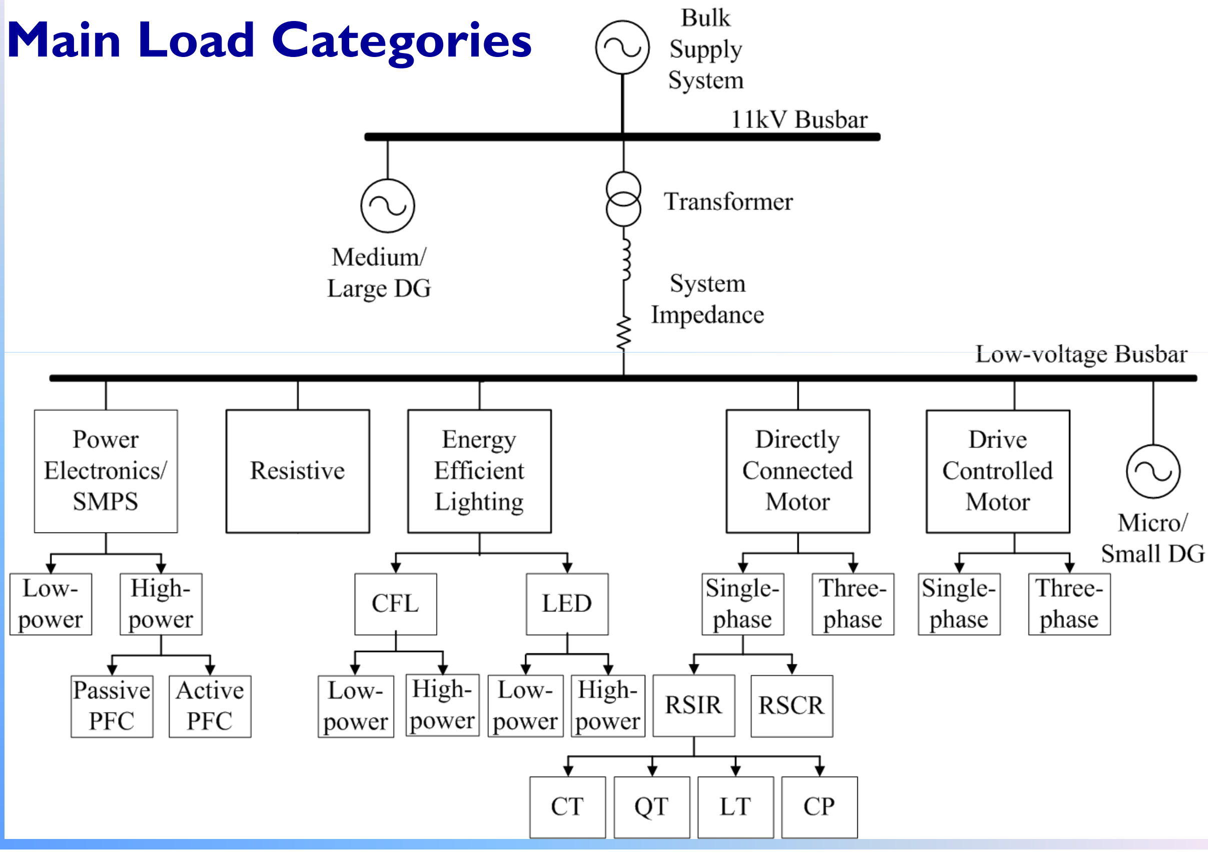
## Daily Load Curves Available (at 11kV or higher levels)

## Should be "Decomposed" in Main "Load Categories"



# Aggregate LV Load Model (2)

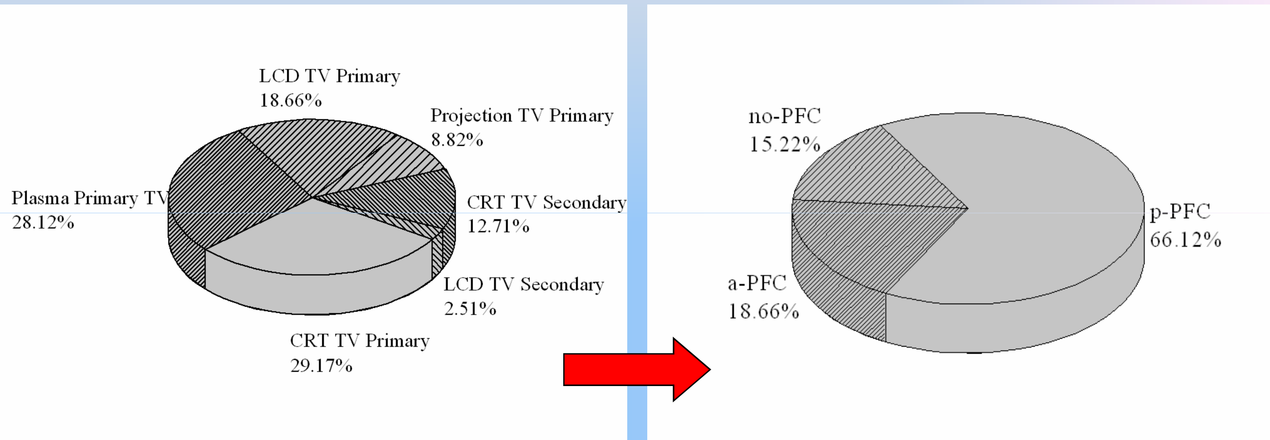
## Main Load Categories






# Aggregate LV Load Model (3)

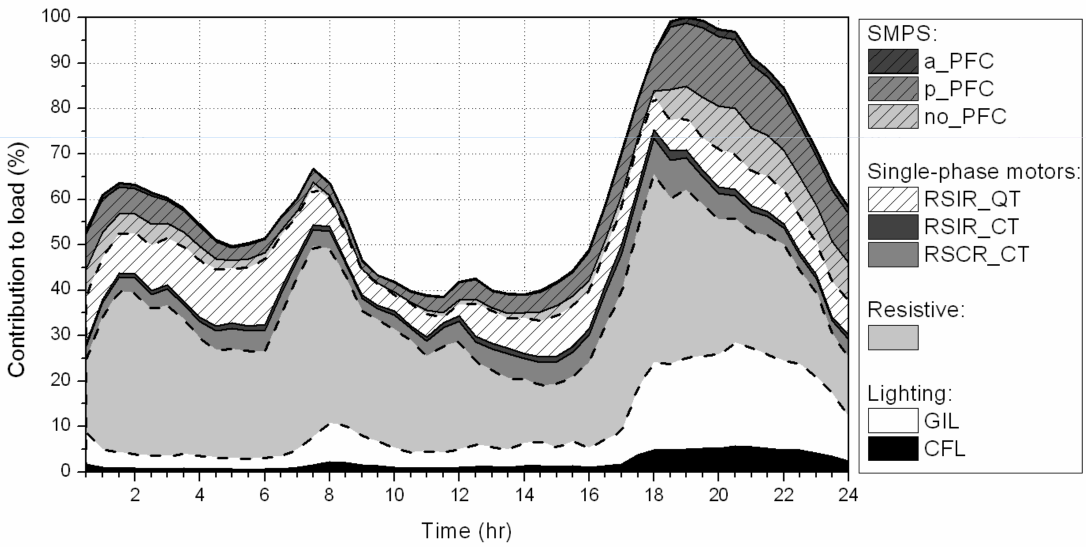
## From (End-use) Load Type to (Modelling) Load Category




**It is only an example – can be applied to all other types of loads…**

# Aggregate LV Load Model (4)

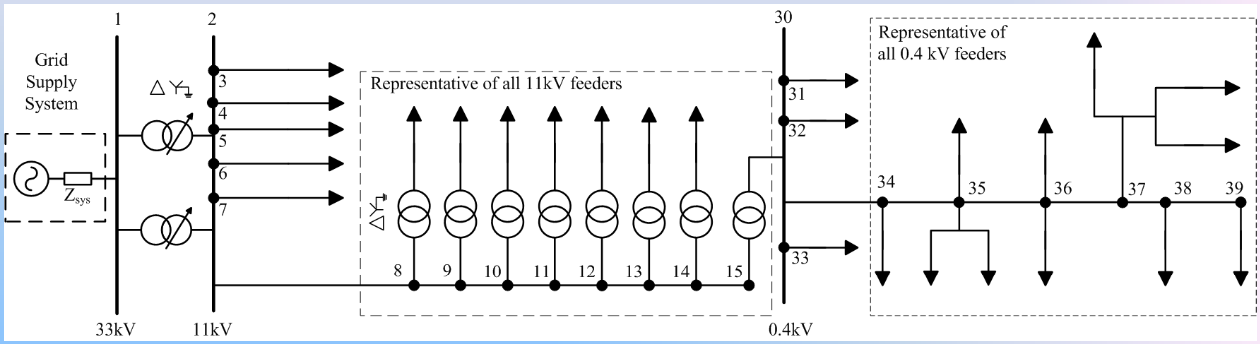
## Decomposition of Daily Load Curve






# LV Network Model

## Typical LV/MV Residential Network (Configuration & Parameters)




**Cables:**

| Operating Voltage (kV) | Feeder Type | Max. Length (km) | Cross section ($mm^2$) | R/km | X/km | B/km |
|---|---|---|---|---|---|---|
| | | | | (p.u. on 100MVA) | | |
| 11 | Cable | 10 | 185 | 0.12271 | 0.06575 | 0.00023954 |
| | | | 95 | 0.14403 | 0.06662 | 0.00017804 |
| 0.4 | | 0.2 | 185 | 89.84 | 43.68 | - |
| | | | 95 | 171.12 | 53.47 | - |

**Transformers:**

| Operating Voltage (kV) | Vector Group | Rating (MVA) | R | X | Tap range (p.u.) Min | Tap range (p.u.) Max | Tap step (p.u.) |
|---|---|---|---|---|---|---|---|
| | | | (p.u. on 100MVA) | | | | |
| 33/11 | Dyn11 | 15 | 0.06 | 1 | 0.8 | 1.05 | 0.0143 |
| 11/0.4 | Dyn11 | 0.5 | 2.04 | 9.28 | 0.95 | 1.05 | 0.025 |

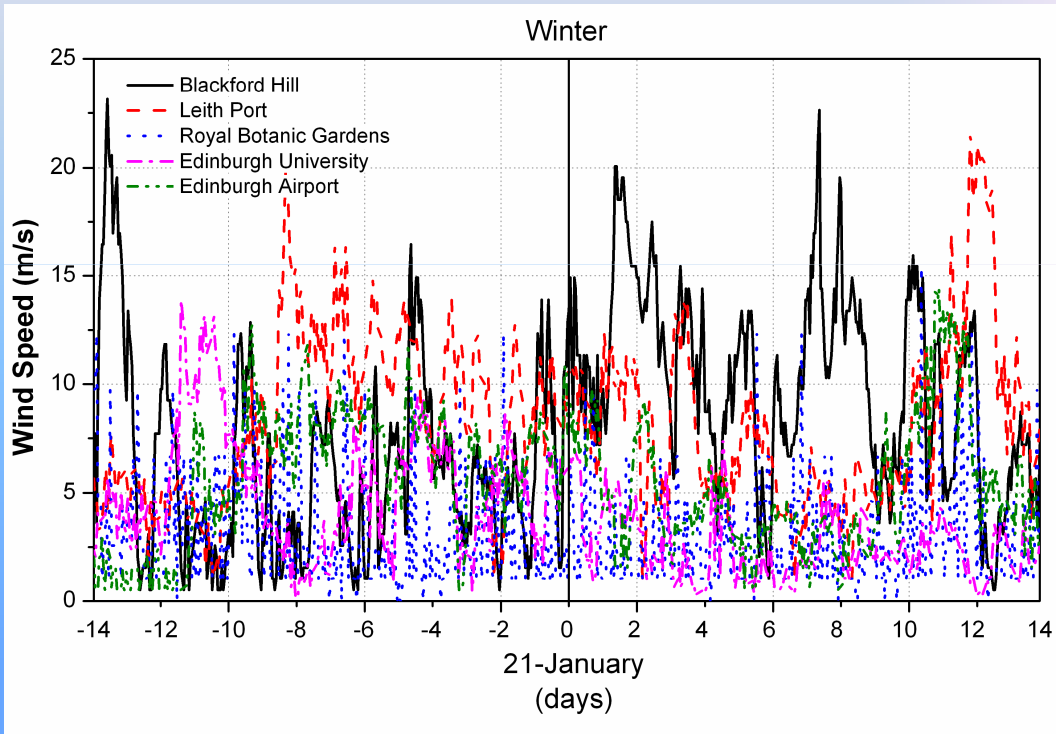
# Aggregate Micro-generation Model (1)

## Assessment of Input Energy Resources: City of Edinburgh (15km x 15km)



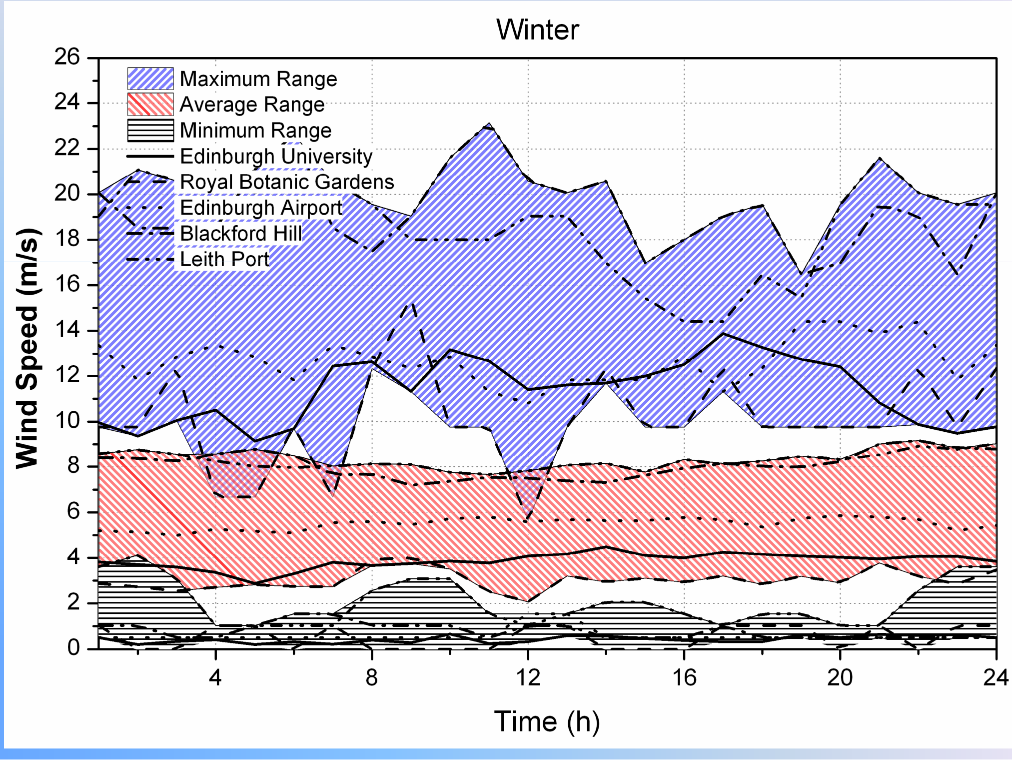
# Aggregate Micro-generation Model (2)

## Assessment of Wind Energy Resources: 5 Sites, ±14 Days



# Aggregate Micro-generation Model (3)

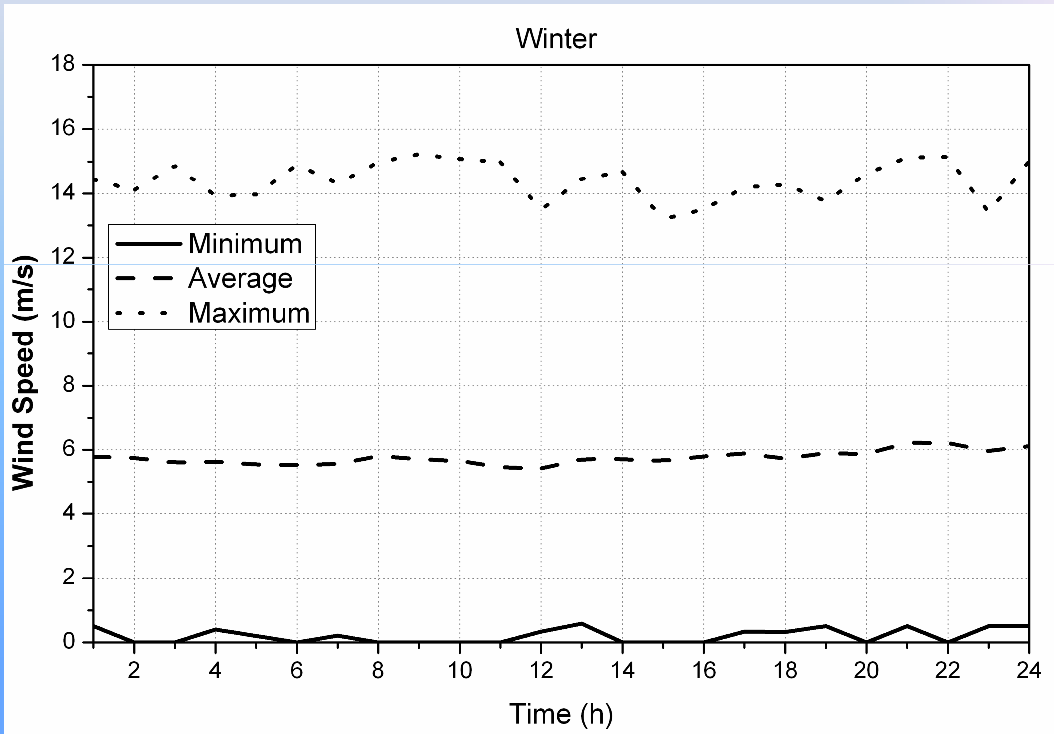
## Assessment of Wind Energy Resources: 5 Sites, Averages






# Aggregate Micro-generation Model (4)

## Assessment of Wind Energy Resources: All Sites, Max/Min/Ave



# Aggregate Micro-generation Model (5)

## Assessment of Power Outputs: Generic µWind Models:

- Database with ~190 µWTs from 60+ manufacturers
- Manufacturers from US, UK, China, Canada, Spain, Ireland…
- Horizontal/Vertical Axis Systems (168xHAWTs, 20xVAWTs)
- 95% with rated power <10 kW
- For ~140 µWTs, power curve provided in specification
- Four Generic µWTs → represent majority of µWTs on the market

$P_{G\mu WT\_1} = -7.29v + 3.12v^2$ , for $v \geq 2.4$ m/s ....................Generic µWT_1

$P_{G\mu WT\_2} = -11.47v + 4.26v^2 - 0.12v^3$ , for $v \geq 3$ m/s ............Generic µWT_2

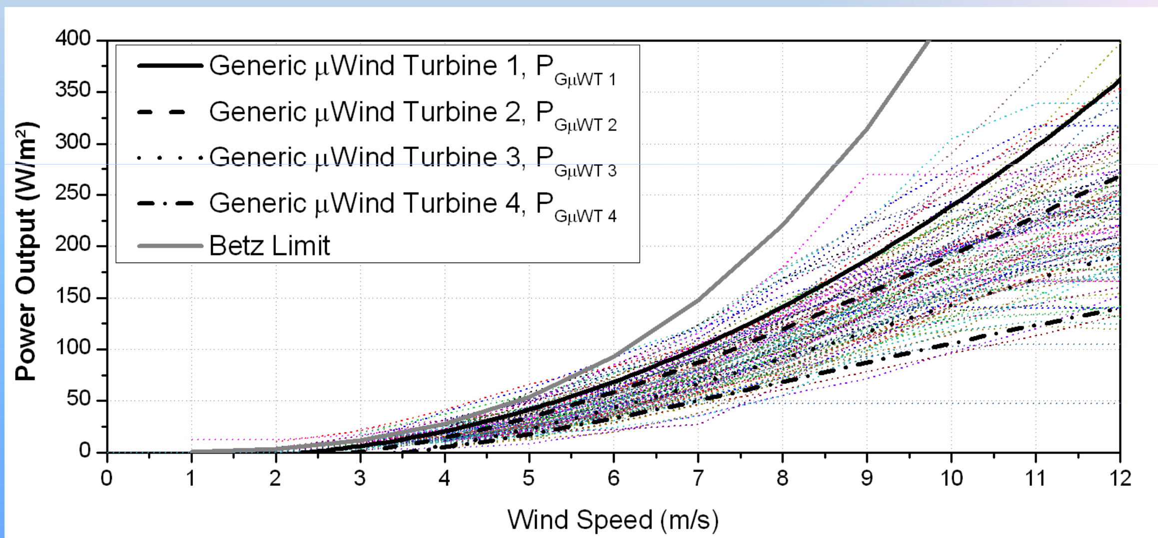
$P_{G\mu WT\_3} = -13.1v + 4.34v^2 - 0.16v^3$ , for $v \geq 3.2$ m/s ............Generic µWT_3

$P_{G\mu WT\_4} = -6.2v + 2.86v^2 - 0.11v^3 - 6$ , for $v \geq 3.3$ m/s .........Generic µWT_4



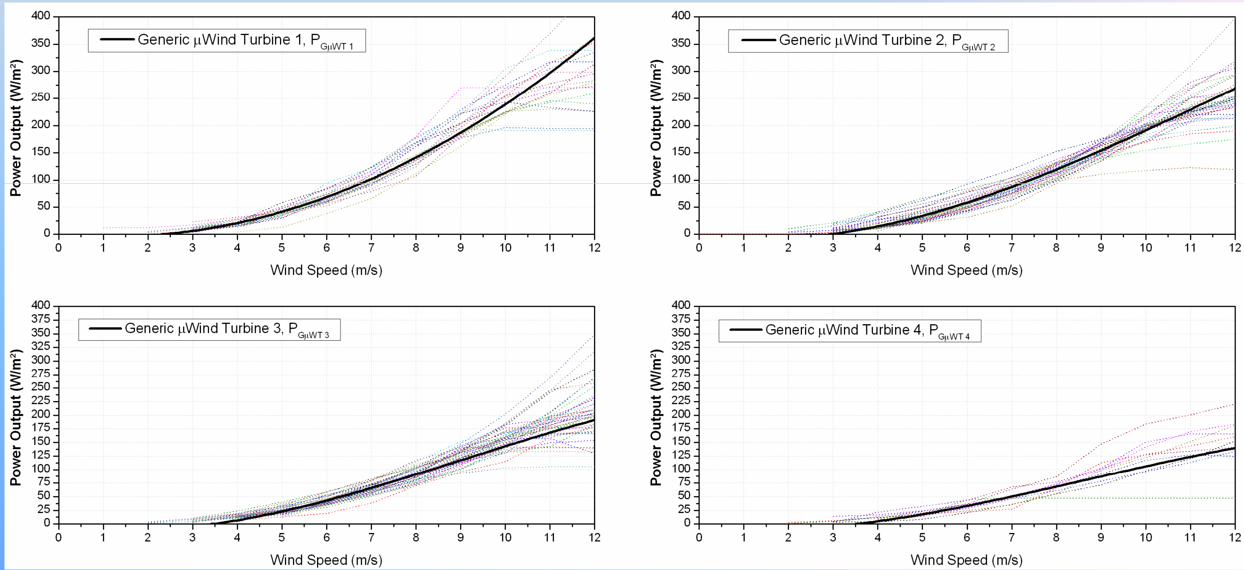
# Aggregate Micro-generation Model (6)

## Generic µWind Turbine Models: Power Curves



# Aggregate Micro-generation Model (7)

## Generic μWind Turbine Models: Power Curves

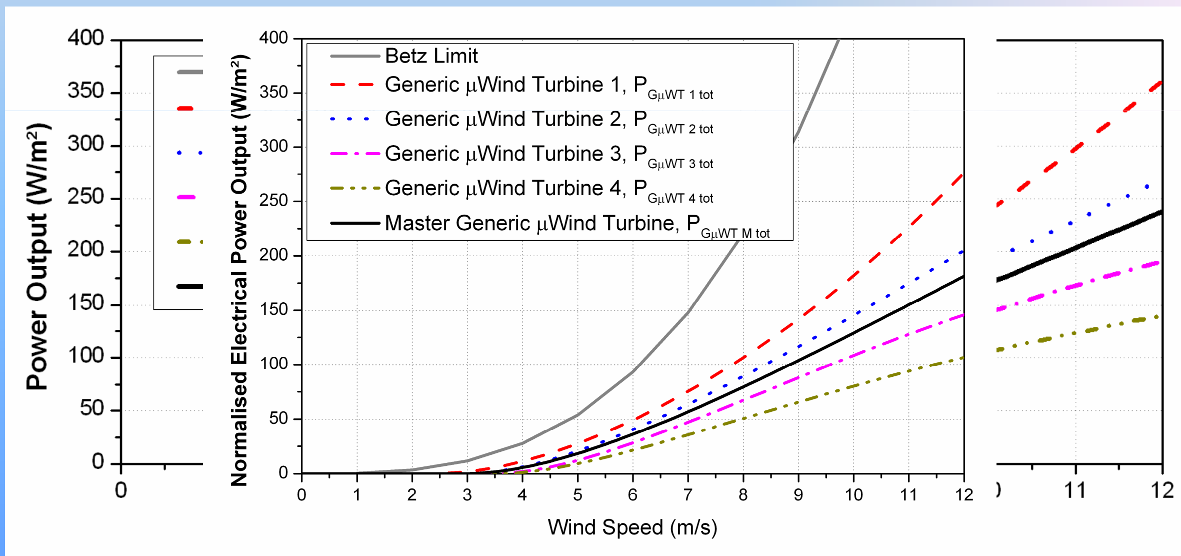





# Aggregate Micro-generation Model (8)

## Aggregate ("Master") Generic μWind Turbine Model

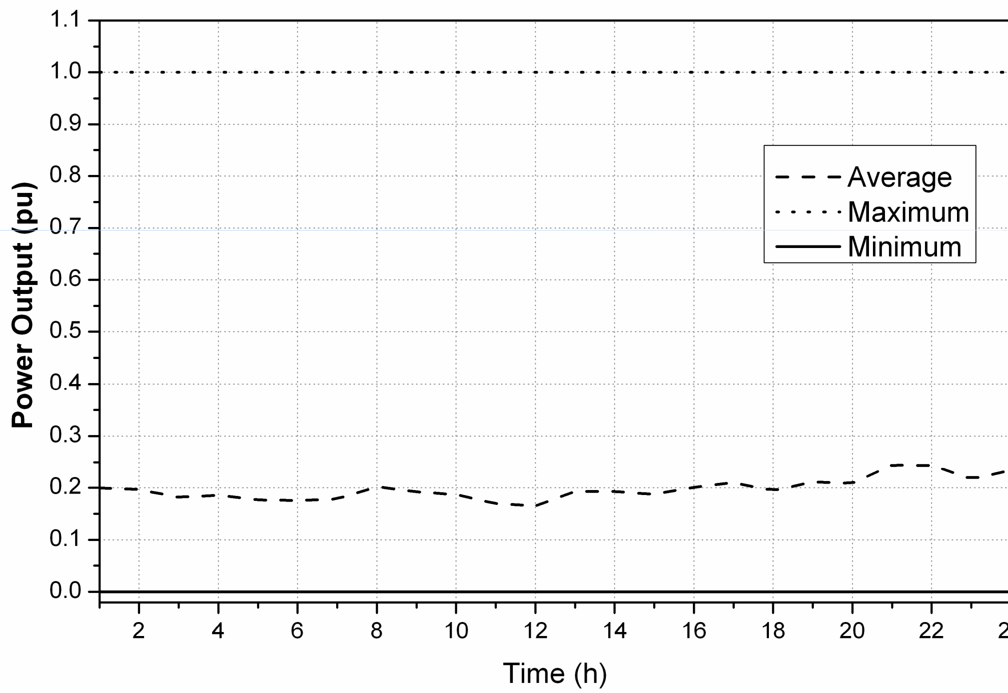
**Mix/Aggregation of Generic μWT1 - 18%, Generic μWT2 - 32%**
**Generic μWT3 - 32%, Generic μWT4 - 18%**




$$P_{G\mu WT\_M\_tot} = (1 - e^{-0.75(v-3)})(-7.87v + 2.92v^2 - 0.084v^3)\ ,\ \text{for}\ \ v \geq 3\ \text{m/s}$$

# Aggregate Micro-generation Model (9)

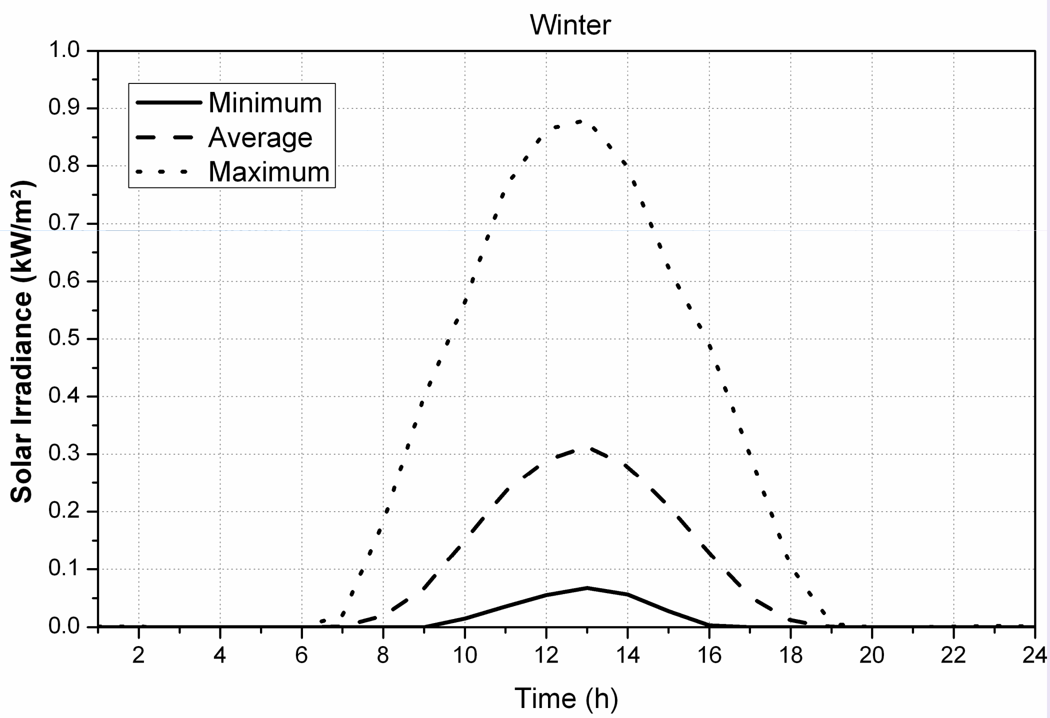
## μWind Power Outputs for Estimated Wind Resources






# Aggregate Micro-generation Model (10)

## Assessment of Solar Energy Resources: Following the Same Procedure as for Wind Energy Resources…



# Aggregate Micro-generation Model (11)

## Assessment of Power Outputs: Generic µPV Models:

- Database with 240+ µPV systems from few dozen manufacturers
- Again, manufacturers from around the World
- Four main technologies
- Monocrystalline, polycrystalline, thin film and amorphous
- Manufacturer's specifications thoroughly examined
- Four Generic µPVs → represent majority of µPVs on the market

$P_{G\mu PV\_1} = 0.134(1 - e^{-0.04 S_{irr}}) S_{irr}$ ..............................Generic µPV_1

$P_{G\mu PV\_2} = 0.136(1 - e^{-0.04 S_{irr}}) S_{irr}$ ..............................Generic µPV_2

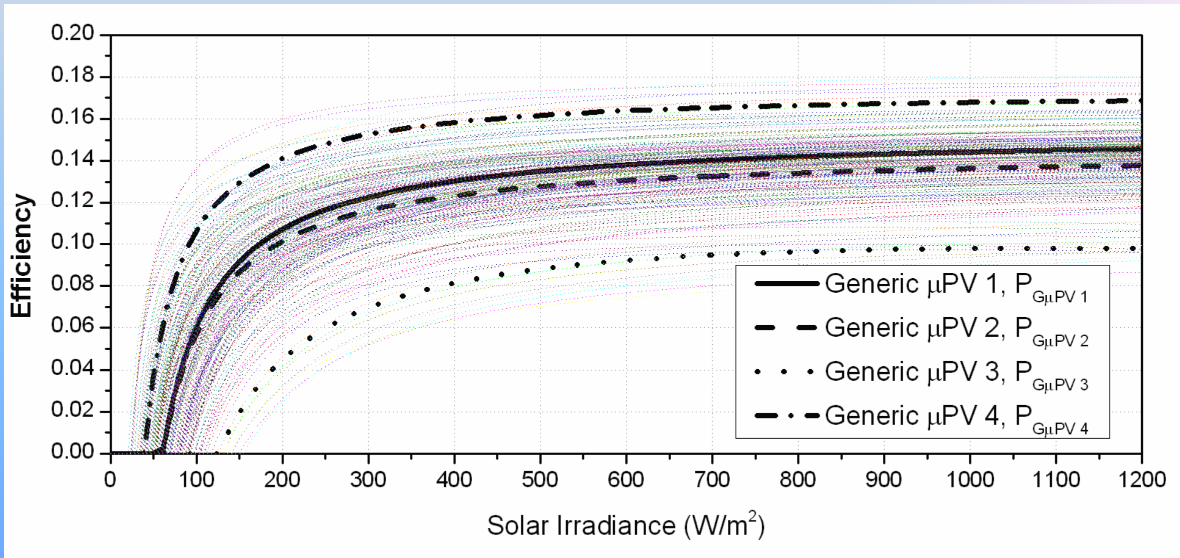
$P_{G\mu PV\_3} = 0.09(1 - e^{-0.04 S_{irr}}) S_{irr}$ ..............................Generic µPV_3

$P_{G\mu PV\_4} = 0.163(1 - e^{-0.04 S_{irr}}) S_{irr}$ ..............................Generic µPV_4



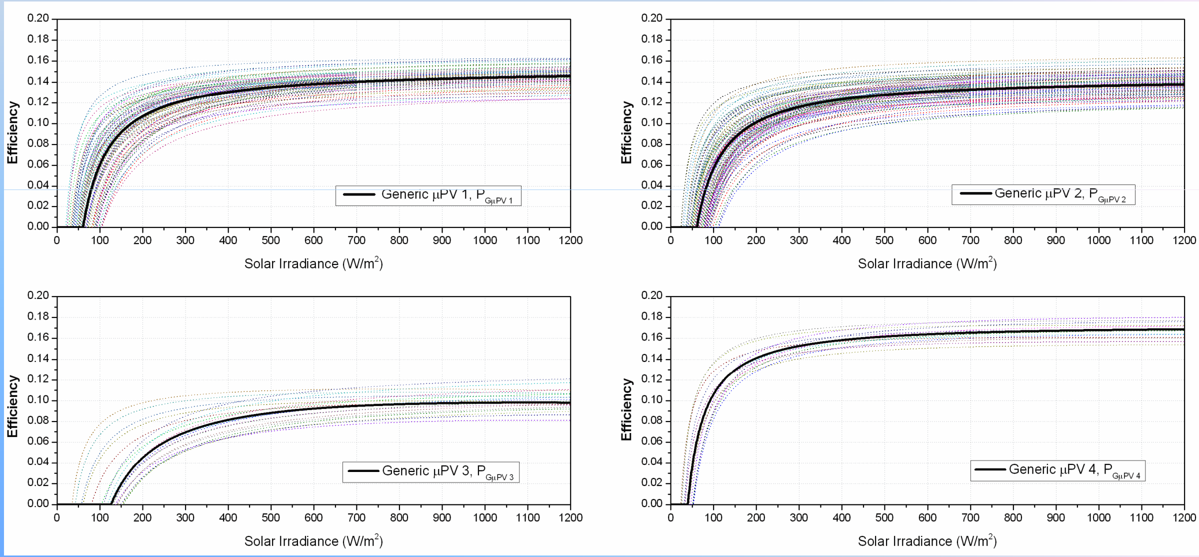
# Aggregate Micro-generation Model (12)

## Generic µPV Models: Efficiencies



# Aggregate Micro-generation Model (13)

## Generic µPV Models: Efficiencies

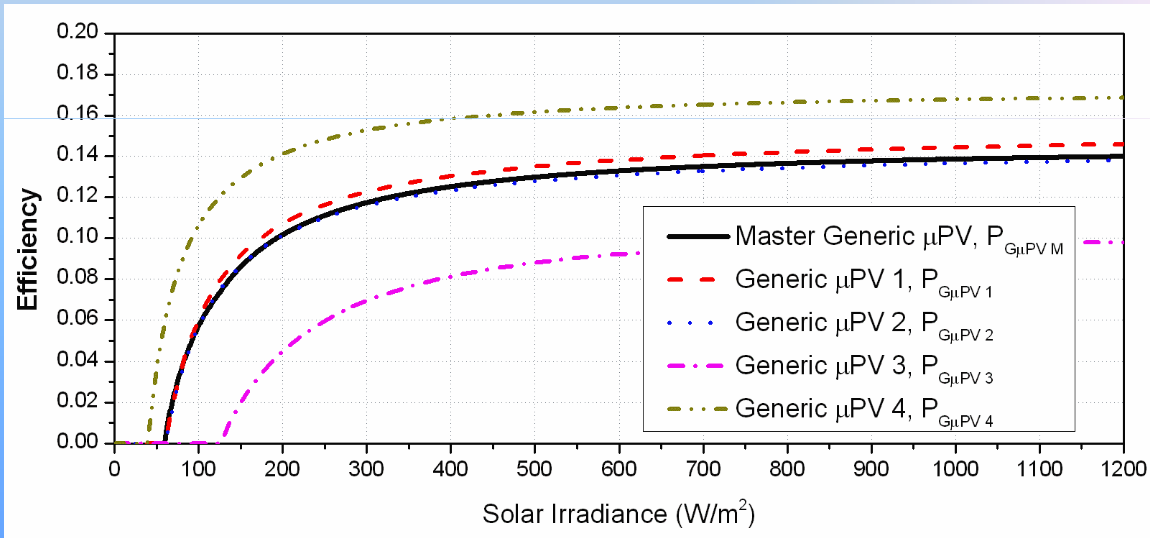





# Aggregate Micro-generation Model (14)

## Aggregate ("Master") Generic µPV Model

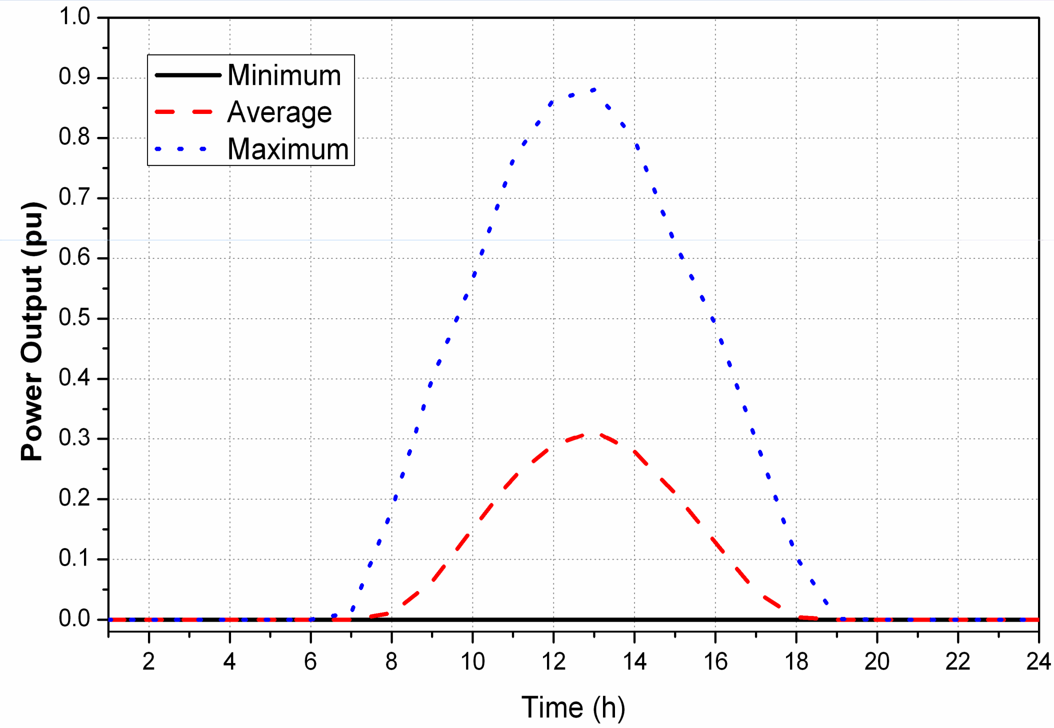
**Mix/Aggregation of Generic µPV1 - 40%, Generic µPV2 - 43%**
**Generic µPV3 - 9%, Generic µPV4 - 8%**




$$P_{G\mu PV\_M} = 0.133(1 - e^{-0.04 S_{irr}}) S_{irr}$$

# Aggregate Micro-generation Model (15)

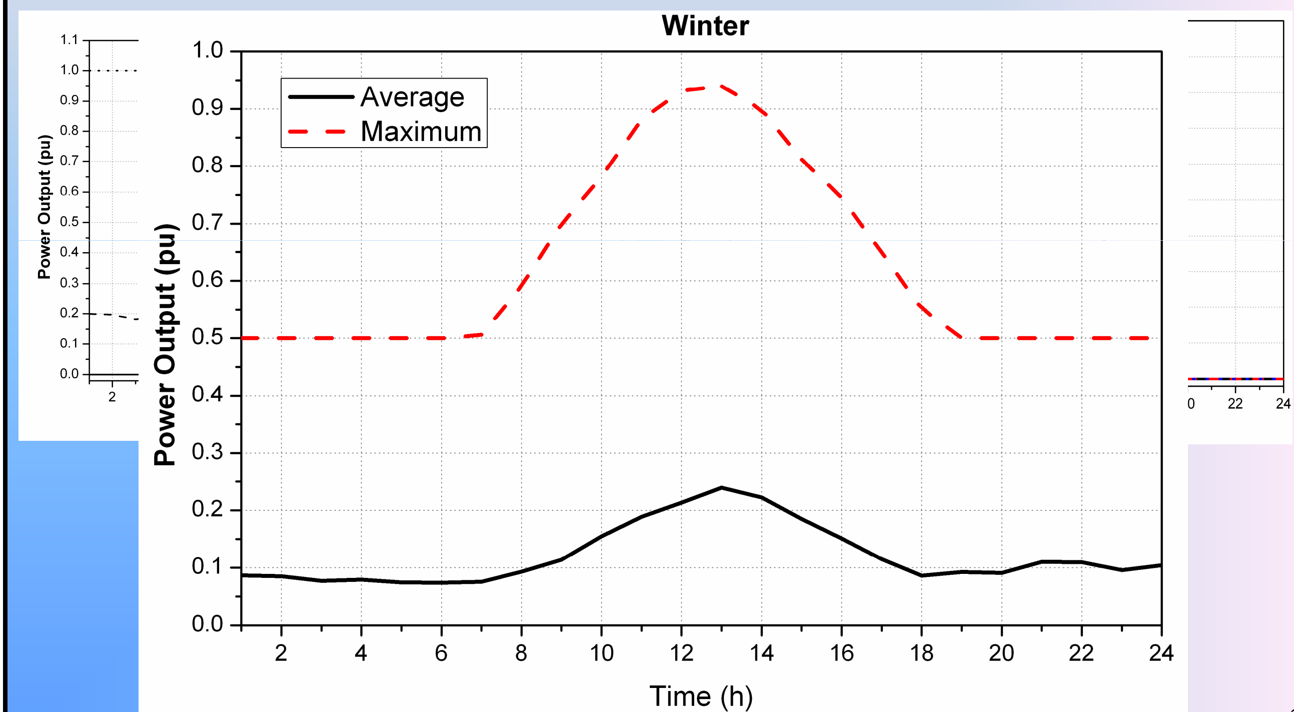
## µPV Power Outputs for Estimated Solar Resources





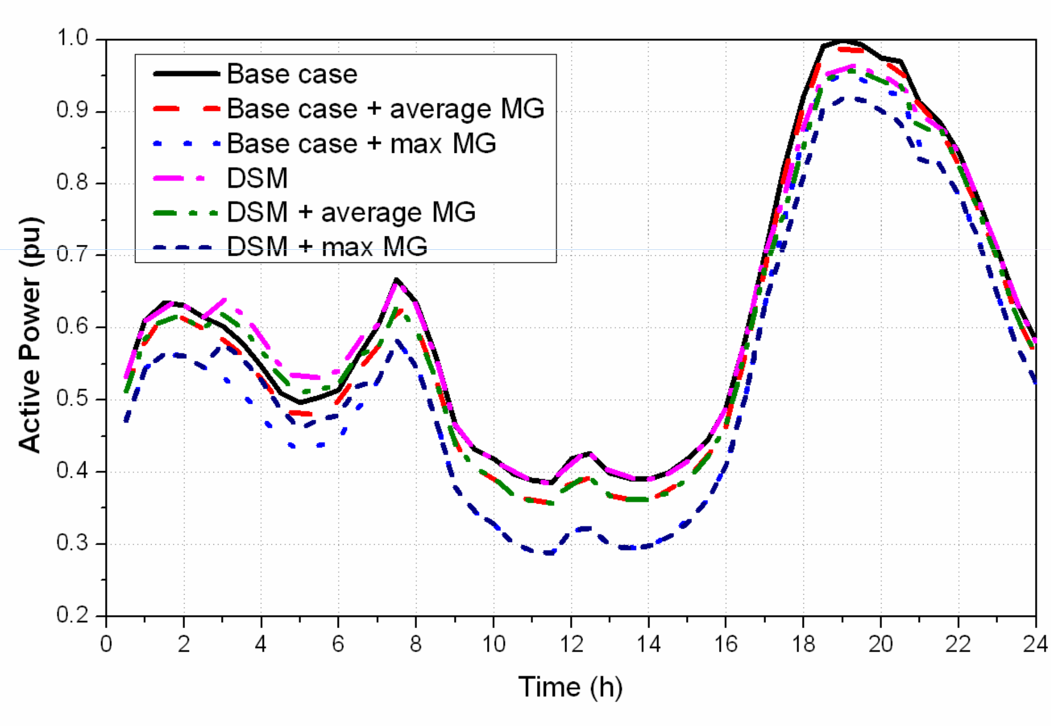

# Aggregate Micro-generation Model (16)

## Combined µWind & µPV (50%-50%) Power Outputs



# Impact & Performance Assessment (1)

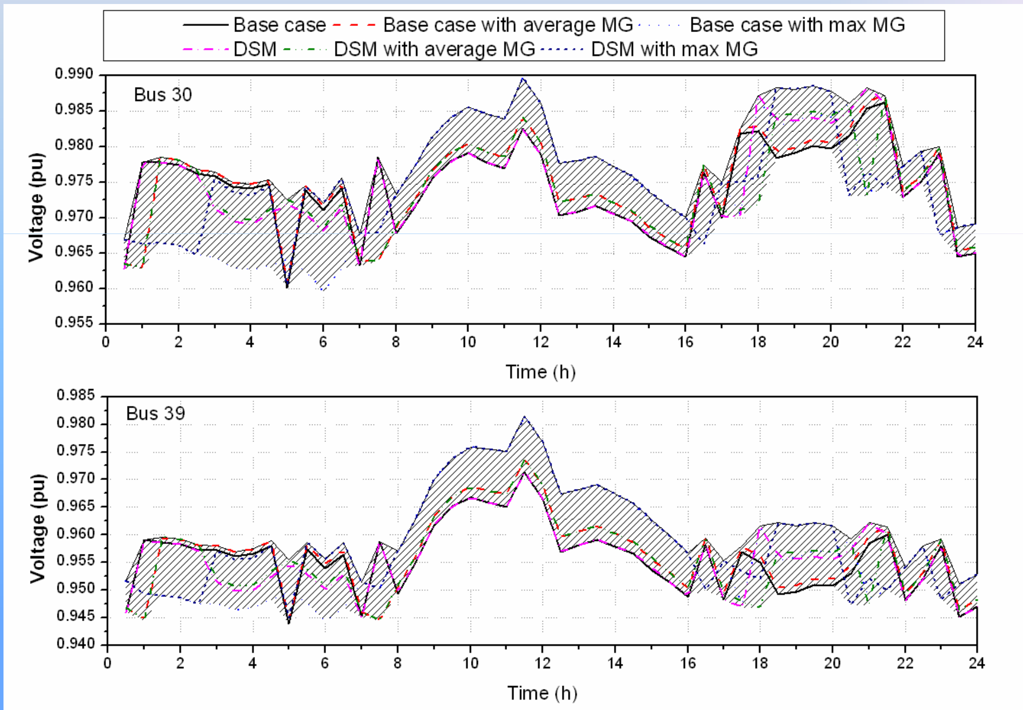
## Change in Active Power Demand:





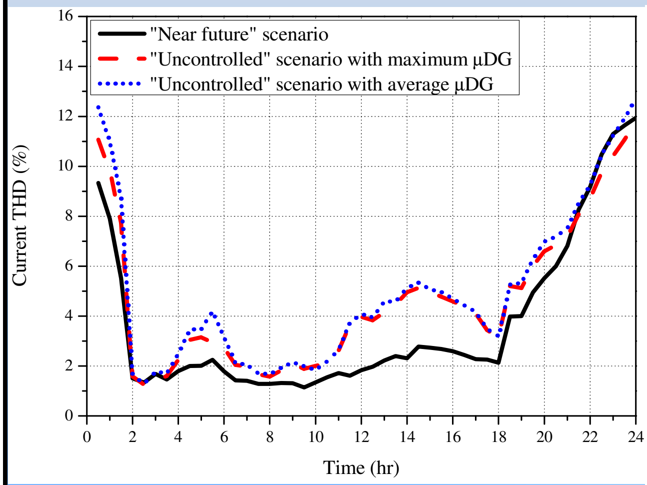

# Impact & Performance Assessment (2)

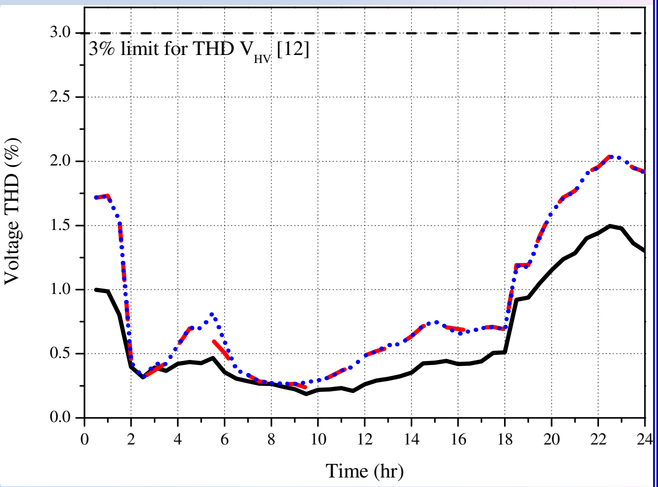
## Change in Voltage Profiles:



# Impact & Performance Assessment (3)

## Harmonic Distortion (MG & Incandescent → CFL):



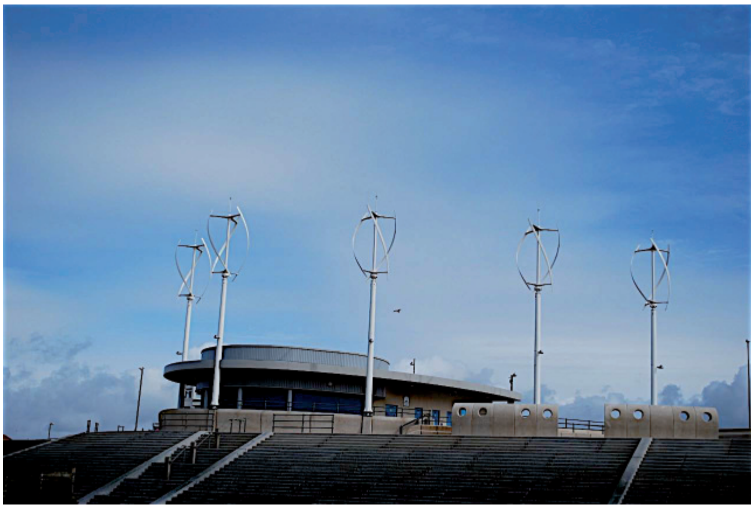






# THANK YOU!

# Discussion & Questions?

# Wind Energy Forecasting for Distributed Generation

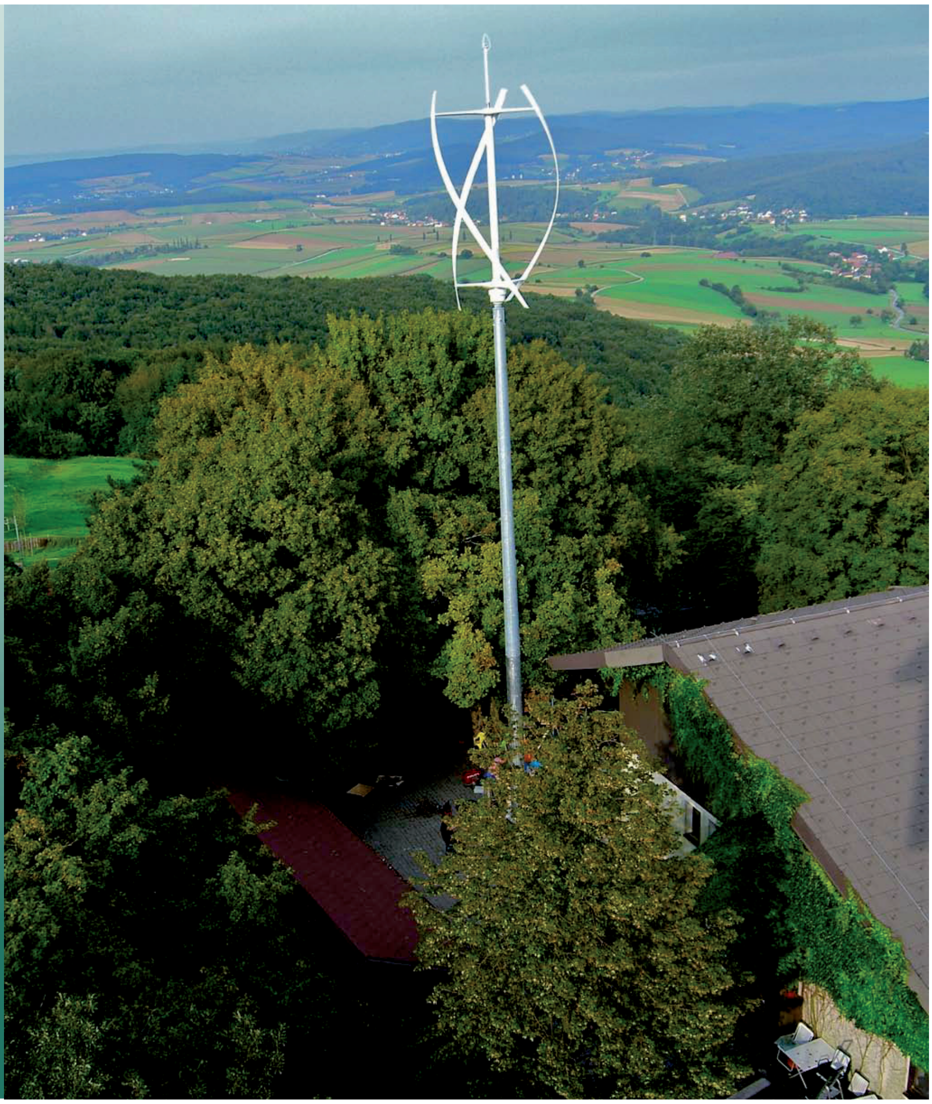


**SmartCoDe Expert Cooperation Workshop 2011**

Author: Dr. Tamás Bertényi, Quiet Revolution Ltd.

Date: October 12, 2011

Dissemination Level: Public



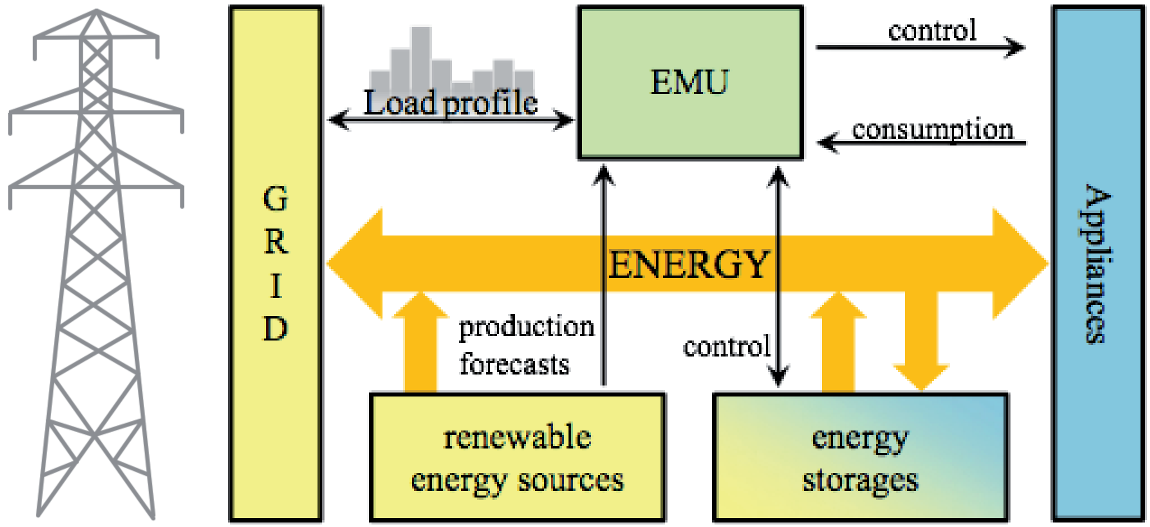
**Energy Neighbourhood:**

–Building with Energy Using Products (EUP)

–Daily energy use profile

–Local Energy Producer (LEP) in the form of a vertical axis wind turbine

–Energy Management strategy to optimise local energy use and local energy production




**Energy Neighbourhood:**

–Energy Management strategies become much more interesting when you integrate energy storage and local energy production

–Energy storage can be a variety of different "virtual storage" solutions. LEP is a qr5 vertical axis wind turbine

–Objective is to optimise the local energy consumption


FP7 ICT-2009 GA-No. 247473

# quietrevolution qr5

- Small Scale: <50kW and <200m$^2$
- QR5: 7.5kW peak aerodynamic, 16m$^2$
- larger than micro wind
- Decentralised energy production
- Integrated with society
- Cost: €23,000 + installationDesign
  Life: 25 years

quietrevolution

# Why do we need Energy Forecasting?

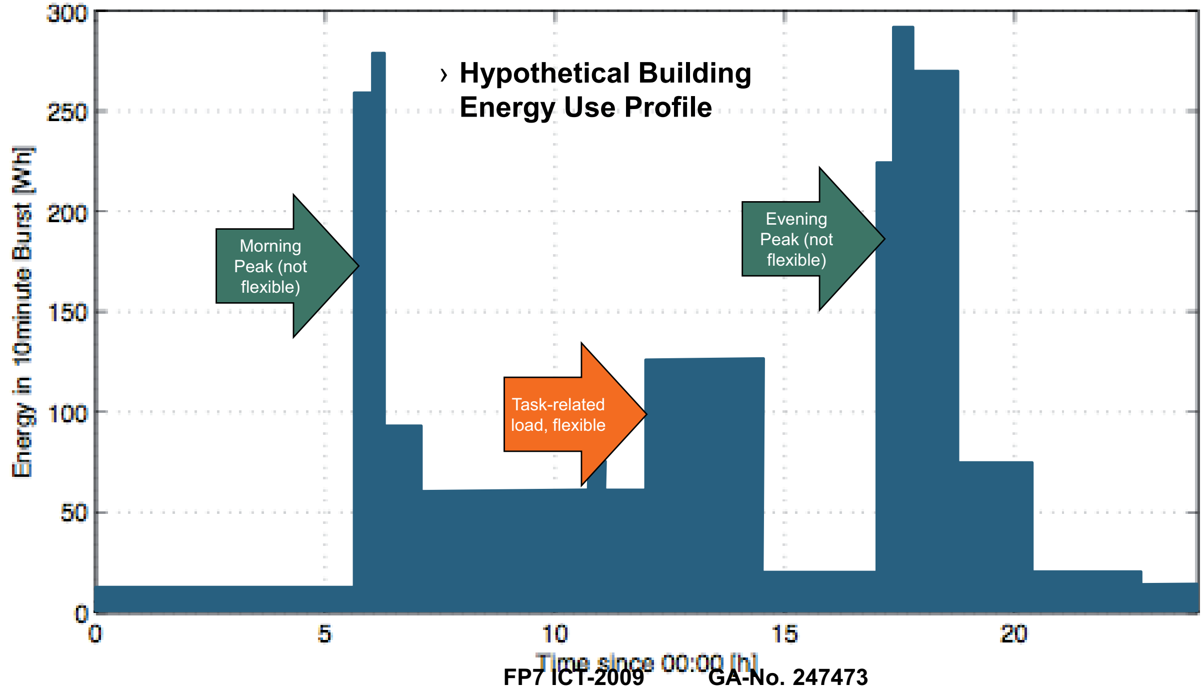
› DSM and SmartCoDe project becomes a lot more interesting if there is a **Local Energy Producer**

› Provides end user with options:

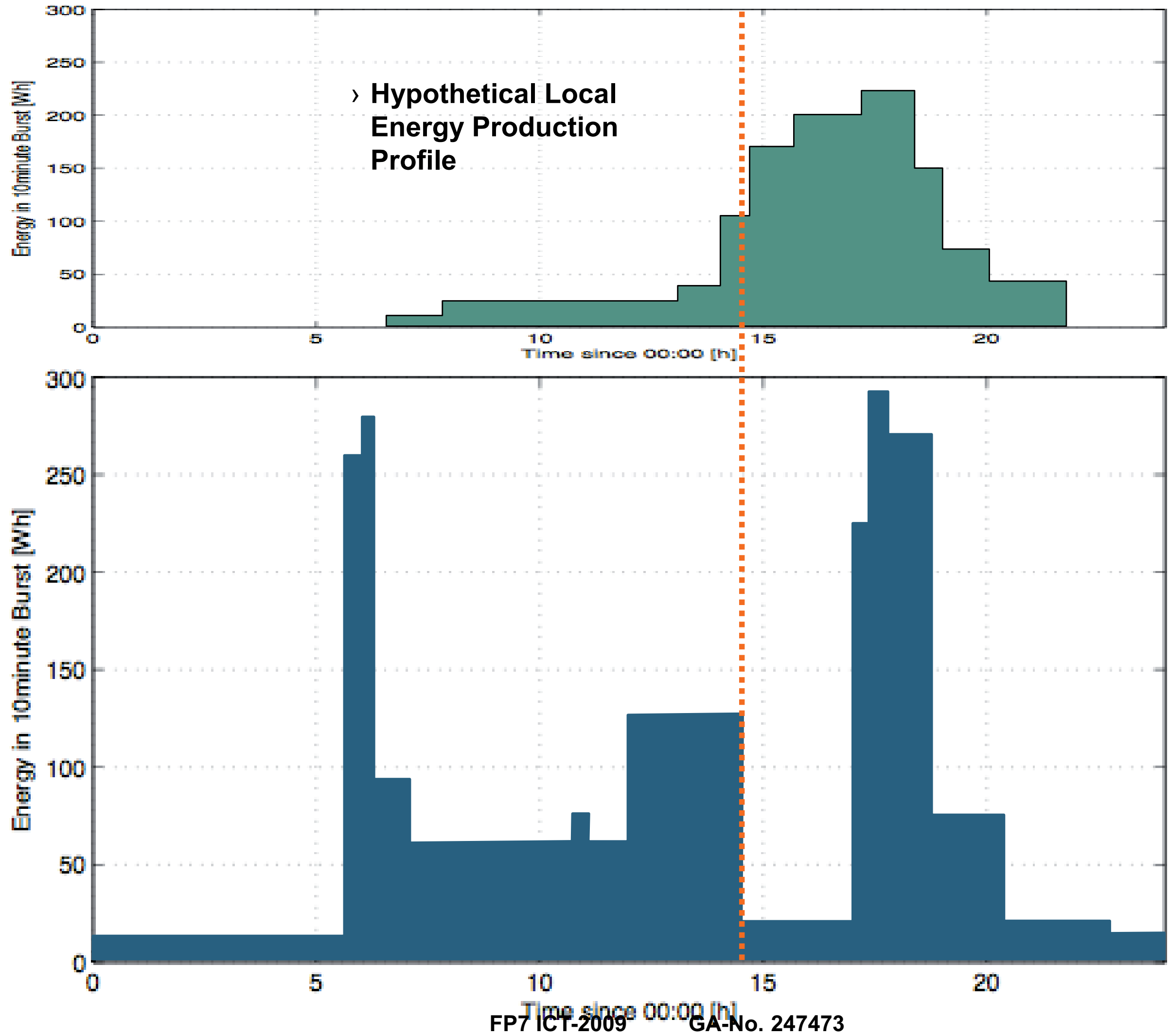
– use locally generated energy (offset local consumption); coordinate demand with forecast supply

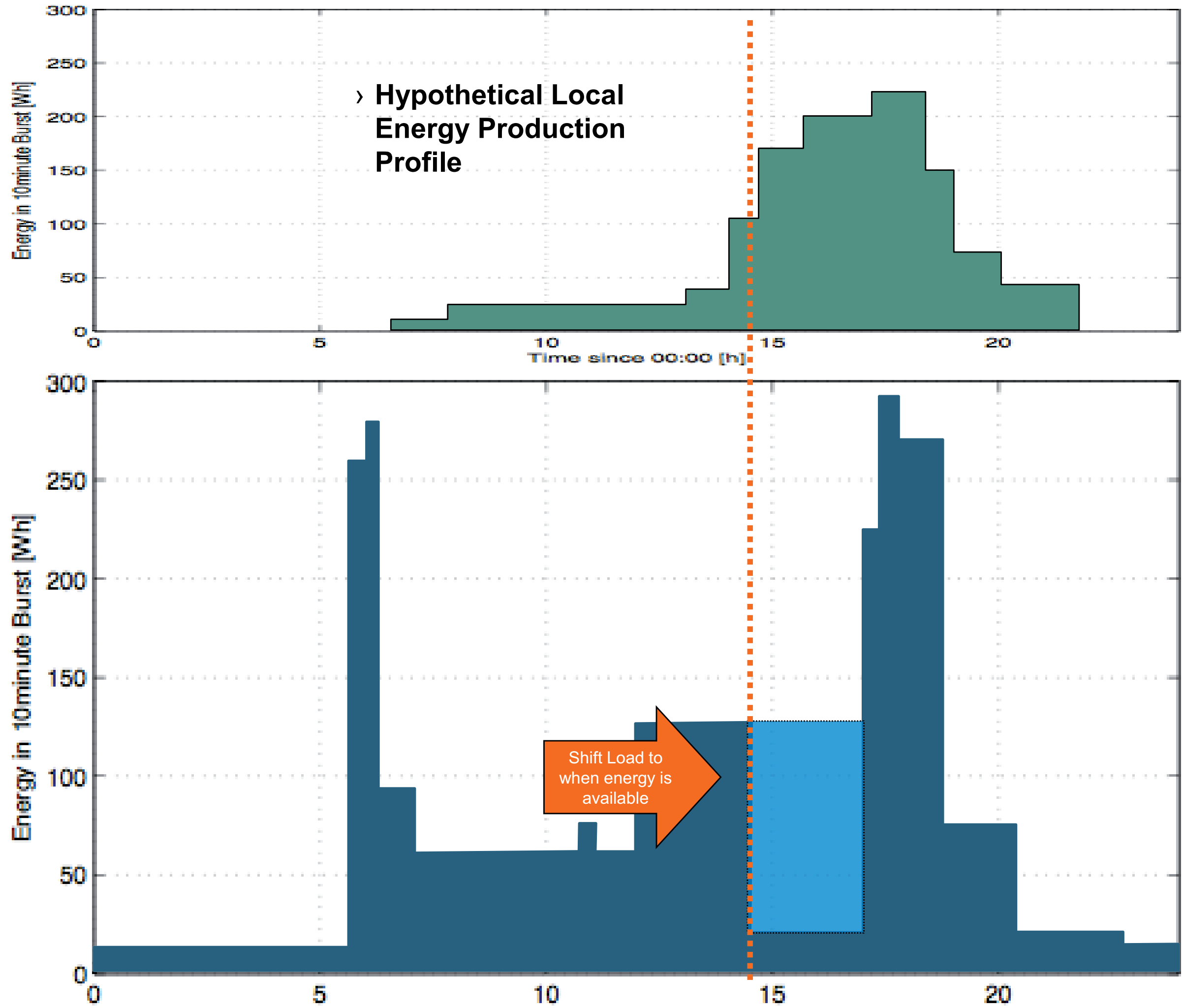
– or sell back to grid (export) when tariff is high

– potential to engage in spot energy market (strategically timed export)



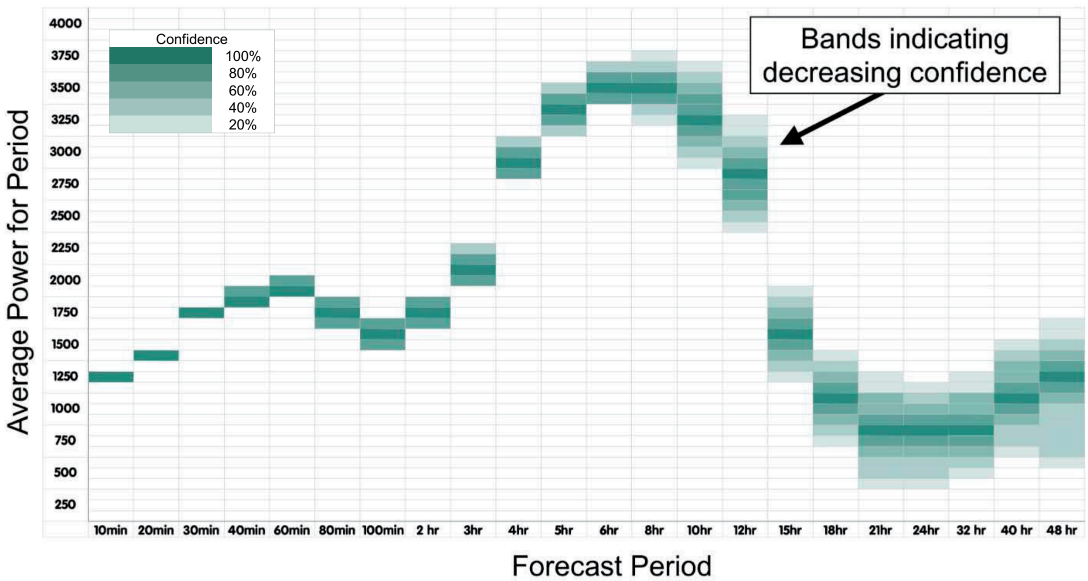







# Wind energy forecast can be critical input for effective demand side management




› Energy forecast is supplied to Energy Management Algorithm

› Represents forecast energy for period

› Duration of period gets longer the further into the future we look

› Band of confidence to aid decision making

# Why is quietrevolution interested in SmartCoDe?

› Effective integration of Local Energy Producer (such as a small-scale wind turbine) into energy neighbourhoods can:

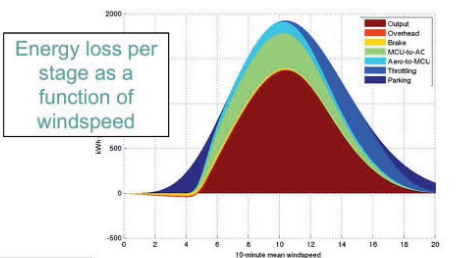
- **Increase the value of the energy produced by the turbine**
- **Decrease the volatility of the renewable energy source to the overall electrical network**

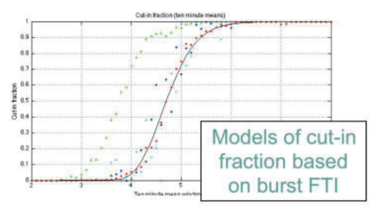


# Wind Resource Forecast -> Wind Energy Forecast

› In year 1 of the SmartCoDe project we developed an Advanced Energy Yield Model

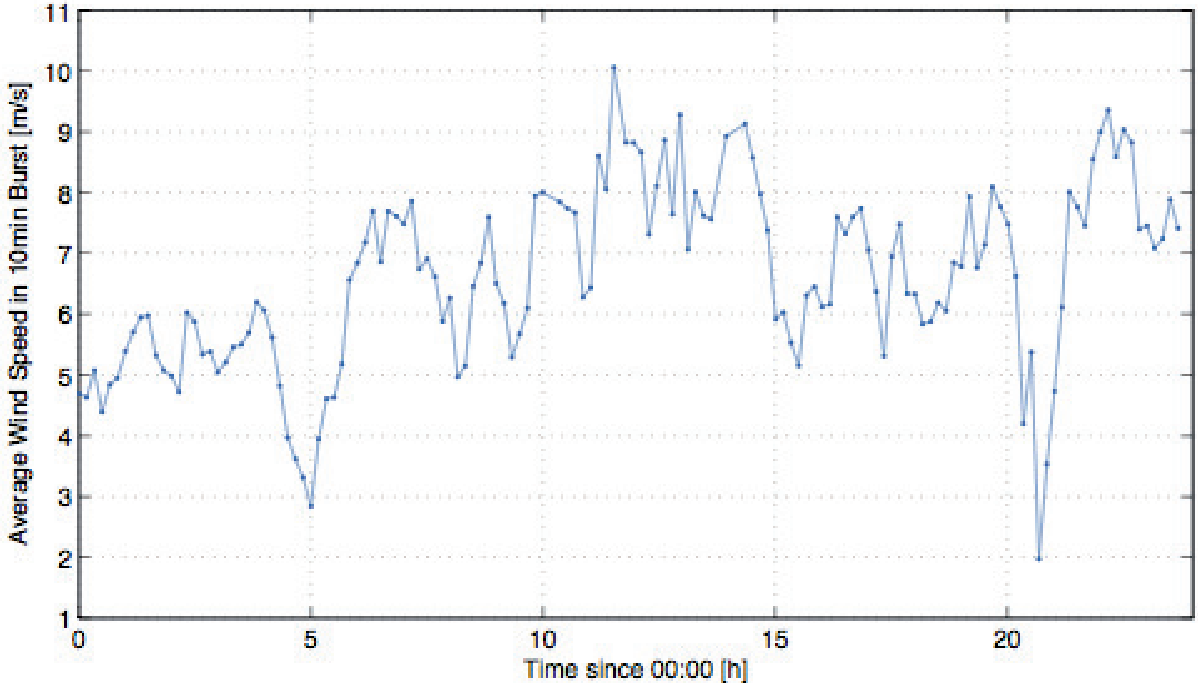
› Allows us to accurately predict energy output of the wind turbine based on the available wind resource, even for very short periods


# The challenge of wind resource forecasting

› Wind speed is very variable or "volatile"

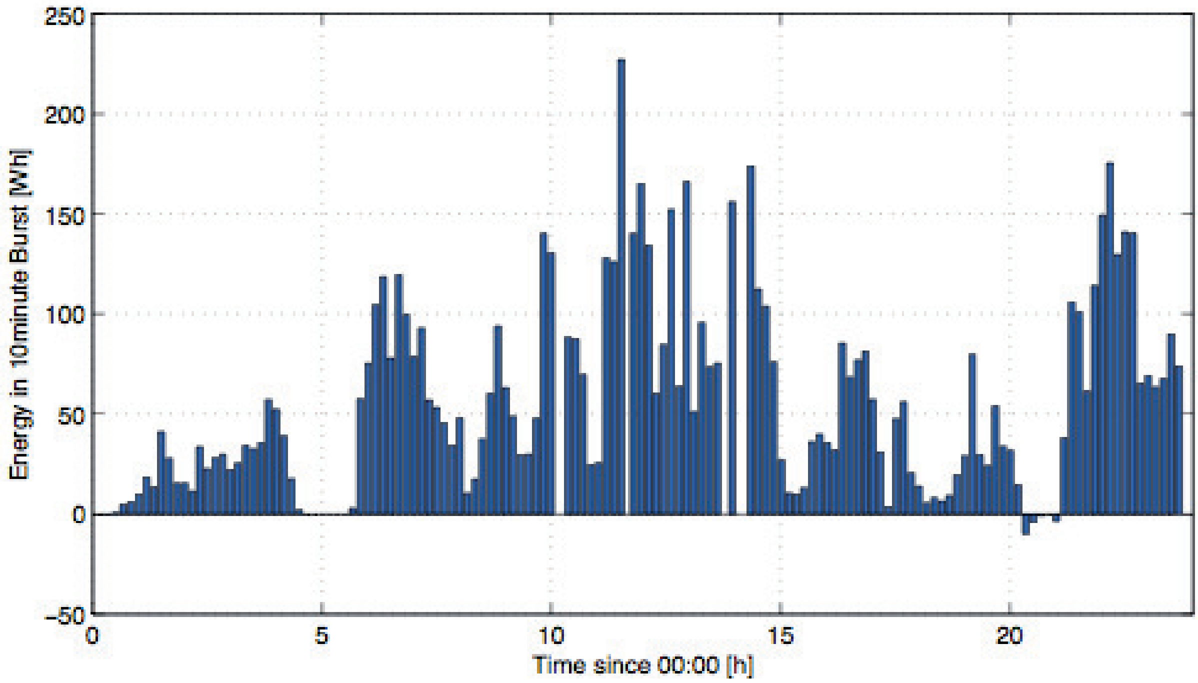



– The above is a 24 hour period (September 8, 2011) measured wind data from the SmartCoDe demonstrator site presented as ten minute averages



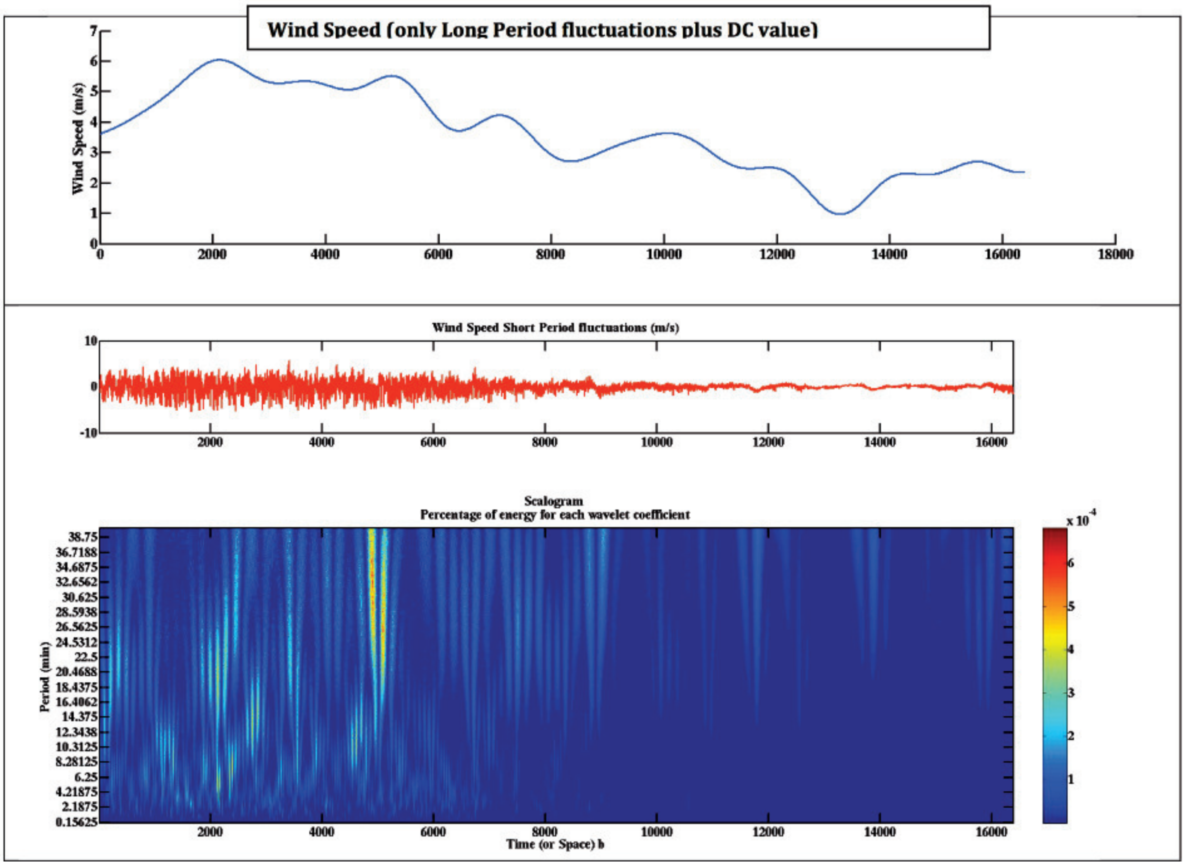
# The challenge of wind resource forecasting

› And worse, energy is proportional to the **cubic** power of wind speed!




– The 10 minute average energy produced by the SmartCoDe demonstrator turbine for the same 24 hour period.

## Fluctuations exist in both frequency and time






## How do we do wind energy forecasting?

› We are **not re-inventing** weather forecasting!

› Use weather forecasting of wind resource from a nearby weather station(s) as **input** to energy model

› But forecast information is given at coarse **macro scale**, far away from wind turbine, and usually at wrong height

› Need to **correct** macro scale forecast to **local micro-scale**

# How do we "correct" the weather forecast?

**One Option:** physical model

› Need to **correct** macro scale forecast **to local micro-scale**

–Local terrain roughness

–Local turbine height

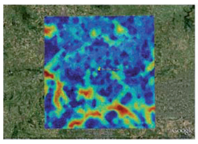
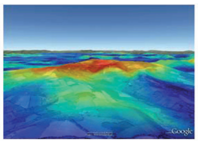
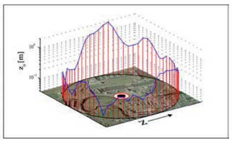
› Need to understand atmospheric boundary layer physics

› **Not a practical solution**

–requires too much detail

–too much subjective "tuning" required

–expensive and not robust

| $z_o$ [m] | Classification | Landscape description |
|---|---|---|
| 0.0002 | Sea | Water surface: Open sea or lake, tidal flat, snow-covered plain. |
| 0.005 | Smooth | Featureless land surface: Beaches, marsh and fallow open country. |
| 0.03 | Open | Level open country: Heather, moor and tundra. |
| 0.10 | Roughly open | Open agricultural: Cultivated or natural area, low crops or plant cover. |
| 0.25 | Rough | Built agricultural: Cultivated or natural area, high crops and buildings. |
| 0.5 | Very rough | Suburban: Intensely cultivated landscape |
| 1.0 | Skimming | Towns: Densely built-up area. |
| ≥ 2 | Chaotic | High-rise: City centres with a mixture of |

Existing classification of $Z_0$ is very subjective and prone to significant error



# How do we "correct" the weather forecast?

**Better Option:** fit empirical model using "machine learning" (such as ANNs and variations)

› Identify key variables: wind speed, turbulence, wind direction

› Start by **training** the model

– provide a data set of **historical** data from nearby weather station

– local wind data from turbine for the same period of time

– need to judiciously select training data to provide a **complete** set of statistics but at same time avoid over-learning

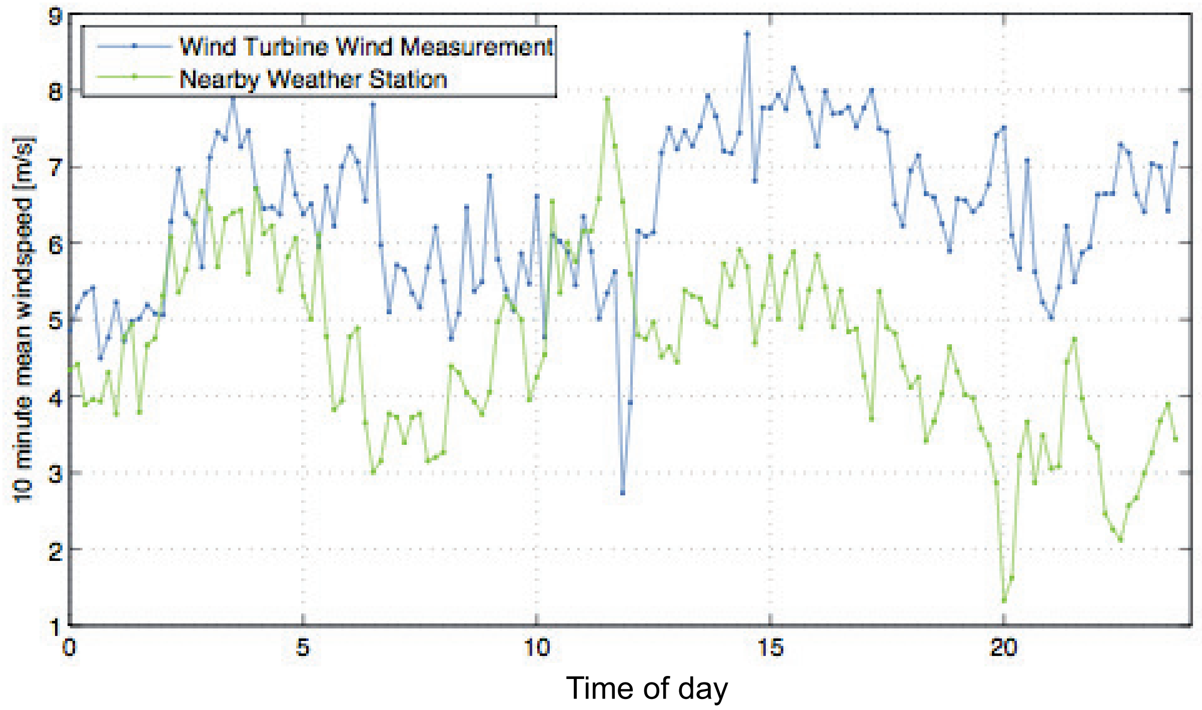
› Once model has learnt how to correct weather station to local turbine based on historical data, can apply to future wind forecast

› In parallel, continue machine learning

– continue to compare current conditions at local site to current conditions at weather station. Model adapts to longer-term variations, such as seasonal changes or local topographical changes (growth of trees, new buildings)

› Inconsistency in mapping weather forecast can provide input to confidence weighting

# Correct nearby weather station to local turbine




– Real-world data is presented from qr5 wind turbine and a weather station located 21 km away

– Correlation is not simply scaling absolute data - need to understand underlying physics

– Additional inputs are turbulence in each 10 minute burst and average wind direction



# Wind Energy Forecasting for Distributed Generation

› Integrating Local Energy Production into an energy neighbourhood opens up many more opportunities for effective Energy Management

› Knowledge of future energy production (i.e. wind energy forecast) needs to be matched with expected energy demand profile for best results

› Wind energy forecast is challenging due to volatility of wind

› Use existing nearby weather station forecasts as input - don't reinvent the wheel!

› Develop machine-learning algorithms to correct weather station wind forecast to local wind turbine location

› Model is continuously adapted with time

Funded by the EU FP7

## Invited Paper:
## Short-term solar energy forecasting for network stability
## Prof Dr. H. Hermanns (Saarland University)

Prof. Dr.-Ing. Holger Hermanns is a full professor in the Department of Computer Science at Saarland University, Germany, holding the chair for Dependable Systems and Software since 2003.

Holger Hermanns studied at the University of Bordeaux, France, and the University of Erlangen/Nürnberg, Germany, where he received the diploma (with honours) in Computer Science in 1993 and a Doctoral degree (with honours) from the Department of Computer Science in 1998. From 1998 to 2006, he has been with the University of Twente, The Netherlands, holding an associate professor position since October 2001. He is the first computer scientist to ever receive the Dutch national innovation award 'Vernieuwingsimpuls' (2001).

His research interests include modelling and verification of concurrent systems, resource-aware embedded systems, and compositional performance and dependability evaluation, including dependable energy distribution grids. In these areas he has authored or co-authored more than 120 peer-reviewed scientific papers (h-index 34). He has served on various organising and programme committees (more than 40 in the last 5 years), has co-chaired the programme committees of major international conferences such as TACAS 2006, CONCUR 2006, and CAV 2007, has served on the steering committees of ETAPS and QEST, and has authored a monograph in the LNCS series of Springer-Verlag based on his dissertation. He is a founding member and principal investigator of the German special research initiative SFB AVACS and holder of several other national and European research grants.

### Abstract

Photovoltaic energy production is an important part of the future global energy market. Especially in Germany, small scale solar production is growing massively, owed to financial incentives by the governement. A crucial feature of renewable energy sources is its unreliable and partly uncontrollable behaviour. This problem is amplified by specifics of solar producers operating in close geographic vicinity: They have a very high coincidence factor meaning that their production may change rapidly and almost synchronously owed to changes in cloud coverage. This makes the stable operation of a local area power network especially vulnerable to short term changes.

To predict critical conditions, we are developing forecasting techniques for photovoltaic energy production based on precise local information and short-term weather predictions.

SmartCoDe has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013]) under grant agreement n°247473

# Short-term solar energy forecasting for network stability

Holger Hermanns
Dependable Systems and Software
Saarland University
Germany

## What is this talk about?

Photovoltaic energy production is an important part of the future global energy market. Especially in Germany, small scale solar production is growing massively, owed to financial incentives by the governement. A crucial feature of renewable energy sources is its unreliable and partly uncontrollable behaviour. This problem is amplified by specifics of solar producers operating in close geographic vicinity: They have a very high coincidence factor meaning that their production may change rapidly and almost synchronously owed to changes in cloud coverage. This makes the stable operation of a local area power network especially vulnerable to short term changes. To predict critical conditions, we are developing forecasting techniques for photovoltaic energy production based on precise local information and short-term weather predictions.

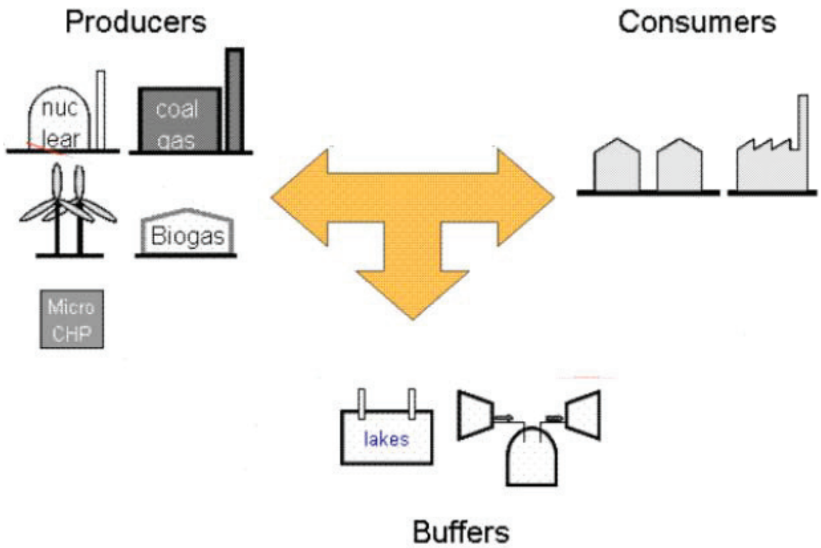
# Background



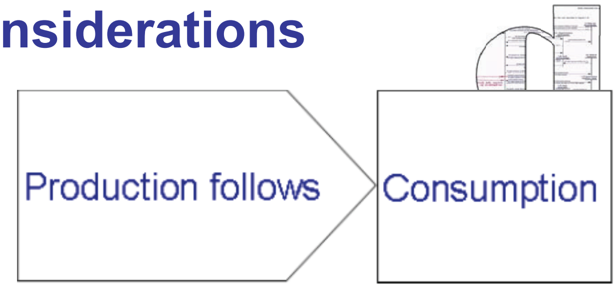
# Principal Electricity Market Participants

Producers
- thermal:
  nuclear,
  gas,
  coal
  cogeneration of
  heat/power

- renewable:
  wind, solar, biogas, water
  geothermal



# Principal Electricity Market Considerations




**Production follows Consumption**

Base assumptions:

- the electricity demand never exceeds the potential offer

- the producing entities are fully controllable



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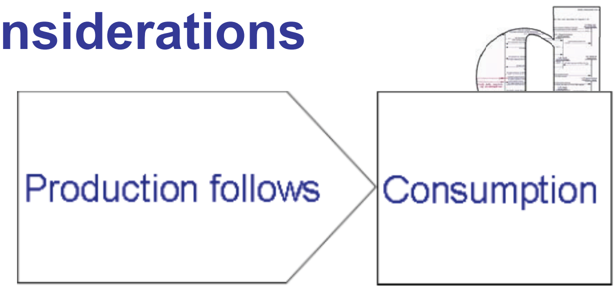



**Production follows Consumption**

Base assumptions:

- the electricity demand never exceeds the potential offer

- the producing entities are fully controllable

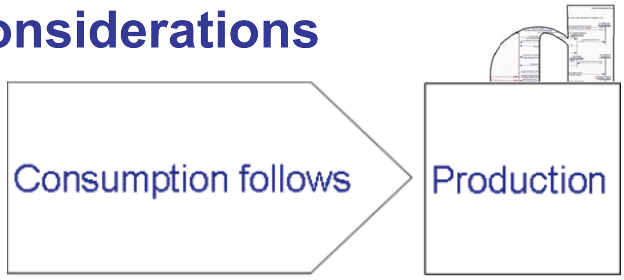
Features:

- barely any regulation on the consumer side

- producers are structured and coordinated in such a way that they satisfy the fluctuations in demand.

- consumers are charged for the costs incurred by the energy they consume

# Principal Electricity Market Considerations




**Consumption follows Production**

Base Assumptions:

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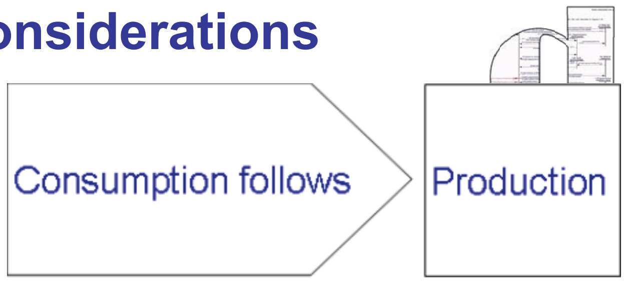



**Consumption follows Production**

Base Assumptions:

- electricity can only be consumed if it is available

Features:

- production entities are hardly controllable
- frequent interruptions of energy availability on the consumer side
- often comes with the allocation of electricity quotas to consumer
- mechanisms to control the consumer side characteristics

# Principal Electricity Market Considerations

Production follows → Consumption

**How?**

Example: Germany

- currently divided into 4 so **control areas.**


Inside a control area, traders and network users form so-called **accounting grids**.

Each consumption and production unit belongs to a single accounting grid.




# Principal Electricity Market Considerations

Production follows → Consumption

**How?**

Example: Germany

- currently divided into 4 so **control areas.**



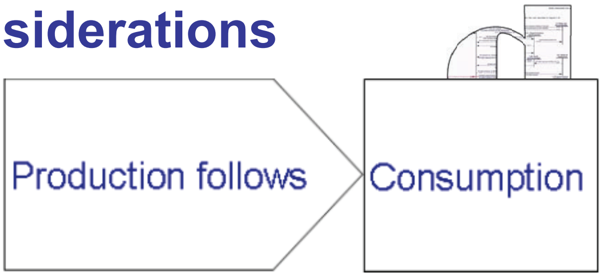

Inside a control area, traders and network users form so-called **accounting grids**.

Each consumption and production unit belongs to a single accounting grid.


Each grid has a responsible **grid coordinator** who interfaces traders and users.
Prime responsibility: maintain the electricity flow inside the grid in balance.
Deviations need to be corrected within pre-specified time bounds

Accounting grids are tightly interwoven by physical entities (cables, transformers) so they form a virtual structure on top of the electricity network.

# Principal Electricity Market Considerations




**How does the grid coordinator act?**

- based on daily load schedules that each grid coordinator has to announce (at 14:30 the latest for the following day)

- load schedules can be adjusted on an hourly basis with a 3 hours deferral period, unless network bottlenecks result.



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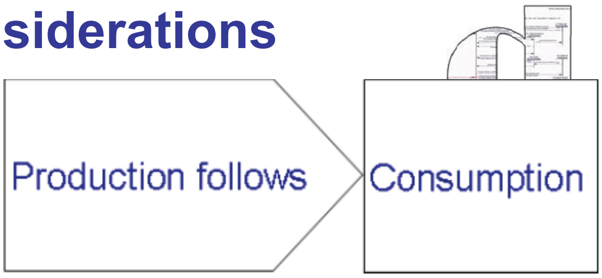


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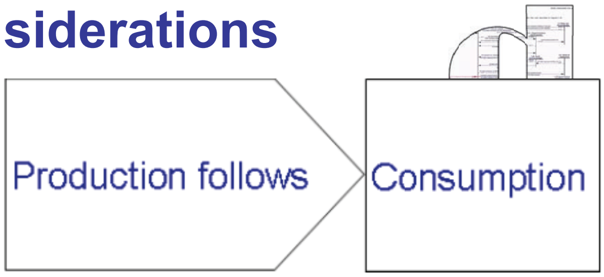


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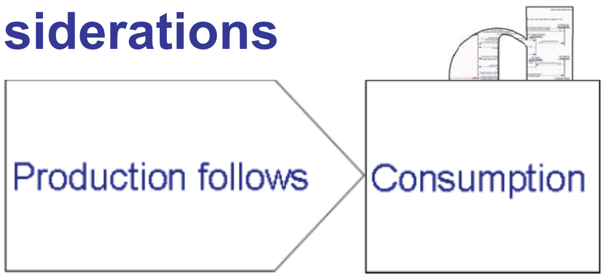
This balance is essential for stable and reliable network operation:

Overprovisioning (or underconsumption) results in frequency drops, underprovisioning results in frequency jumps.

Too excessive frequency deviations : malfunctioning on consumer side. chain reactions may lead to network collapse (’blackout’).



# Principal Electricity Market Considerations




### How does the grid coordinator act on short term?

- use of the concept of **control energy**.
  - electrical power that can be added to or substracted from a grid by the grid controller almost instantaneously.

Technically often realised with the help of pump-storage plants
subtraction amounts to pumping up water
addition turns water downflow into electrical power

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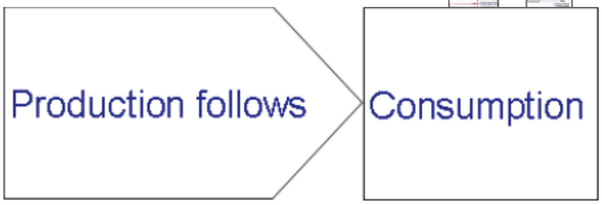


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Technically often realised with the help of pump-storage plants
subtraction amounts to pumping up water
addition turns water downflow into electrical power

about 10% of peak consumption.

Control energy can be traded across grids,
this is a characteristic feature to maintain stability.

Notably, there is a considerable energy loss because of ineffectiveness of pump-storage.



# So, what's the challenge?

**The integration of renewable energy.**

Renewable energy production has a drastically higher volatility and this volatility is uncontrollable.

This asks for increased efforts related to network stabilization.

The drastic increase in volatility may exceed the available control energy.

This has happened for instance on September 6, 2010.

# So, what's the challenge?

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Renewable energy production has a drastically higher volatility and this volatility is uncontrollable.

This asks for increased efforts related to network stabilization.

The drastic increase in volatility may exceed the available control energy.

This has happened for instance on September 6, 2010.

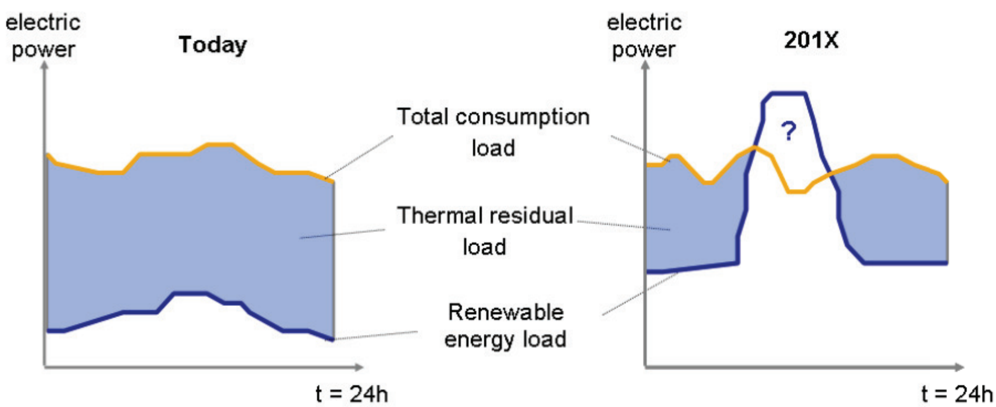
- What happened:
  - drastically more solar power in the net than announced the day before
  - Germany @ lunchtime: surplus of 7000 MW
  - Complete negative control energy exhausted (- 4300 MW)
  - Emergency reserve imported from neighbouring countries (- 2800 MW)



# Challenges for Economic Energy Usage?

Increase in renewable energy induces
- volatility effects on the stock market pricing for short term electricity,
- change in workload characteristics of traditional, thermal power plants.

**Load Changes of Demand and Generation**



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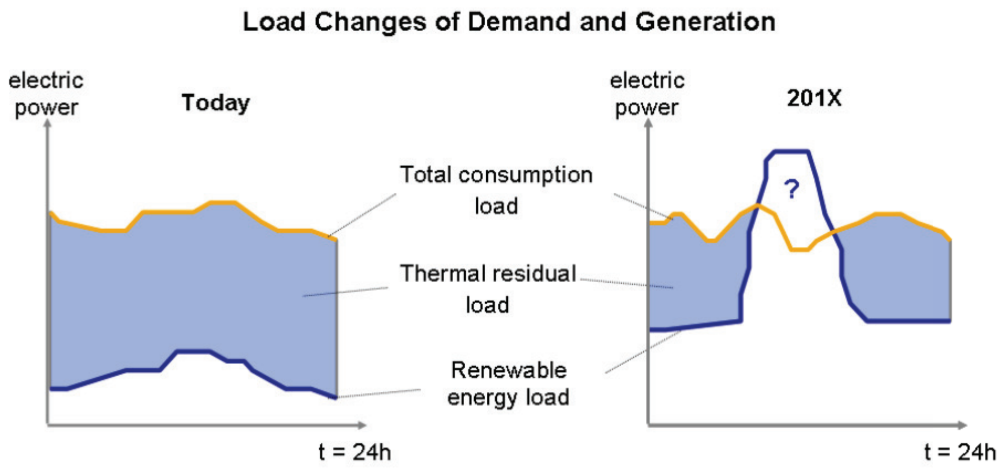


So far: base load power plants have low marginal costs
should operate most suitable all the time (running river, nuclear or lignite fired).

*Concerns:*
*- What happens in situations when renewable energy production is higher than total consumption?*

*- What production entities are needed,*
*if all the base consumption load is covered by renewable energy?*



# Challenges for Economic Energy Usage?

Economical and ecological reasons will dictate a **shift away** from the

***Production follows consumption*** principle.

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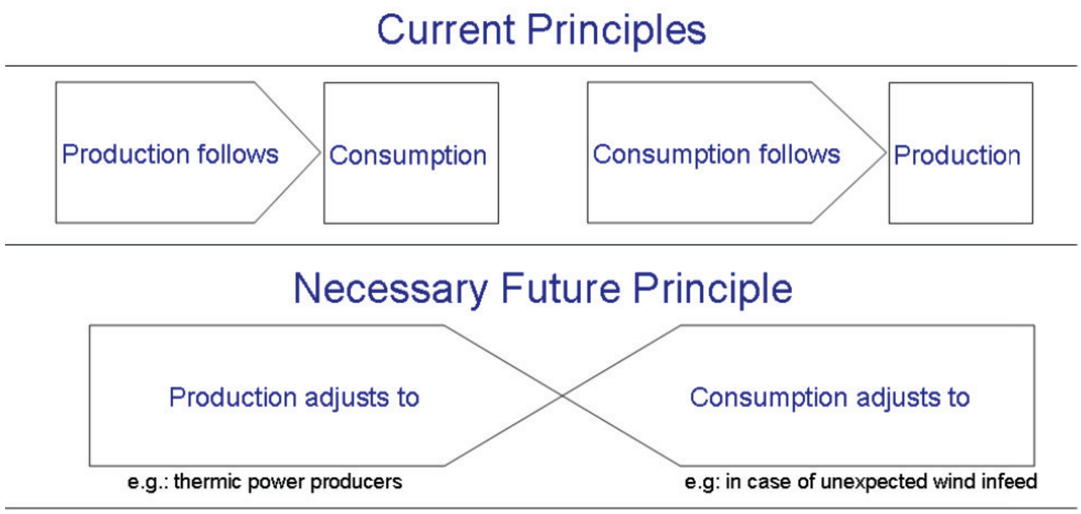



*Balancing the volatility in production (partly) on the consumer side*



# What to Control on the Consumer side?

Light bulbs?

Ironing?

PC?

TV?

Electrical water warming?

Climate control?

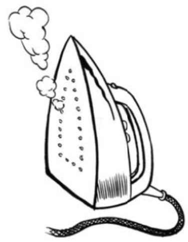
Cooling control?

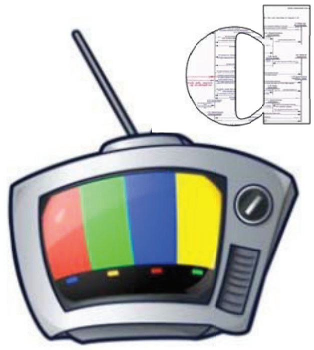
Air pressure applications?

Off-peak storage heating?

Geothermal heating?

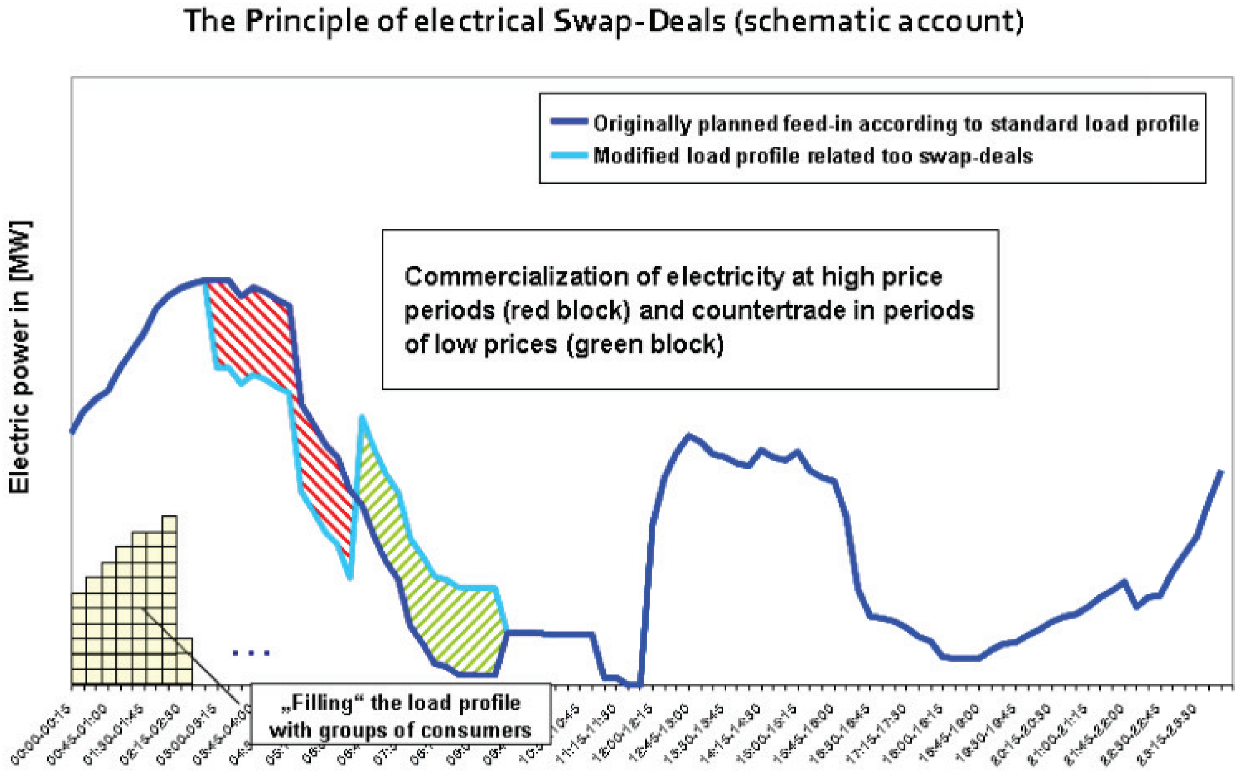
Electrical and hybrid electrical vehicles?





The segment of 'schedulable' consumers in Germany is in the order of a few ten thousands of MW.

# How to make profit from this?
# And stabilize the network ?




Holger Hermanns Saarland Unversity

# Short term prediction of photovoltaic energy production

Holger Hermanns Saarland Unversity

# Particularities of solar production

- 75% of all installations are not measured (about 14.000 MW)
  are balanced out once per year



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  - without considering day-night differences
    (forbidden as of January 1, 2011)

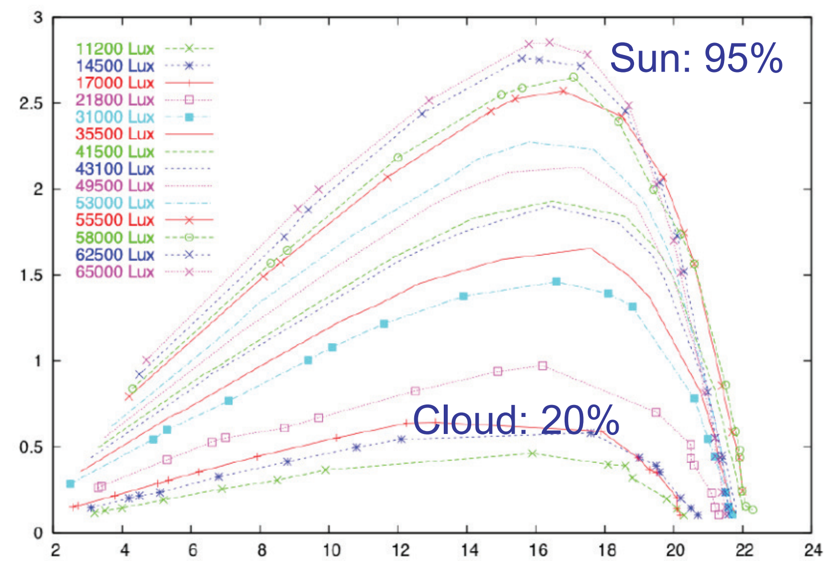
Result: Overestimation on rainy days (and in nights)
Underestimation on sunny days (and at daytime)



# Another particularity

Specifics of solar producers in close geographic vicinity:

very high coincidence factor




Pai H. Chou, Dexin Li and Sungjun Kim
Maximizing Efficiency of Solar-Powered Systems by Load Matching.
*ISLPED*, August 9–11, 2004.

Voltage vs. power @ various sunlight intensity

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This means:

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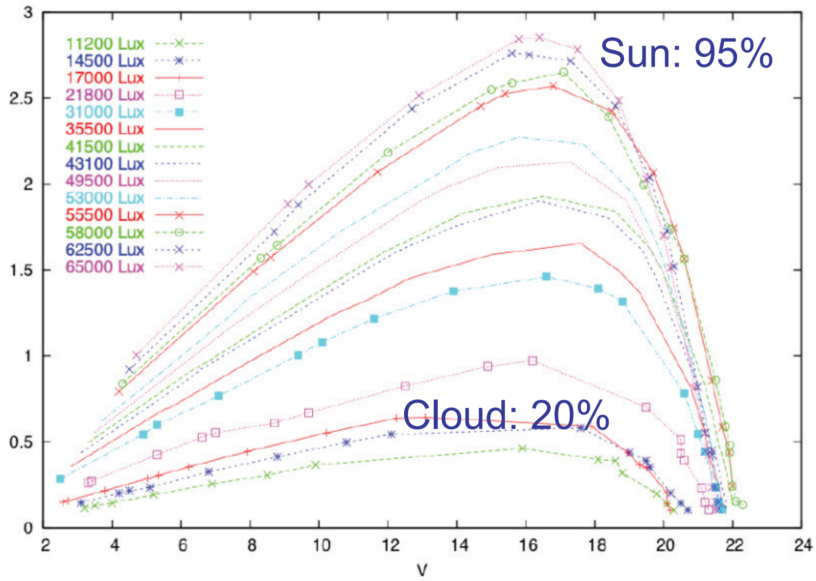


Voltage vs. power @ various sunlight intensity



# Problem Statement

**Given:**

1) a set of solar energy production facilities (panels)
2) a precise weather forecast for the next 48 hrs for the area

**Goal:**

Estimate the net solar power production for each relevant time point.

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**Solar panels**
- geographical position (all in the same area)
- orientation of panel surface in 3D
- nominal power production profile
  function of light intensity, orientation towards sun, etc



# Problem Statement

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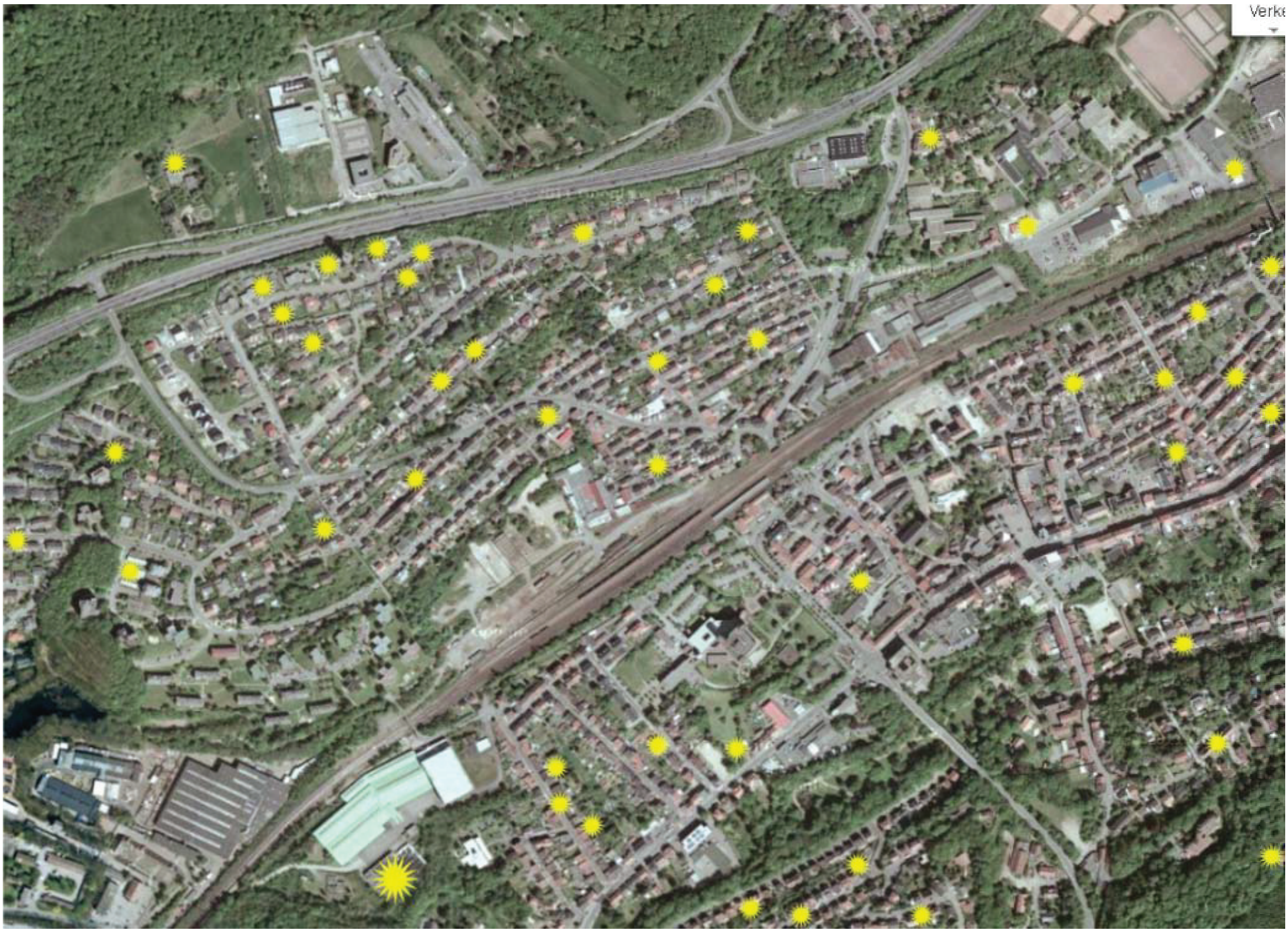
**Goal:**

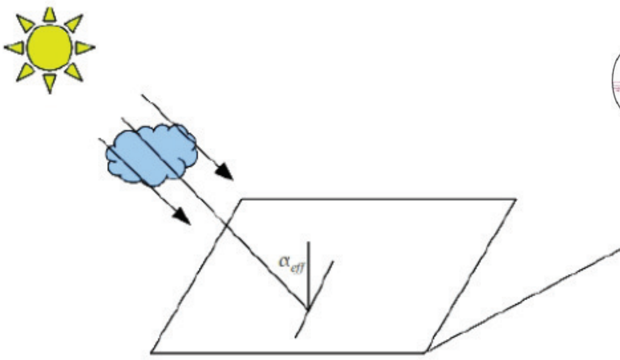
Estimate the net solar power production for each relevant time point.

**Weather forecast:**
- cloud cover
- light intensity
- diffusion
  - at high, middle, low altitude
  with
  - fine time granularity (1 hr)
  - spatial resolution as fine as possible (3.8 km)



# Solution

Requires calculations
based on
- sun position
- spehric model of earth
- discretisation
- interpolation




Effective angle between sun light and surface of solar panel

$$\phi_{ij} = f(sun\,angle, weather) * \phi_{max}$$

$\phi_{max}$ is a constant and equals $\approx 1300 W/m^2$ .

$$\alpha_{ij}^{eff} = f(sun\,angle(t), \gamma_{ij}, \theta_{ij})$$

Discretization of power production:

$$w_{ij} = \sum_{t=t1}^{t2} P_{ij}(\phi_{ij}(t), \alpha_{ij}^{eff})\Delta t$$

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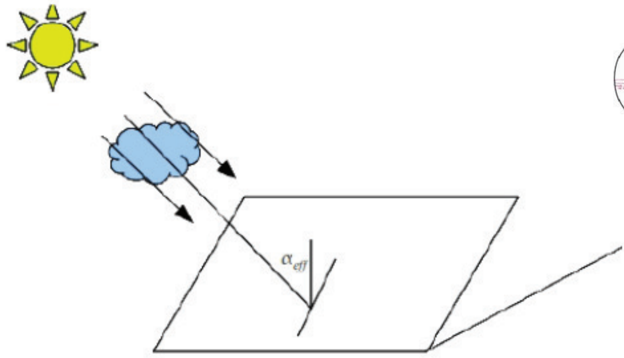


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Put into practice for a local distribution grid
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- Stadtwerke Sulzbach
  provided data about solar panels

- Luxea GmbH
  provided expertise in long-term
  behaviour of photovoltaic installations



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Prototype system is up and running.
Focus on critical impact on network stability.

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*I mow the lawn at 3 pm,*
*since the sun will shine on the house of my neighbour then.*

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Institut für Computertechnik
Institute of Computer Technology

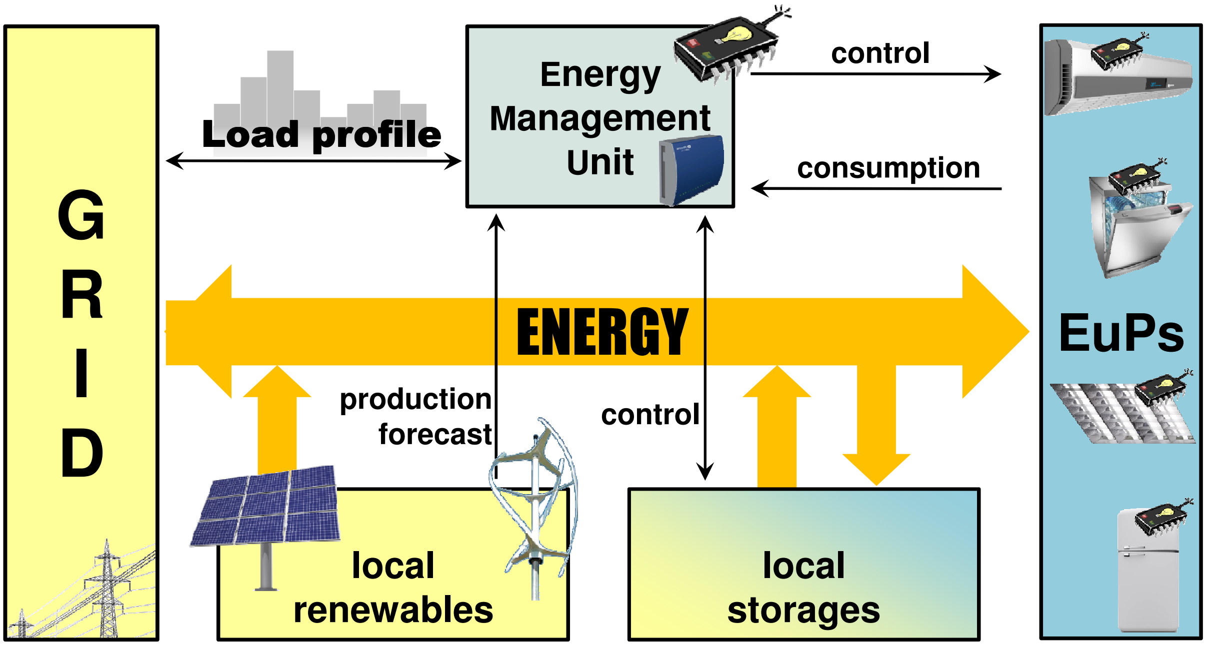
# Categorizing Energy using Products for partially decentralised Energy Management

Markus Damm

## Outline

- SmartCoDe Energy Management problem
- A semi-decentralised approach
- Cost function-based Energy Management
- Classification of Energy using Products (EuPs)
- EuP-class specific Energy Management
- Conclusion

# SmartCoDe Energy Resource Cluster




**Goal:** Harmonise energy consumption with local energy production

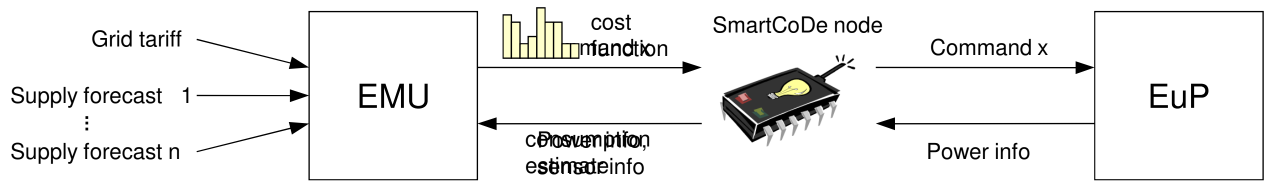


# Target Area and Requirements

- **Target Area:**
  - Average EU neighbourhoods & small commercial buildings
  - Connected to the public grid
  - Utilise local renewable energy (solar-panel, wind-turbine)
- **Requirements for Energy Management (EM)**
  - The EM-approach should allow to **maximize the usage of** locally produced **renewable energy**.
  - The EM-interference **should be acceptable by the user.**

# Centralised and Semi-Decentralised Control






**Centralised:** Node passes on commands, provides sensor info

**Semi-decentralised:**

- Cost functions concerning future time periods issued by EMU
- Node controls EuP autonomously while obeying to costs



# Centralised vs. Semi-Decentralised Energy Management Approach



| | Centralised | Semi-decentralised |
|---|---|---|
| **Communication overhead** | • Sensor data has to be transmitted<br>• Control commands with high frequency | • No sensor data has to be transmitted<br>• Directives can have lower frequency |
| **EuP Management** | • Micromanagement<br>• *Every* important aspect of the EuP has to be known by EMU | EuP only needs to know<br>• EuP class<br>• Power consumption forecasts |
| **EMU crash / absence / communication problems** | • SmartCoDe nodes "headless"<br>• What happens to control loops? | • SmartCoDe nodes can operate autonomously |
| **SmartCoDe Node design / software** | Simple | Complex |
| **Load balancing between nodes** | **Easier** to achieve since EMU has complete control and knowledge | **Harder** to achieve due to autonomy of SmartCoDe nodes |
| **Micro-managing** | Is the principle here | **Still possible** for selected EuPs / EuP classes |

# SmartCoDe Semi-Decentralised Energy Management approach

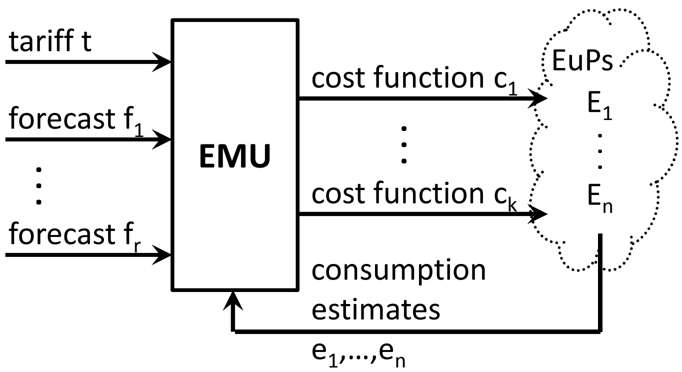


## Energy Management Unit:

- Receives tariffs, consumption and production forecasts
- Issues **cost functions** to EuPs w.r.t. a certain optimisation goal

## SmartCoDe Node:

- Receives cost function
- Controls EuP while minimising cost w.r.t. cost function
- Produces power **consumption estimates**






# Existing demand control message: The ZigBee® Smart Energy Load Control Event

www.ict.tuwien.ac.at

| Octets | 4 | 2 | 1 | 4 | 2 | 1 | 1 |
|---|---|---|---|---|---|---|---|
| Data Type | Unsigned 32-bit integer | 16-bit BitMap | Unsigned 8-bit integer | UTC Time | Unsigned 16-bit integer | Unsigned 8-bit integer | Unsigned 8-bit integer |
| Field Name | Issuer Event ID (M) | Device Class (M) | Utility Enrolment Group (M) | Start Time (M) | Duration In Minutes (M) | Criticality Level (M) | Cooling Temperature Offset (O) |

| Octets | 1 | 2 | 2 | 1 | 1 | 1 |
|---|---|---|---|---|---|---|
| Data Type | Unsigned 8-bit integer | Signed 16-bit integer | Signed 16-bit integer | Signed 8-bit integer | Unsigned 8-bit integer | 8-bit BitMap |
| Field Name | Heating Temperature Offset (O) | Cooling Temperature Set Point (O) | Heating Temperature Set Point (O) | Average Load Adjustment Percentage (O) | Duty Cycle (O) | Event Control (M) |

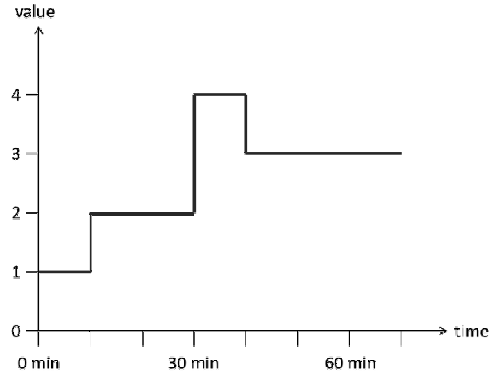
| Criticality Level | Description | Participation |
|---|---|---|
| 0 | Reserved | Voluntary |
| 1 | Green | Voluntary |
| 2 | 1 | Voluntary |
| 3 | 2 | Voluntary |
| 4 | 3 | Voluntary |
| 5 | 4 | Voluntary |
| 6 | 5 | Voluntary |
| 7 | Emergency | Mandatory |
| 8 | Planned Outage | Mandatory |
| 9 | Service Disconnect | Mandatory |
| 0x0A-0x0F | Utility Defined | Utility Defined |
| 0x10-0xFF | Reserved | |

**Problems:**

- Too much information for our purposes
- Small granularity leads to a lot of messages
- …and we need small granularity (~10 minutes)

# SmartCoDe Cost Function Format

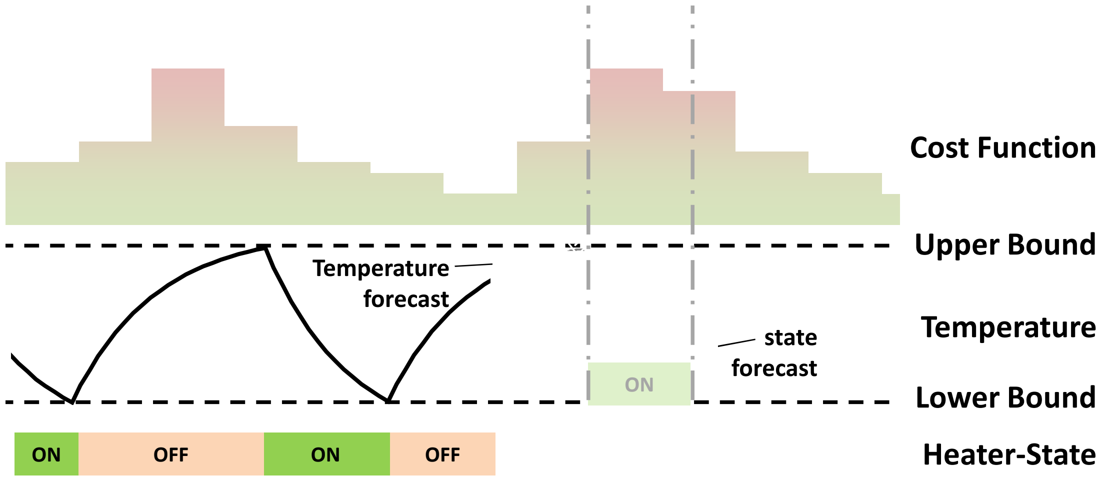
- Values are **abstract** costs
- **Step-function** approach
- Example: (10 min , 1) , (20 min , 2) , (10 min , 4) , (30 min , 3)
- Time resolution can be set (1s – 1h)
- Basically bundles a series of ZigBee SE load control events




| Data Type | 8-Bit Flag register | UTC Time | Unsigned 8-bit integer | Unsigned 8-bit integer | Unsigned 8-bit integer | (repeat) … | Unsigned 8-bit integer | Unsigned 8-bit integer |
|---|---|---|---|---|---|---|---|---|
| Field Name | Time Resolution | Start Time | cost function length n | Criticality Level 1 | Duration 1 (in time resolution units) | … | Criticality Level n | Duration n (in time resolution units) |

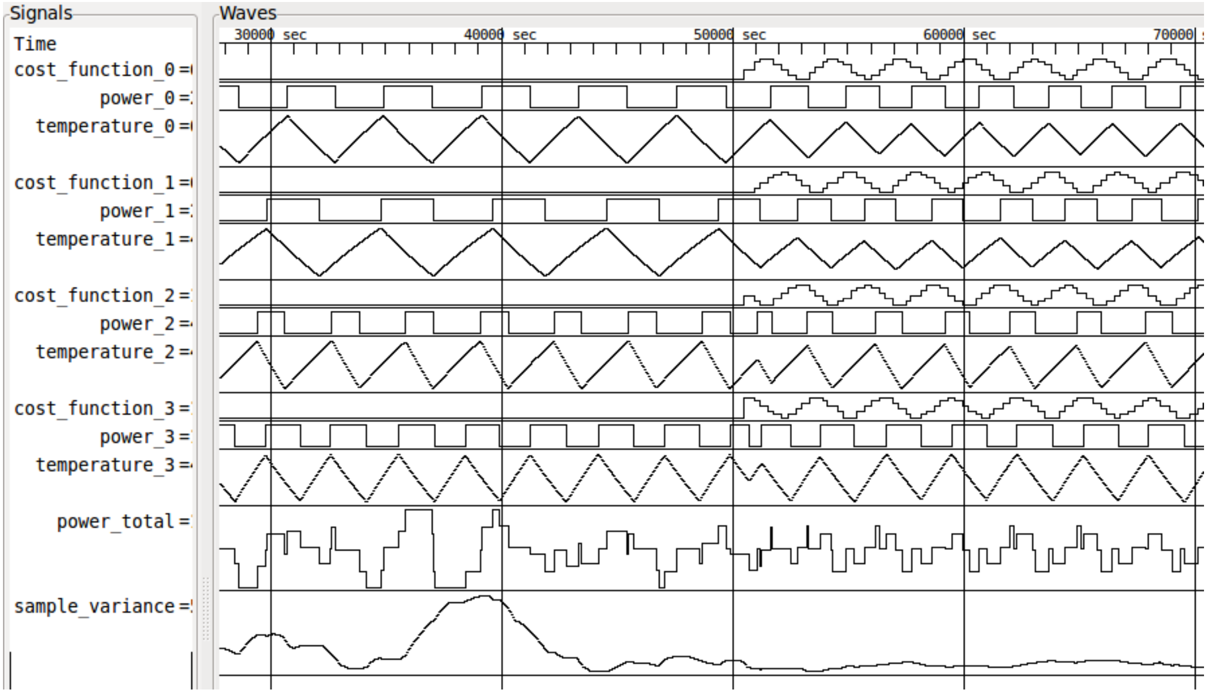


# Local Control Example: Cost Function Based Bang-Bang Control of a Fridge



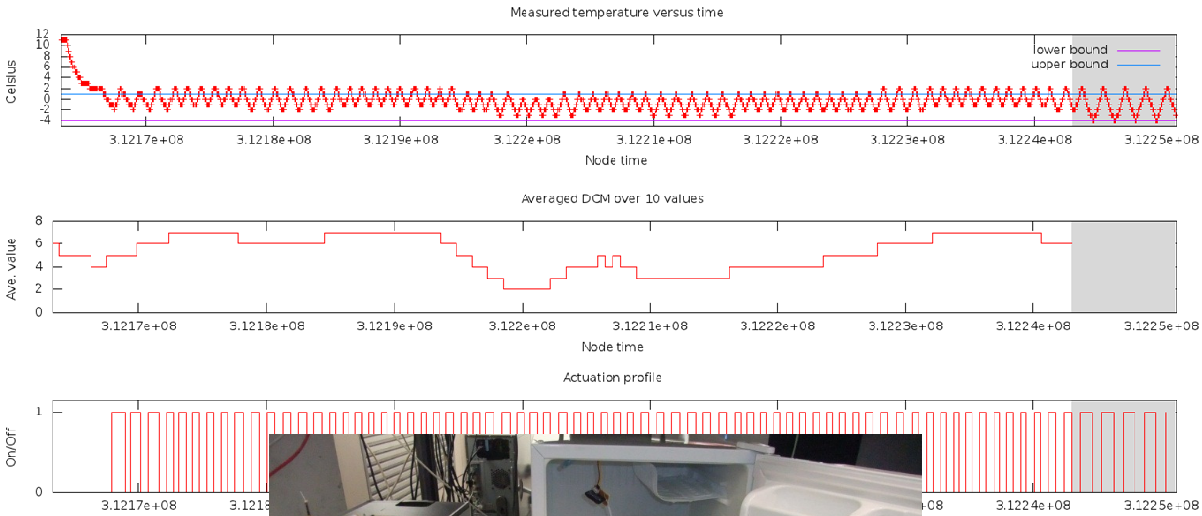

- SmartCoDe node plans ahead to minimise costs
- Generates control plan → effectively a consumption forecast
- Temperature forecast needed

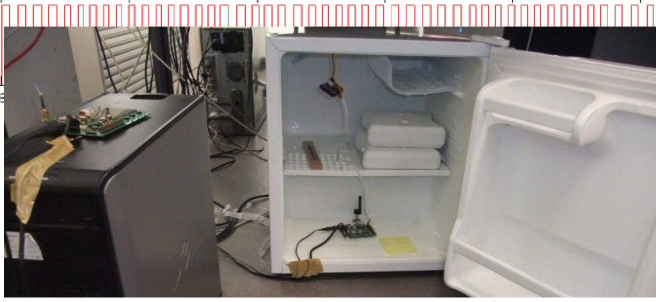
# Global Control Example: Load Balancing of Four Fridges with Cost Functions






# Working Cost-Function Based Bang-Bang Control on the Functional Node Prototype



# EuP Classification - Motivation

- Each class collects EuPs with similar...
  - Service
  - Interfaces
  - Energy Management leverage
- One SmartCoDe node variation for each class
  - Mostly software, in principal also hardware
  - Especially: cost function-based energy management





# SmartCoDe EuP Classification

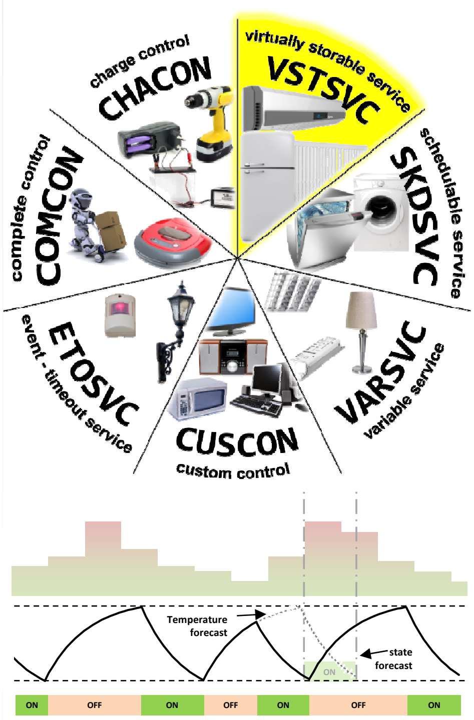

www.ict.tuwien.ac.at

# SmartCoDe EuP Classification

| Class | Description | Parameters | | | Energy Management | | Examples |
|---|---|---|---|---|---|---|---|
| | | Configuration | Sensor input | Online input | Strategy | cost | |
| VARSVC | **Variable Service:** The appliance provides a user-variable service, possibly balanced with sensor input. | tolerance bounds | current state of the service, e.g. illuminance | user demand, e.g. setpoint for illuminance | Minimise consumption while balancing the service with user demand, tolerance bounds and sensor measurement. | No | dimmable lighting, blinds, fans |
| VSTSVC | **Virtual Storage service:** The appliance provides a inert, user-variable service which can serve as a virtual storage. | tolerance bounds | current state of the service, e.g. temperature | user demand, e.g. setpoint for temperature | Balance service with user demand and sensor measurement while exploiting the virtual storage property. | Yes | Fridge, Freezer, HVAC, Water-boiler |
| SKDSVC | **Schedulable Service:** The appliance provides a service which can be scheduled within a certain time-frame. | runtimes and power profiles of the different programs | none | time-frame | Start program within the given timeframe such that the program's load profile produces minimal costs. | Yes | washing machine, dryer, dishwasher, baking machine |
| ETOSVC | **Event-Timeout Service:** The appliance is control-led by sensor events and time-outs. | time span | sensor event, e.g. presence detection | none (indirectly through sensor input) | Control appliance according to sensor events and time-outs. | No | lighting controlled by presence detector (e.g. on corridor) |
| CHACON | **Charge Control:** The appliance charges a possibly removable device. | charging policy | current charge status, device presence | device removal re-insertion | Charge device such that costs are minimised, while obeying charging policy. | Yes | battery chargers, hand-held vacuum, emergency backup storages |
| COMCON | **Complete Control:** Like CHACON, but the usage of the charged power can also be con-trolled. | charging policy, duty cycles, time slots | current charge status | none | Like CHACON, but also control the usage of the appliance cost-effectively while obeying to the given time-slots and duty cycles. | Yes | robot vacuum, robot lawn-mower |
| CUSCON | **Custom Control:** device does not fit into other classes. | none | none | user demand | Automatic Energy Management probably not tolerable by user; custom schemes can be defined which are implemented by the EMU. | No | HiFi, PC, Oven |



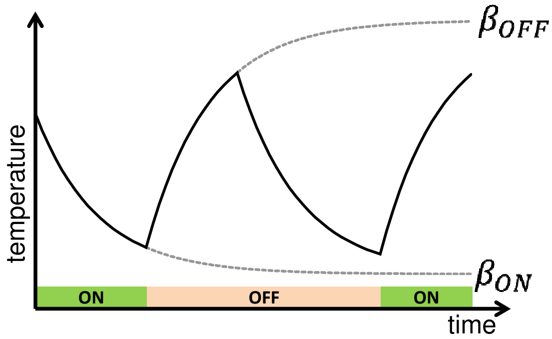
# VSTSVC – Virtual Storages




- Inert service (mostly thermal) which can store energy
- Energy Management:
  - Store energy (e.g. cool down) when cost is low, switch off when cost is high
  - Keep temperature in between bounds
- Issues
  - Parameters of thermal process (e.g. thermal capacitance) needed for planning
  - These parameters need to be learned by the SmartCoDe node

# VSTSVC: Modelling and Learning the Thermal Process

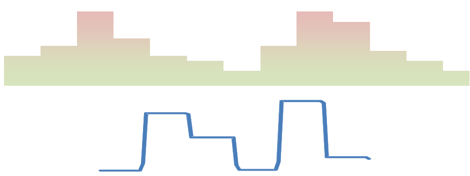
- Discrete time lowpass model:
  $t_{i+1} = \alpha \cdot \beta + (1 - \alpha) \cdot t_i$
  - $t_i$ : temperature in step i
  - $\boldsymbol{\alpha}$ : Smoothing factor
  - $\boldsymbol{\beta}$ : boundary temperature (one $\beta$ for each power level)
- Useful for
  - Temperature forecast
  - Power forecast
  - Smart cost-function based control algorithm




- Need to learn $\alpha$ and the $\beta$'s
- Microcontroller algorithm
  - Least square method
  - Error term computed from temperature measurements
  - random search

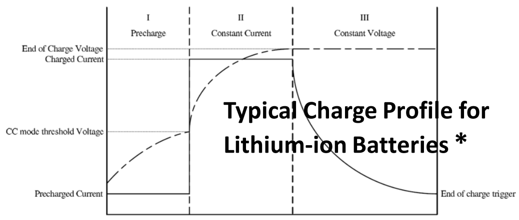


# SKDSVC – Schedulable Services

- User chooses a program and a deadline
- Energy Management:
  - Run program such that deadline is met
  - Find start time such that program load profile produces minimal cost
- Issues
  - Program load profile might not be fixed, e.g. can depend on load
  - In principle, a program can be interrupted, but the process might suffer

# CHACON & COMCON – Charging EuPs


Typical Charge Profile for Lithium-ion Batteries *

- In between VSTSVC and SKDSVC
  - Provided service: charge status – is inert
  - Charging process can be scheduled
- Energy Management:
  - Schedule charging at minimal cost
  - Obey to charging policy
- COMCON: robotic services
  - Discharging (i.e. using the device) can also be controlled
  - Still exotic, yet interesting EM opportunities

* Taken from Dung, L.-R., & Yen, J.-H *ILP-based algorithm for Lithium-ion battery charging profile*. Proceedings of the 2010 IEEE International Symposium on Industrial Electronics (ISIE), (S. 2286 - 2291). Bari, Italy



# VARSVC & ETOSVC


- Covers mostly lighting applications
  - VARSVC: Dimmable lighting, possibly controlled by luminance
  - ETOSVC: Presence detection
- No cost-dependent Energy Management
  - Possible user acceptance issues
  - Worth considering in Island scenarios
- Interesting aspects apart from EM:
  - Networking, Commisioning
  - Consumption forecast

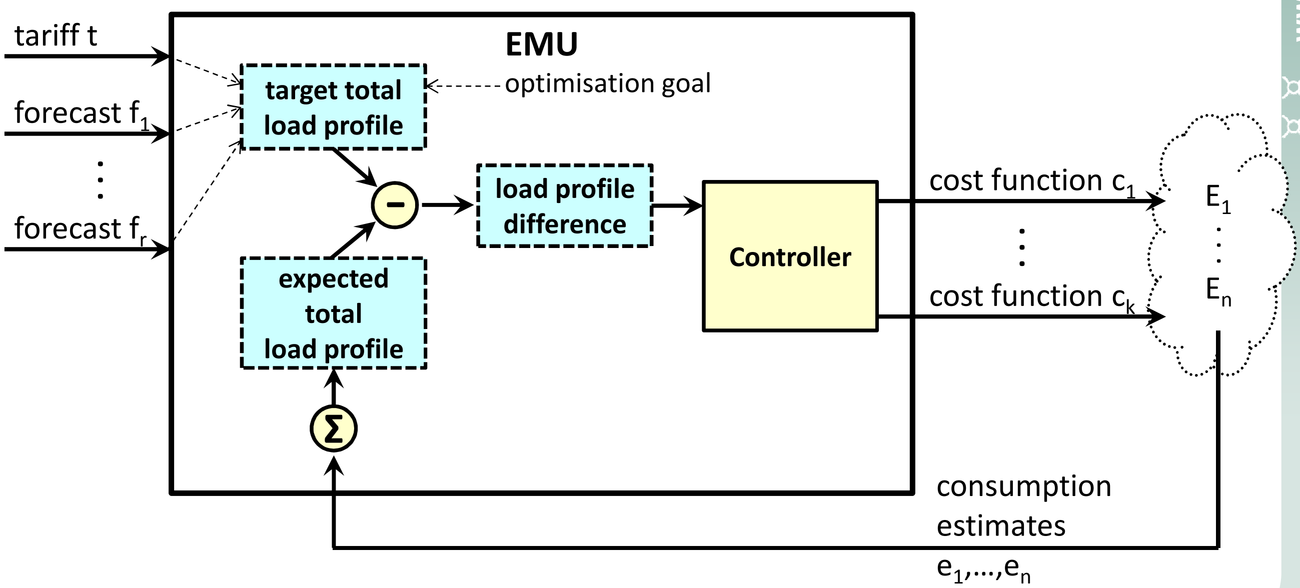
# CUSCON – Custom Control


- No Energy Management possible
  - User interaction too high
  - Or process too critical
- SmartCoDe infrastructure usable for custom control
  - Remote control, e.g. via a home gateway
  - User defined schedules
  - Ambient assisted living





# A Global Energy Management Control Loop



# Conclusion

- Semi-decentralised Energy Management provides abstraction…
  - …between EMU and EuP
  - …between global and local energy management
  - …to keep competence of EuP control with the manufacturer
- Approach can be extended to cover several hierarchy levels
- EuP classification
  - Collects EuPs which can be handled similar
  - Interfaces and EM-opportunities
  - EM algorithms



# Thank you for your attention!

**Your:**

- Questions
- Remarks
- Ideas
- Objections

COOPERATION

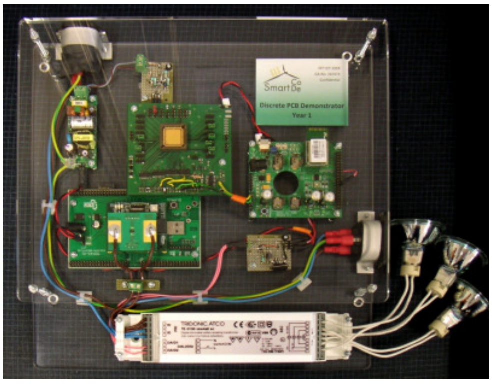
# The SmartCoDe Node Functional Prototype

Author: Edgar Holleis,
Tridonic GmbH & Co KG

Date: 12.10.2011

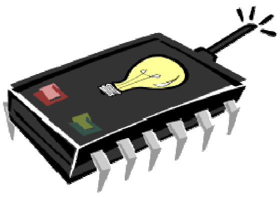
## SmartCoDe Progress

Year 1:
Discrete prototype

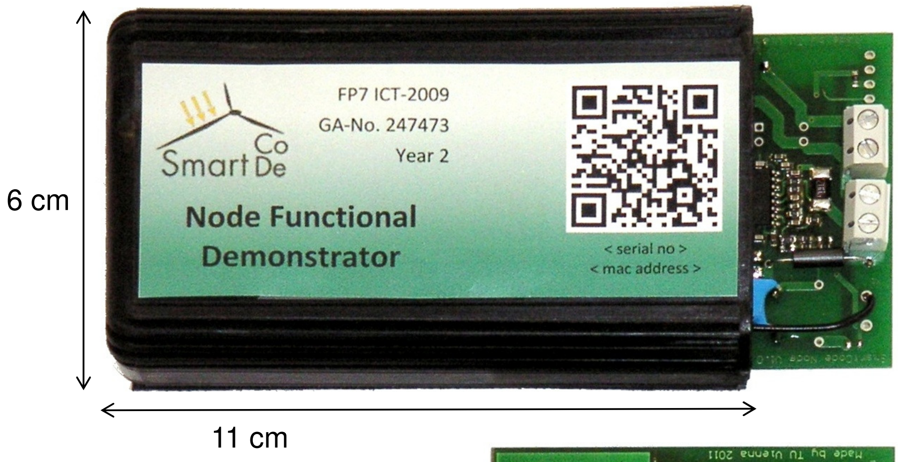


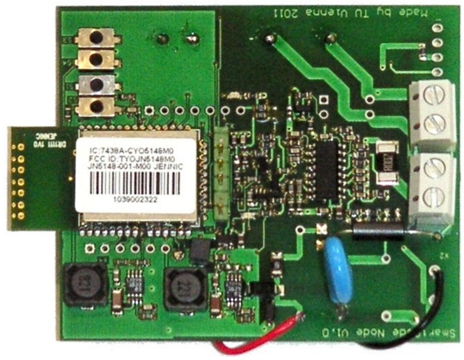

Year 2:
Functional prototype
Demonstrator

Year 3:
System on chip prototype



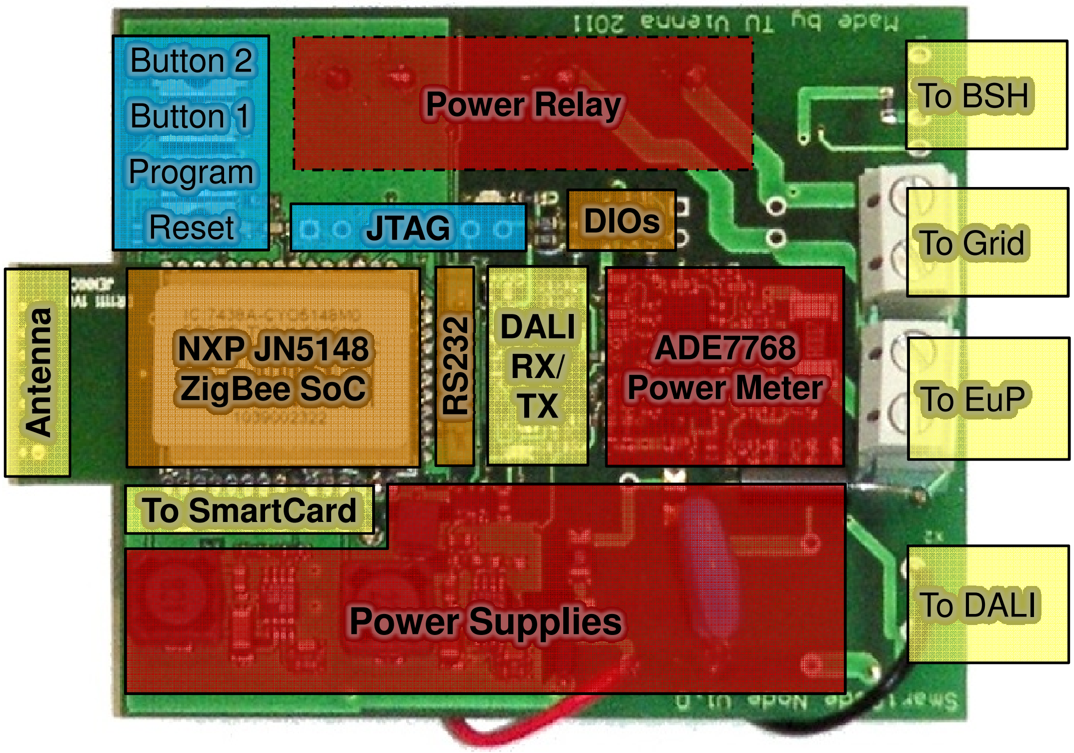
# Finished Functional Prototype





# Finished Functional Prototype



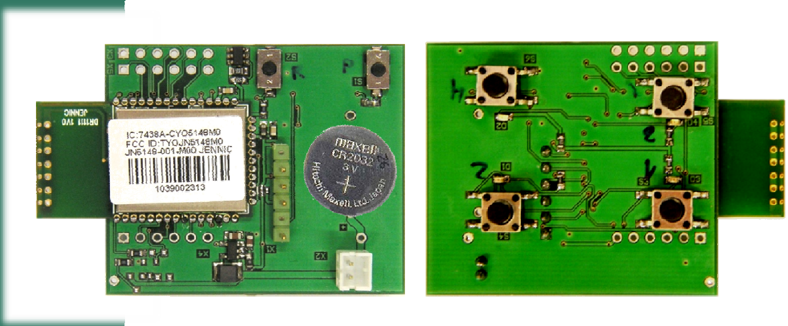
## Functional Prototype Versions & Periphery

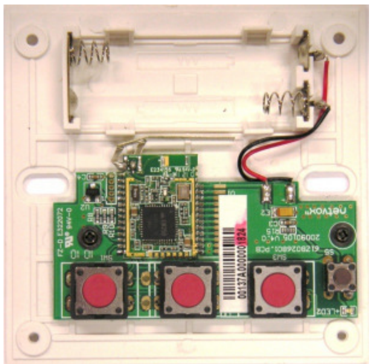
Energy Management

- Power meter
- Power relay
- White box control interface
- Remote temperature sensor node

Lighting Demonstration

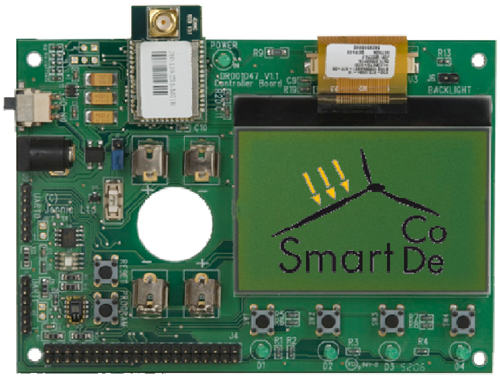
- DALI interface
- DALI supply: 6 mA (1 sensor + 1 ballast)
- Remote light switch





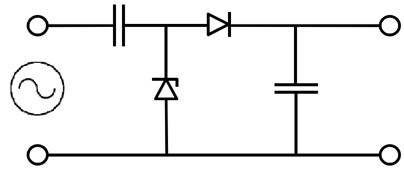


## Energy Management Unit & Coordinator Node




- Monitor & supervise consumption
- Calculate cost functions from forecasts & grid tariff
- Network management

## Power Supply



- Non-insulated
- Capacitive topology: 230 $V_{AC}$ -> 43 $V_{DC}$
- Buck converter: 43 V -> 3.3 V
- Max load: 200 mW, overall efficiency: ~ 70%

- Pros:
  - Realistic test bed for SmartCoDe SoC
  - Low cost, robust & state of the art
- Cons:
  - Need to isolate all I/O and maybe antenna
  - Need to isolate human interface elements
  - Always consumes maximum load on primary side



## NXP JN5148

Transceiver
- 2.4 GHz, IEEE 802.15.4
- AES & MAC accelerator
- Time of flight ranging
- RX: -95 dBm, 17.5 mA
- TX: 2.5 dBm, 15.0 mA


CPU
- 32 bit, 32 MHz RISC
- 128 kB ROM
  128 kB RAM
- External Flash (512 kB)
- 11 mA @ 32 MHz
- Sleep: 3.5 µA – 0.1 µA
- Usual peripherals

Software
- ZigBee 2007 PRO
- Profiles: HA, SE, ...
- Multithreaded OS
- GCC based tool chain
- Over the air upgrade

# Why ZigBee?

Pros:

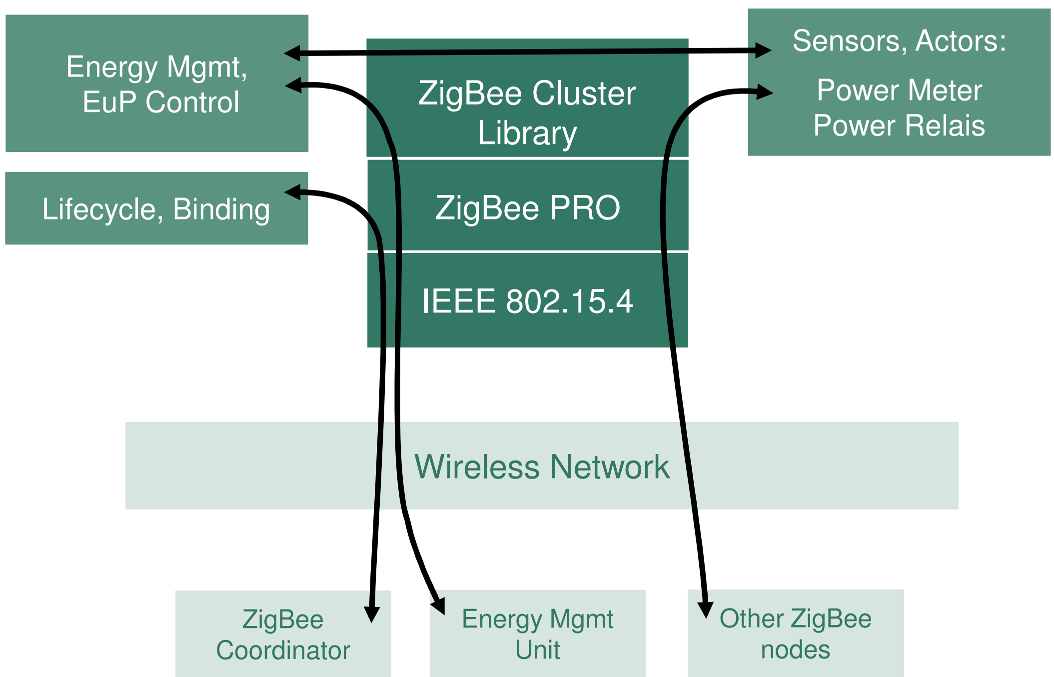
› Ecosystem, tools, commercially available devices
› Standard application protocols to build on
› Cryptographic building blocks to build on
› Network management (discovery & binding protocols)
› Straight forward to put data on the network (using discoverable standard protocols)

Cons:

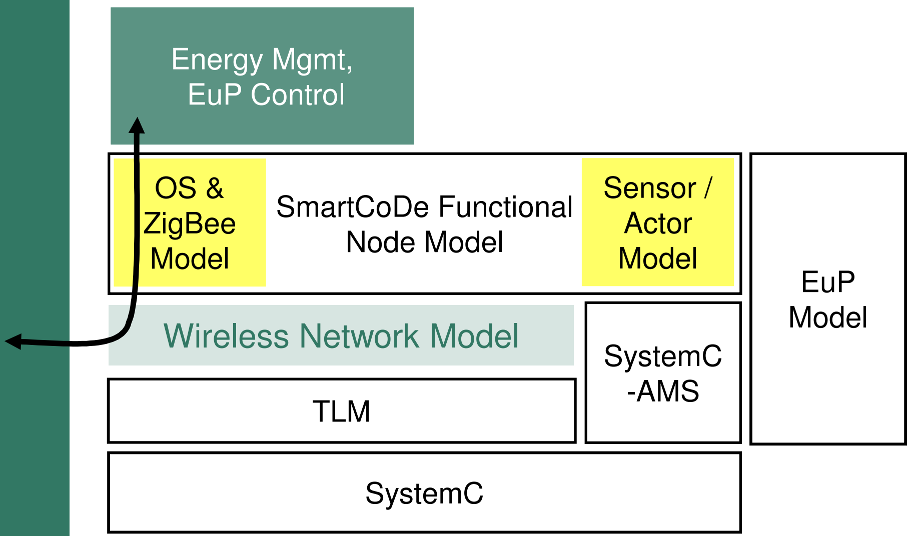
› Large and complex standard
› Hardware requirements (for routers)



# Software Overview



# SystemC Based Simulation Environment



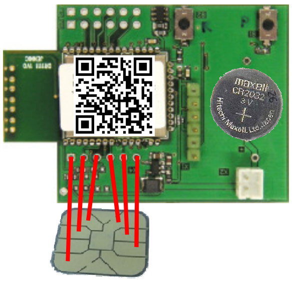

Simple porting between simulation environment and hardware



# Supported Data Services

| | Role | Clusters |
|---|---|---|
| **SmartCoDe Node** | Metering Device | Simple Metering (S) |
| | Mains Power Outlet | On/Off (S) |
| | Temperature Sensor Client | Temp. Measurement (C) |
| | Temperature Sensor | Temp. Measurement (S) |
| | SmartCoDe EuP | **SC Demand Control (C)** |
| | SmartCoDe Schedule UI Client | **SC Schedule (C)** |
| | | Time cluster (C) |
| **Temperature Sensor Node** | Temperature Sensor | Temp. Measurement (S) |
| **Schedule UI Node** | SmartCoDe Schedule UI | **SC Schedule (S)** |
| **SmartCoDe EMU Node** | SmartCoDe EMU | **SC Demand Control (S)** |
| | | Simple Metering (C) |
| | | Time cluster (S) |

# Advancing the State of the Art in Security




› Locally rooted chain of trust (no certification authorities)
› Efficient out of band key exchange
› Applicable to small and large networks

› Security chip (Infineon SLE77) optional
› Security chip improves tamper resilience



Thank you for your attention!

## Invited Paper:
## Sounds for Energy-Efficient Buildings
## A. Barona (Solintel)

### Abstract
The EU FP7 project "Sounds for Energy-Efficient Buildings" (S4EeB) will develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of “occupancy level’ in buildings and surroundings to enhance operations and eliminate unnecessary consumptions of energy for Heating, Ventilation, Air Conditioning, Lighting (HVACL), and other existent production and consumption systems, while maintaining users’ comfort. This will be achieved through the integration of a low-cost novel network of audio sensors with other building sensing and controls and the improvement of the strategies and algorithms of automation and conditioning deployed, calibrated and validated in two shopping malls and one international airport in real operational situation in order to demonstrate that energy savings and benefits justify the investment, providing new market solutions and supporting reduction of climate change.

SmartCoDe has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013]) under grant agreement n°247473

# S4EeB

Sounds for Energy Efficiency in Buildings

**SmartCode Workshop – Vienna, 12th October 2011**

Vladimir Vukovic, AIT; Stefan Goetze, Fraunhofer IDMT; Antonio Barona, Solintel
E-mail: antonio.barona@solintel.eu

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

CONSORTIUM

**COORDINATOR** Solintel

**PARTNERS** Fraunhofer IDMT, IMMS, D'APPOLONIA, AIT Austrian Institute of Technology, SEA Aeroporti di Milano, CÓRIO

Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of "occupancy level" in buildings

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

Solintel

## CONCEPT

Buildings account for 40% of energy end-use in the EU and 70% of this consumption is used for (**HVACL**) systems. Make them more efficient is key to achieve the goals of reducing $CO_2$ emissions by 20%, improving the energy efficiency by 20% by 2020.

The project **S4EeB** builds a simple and cheap ICT solution for Energy-efficient Buildings (EeB), integrating the **OCCUPANCY LEVEL** parameter, providing valuable information cheaply to the Digital Control Centre (**DCC**) for the creation of more Energy efficient Buildings (**EeB**) in **conditioning systems** without losing comfort or privacy of users.

Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of “occupancy level” in buildings

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

Solintel

## CONCEPT

The product, named **BEMO** optimizes the Energy Management system of buildings (BEM). It is composed of three main parts:

- **Audio and Sensors System:** Sensing and Listening.
- **Acoustic Processing Unit:**
  - Meaning and understanding through detection.
  - Discriminates the level of occupancy.
  - Learning through retraining process.
- **Web-Monitor:**
  - Integrating and monitoring parameters of occupancy level.
  - Optimizing strategies and algorithms.
  - Quantifying energy consumption savings.

Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of “occupancy level” in buildings

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

Solintel

## OBJECTIVES

S4EeB will include **low cost and energy-efficient audio and occupancy sensor** in public buildings and surroundings.

S4EeB will record and report:

- Operations of control and quantify the energy savings.
- Total cost of operation.
- CO2 footprint reduction.
- Benefits that accrue to calculate the ROI and pay-back of the investment.



# S4EeB

Solintel

## OBJECTIVES

The objective is to deliver the following marketable prototypes:

**1.Occupancy Monitor:** Acquire through microphones, audio and a central unit to process background sounds and noises and monitor the occupancy level in buildings and surrounding areas.

**2.Occupancy Sensor (all in one):** Acquire sounds and noises, process the raw audio data and transfer the signal to the central unit of the audio system, with a back line for its self retaining.

**3.Acoustic air/water flow metering:** A scalable modular air/water flow metre for HVAC systems to transfer via wireless the flows of conditioning conductions to the central unit of control and optimisation , with a back line for its self retaining.

**4.Central Audio Unit:** A central Acoustic Processing Unit (APU) working on LYNUX open-source software (OSS) for monitoring the types of occupancy and activities in the main areas of buildings and surroundings.

Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of "occupancy level" in buildings

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

Solintel

## OBJECTIVES

5. **BEM Optimiser (BEMO).** Connects to Building Energy Management. It is composed of:

   1. **Syncroniser module:** A BEMO prototype module for a synchronised monitoring of the following paramenters:
      1. Ocuppancy from APU.
      2. Conditioning for the BEM and/or sensing network.
      3. Generation/consumption subsystems.
      4. Automation systems.

      2. **Optimiser module:** A BEMO module for modelling simulation, quantification and optimisation of the BEM strategies and algorithms to reduce the amounts of energy consumed for conditioning and lighting, generation plants and other existent energy systems in the building.



# S4EeB

Solintel

## OBJECTIVES

3. **Messaging Module:**
   1. **Informing**
   2. **Reporting**
   3. **Alerting**
   4. **Alarming**

   4. **Learning Module:** A BEMO module for progressive and semi-automatic self-learning:

      1. AED algorithms
   2. Decision tools and risk management layer of the sounds system.
   3. Optimisation of BEM.
   4. Logical layer for provision of profitable interoperable services of maintenance, control and security without losing comfortability of users.

Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of "occupancy level" in buildings

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

Solintel

## OBJECTIVES

6. **Manual for use, installation, integration and set-up.**

7. **Operative Demonstrators**. In three fully operative buildings:
   - ✓ PRINCIPE PIO shopping mall in Madrid.
   - ✓ MAREMAGNUM shopping mall in Barcelona.
   - ✓ LINATE international airport in Milan.



# S4EeB

Solintel

## EXPECTED IMPACTS

- World-wide innovative ICT for EeB solution
- Savings of 5-10% in energy consumption and cost.
- Reduction of $CO_2$ emissions in 2-4% in Spain or 3.75-7.5% in Italy, approximately.
- 5% reduction of cost in maintaining, repairing conditioning systems fails and malfunctions.
- Controlling and management of public buildings.
- Payback period of less than one year in public buildings

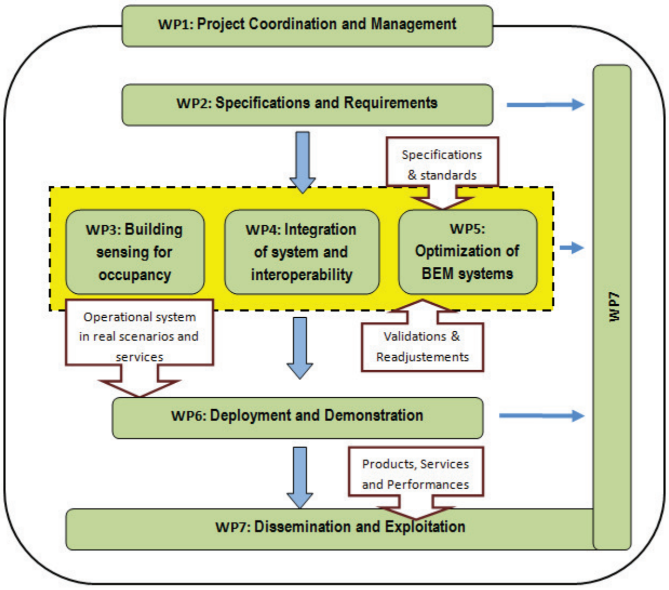
Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of "occupancy level" in buildings

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

Solintel

## STRUCTURE



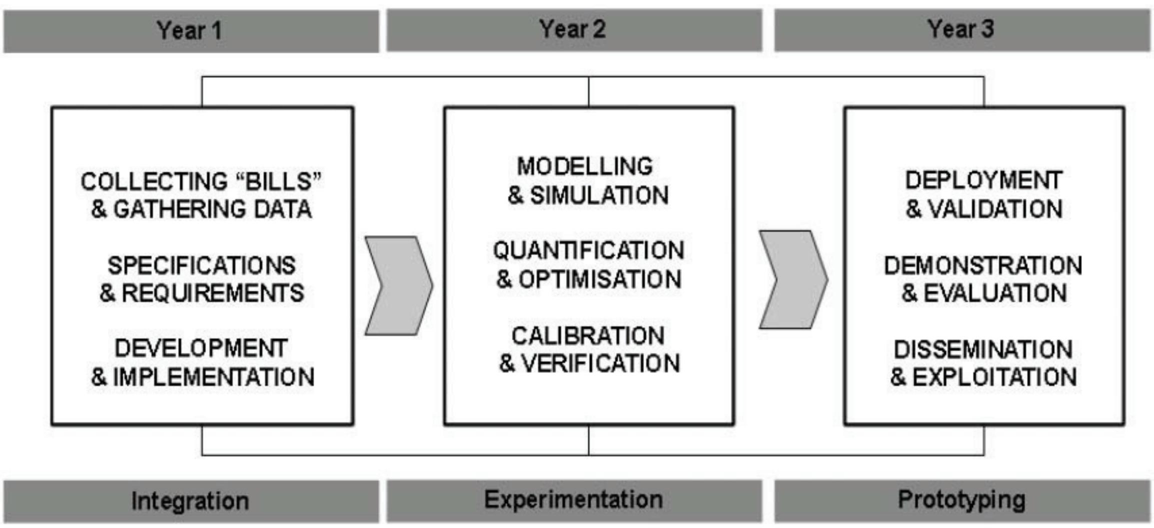

Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of "occupancy level" in buildings

SEVENTH FRAMEWORK PROGRAMME

# S4EeB

Solintel

## ANNUAL STAGES OF PROJECT´S WORK PLAN




Develop and deliver a prototype to optimize the existent Building Management Systems (BMS) by means of acquiring, identifying, monitoring, and adding the parameter of "occupancy level" in buildings

SEVENTH FRAMEWORK PROGRAMME

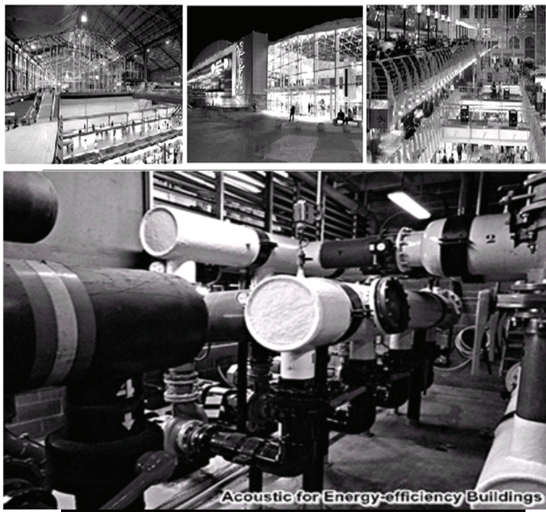
# EU Projekt: Sounds4Energy-efficientBuildings

## Goal

- Energy savings by means of acoustic scene analysis
  - Obtain parameter „ocupancy“. How many persons are doing what in buildings?
  - Use obtained information to manage HACV systems

## Acoustic Technologies

- Acoustic position estimation and tracking / spatial filtering
- Acoustic Event Detection and Classification
- Semi-automatc learning algorithms

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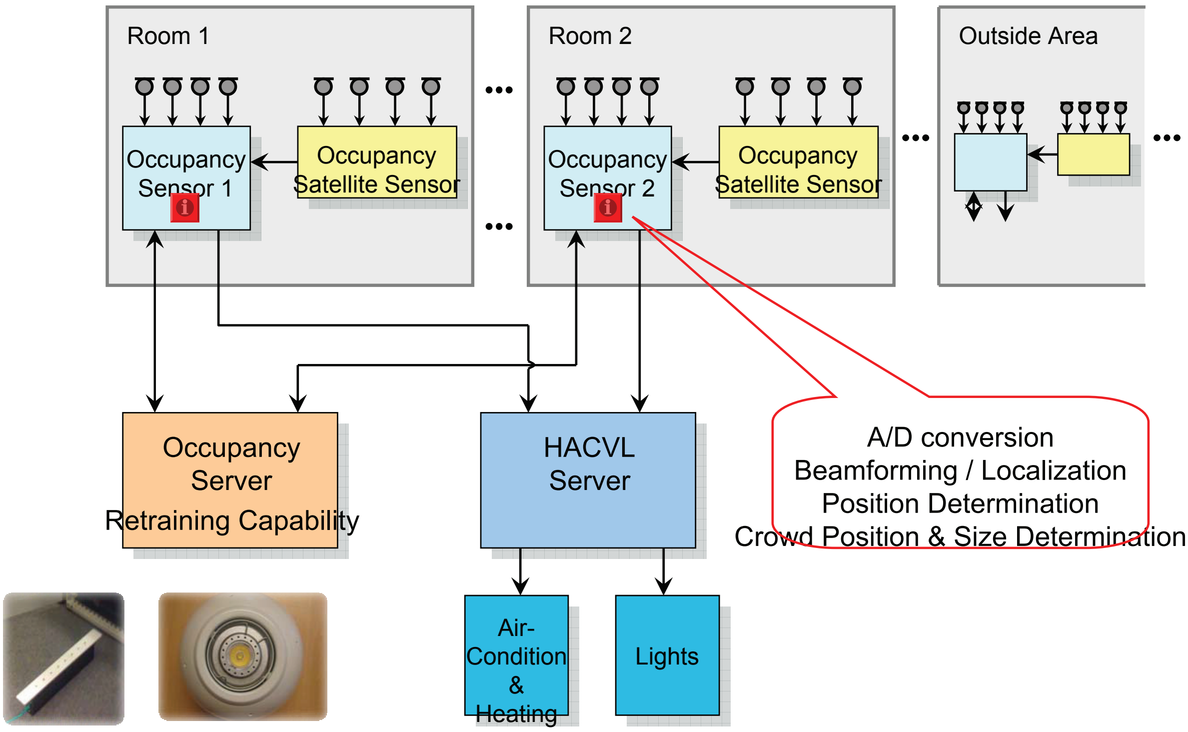
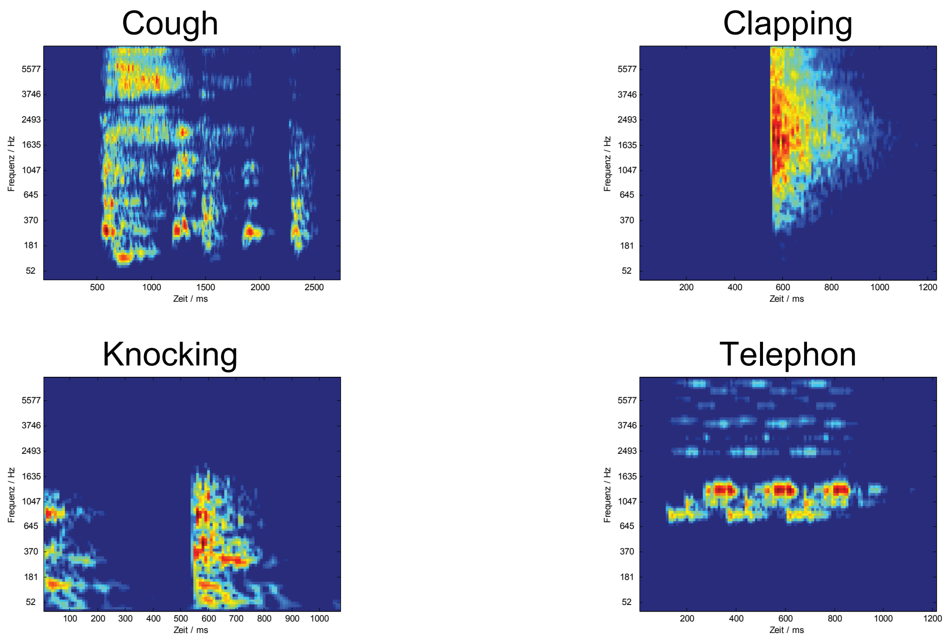
# Acoustic Sensing in S4EeB

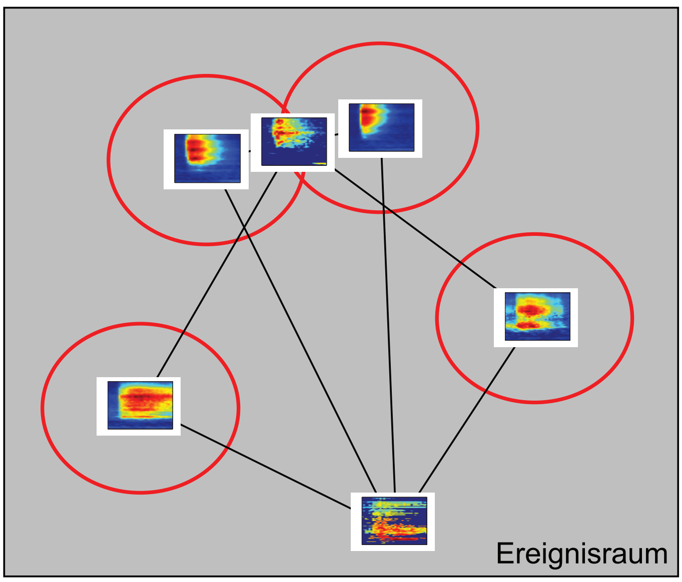


## Acoustic Event Detection and Classification

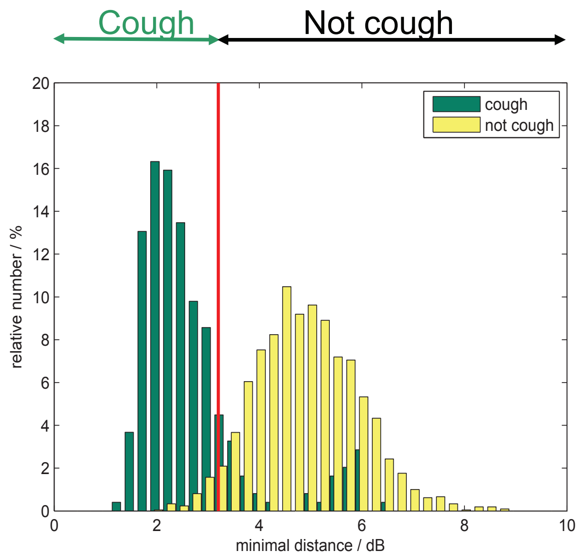



## Cough Detection – A simple classifier

- Simple classifier: Self-Organizing Map (SOM)
- Distance comparison to previously trained models

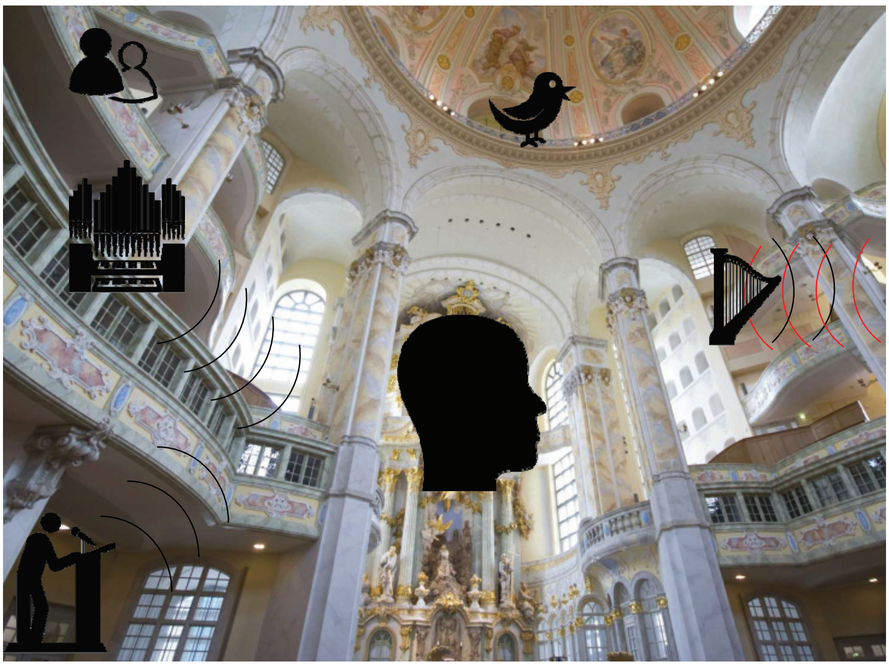


## Classifier Performance




- > 80 % correct hit rate for classification of coughs
- ~ 97% of all non-cough events correctly classified

## Acoustical challenge




Contacts
Vladimir Vukovic, AIT; Stefan Goetze, Fraunhofer IDMT; Antonio Barona, Solintel
E-mail: antonio.barona@solintel.eu

# The SmartCoDe Demonstrator - a testbed to evaluate energy management

Authors: Veljko Malbasa and Roland Kopetzky
Date: October 20, 2011
Dissemination Level: Confidential

## Summary of demonstrator

Objective:

- Set up a demonstrator including „living lab“, together with a local energy generator,
- Demonstrate the Project outcome to a broad community.

Experience to be gained:

- Usability of the approach in a „real world scenario“,
- Dependability of communication between nodes in wireless network,
- Validation of models and simulation results.

## Contacts

Veljko Malbasa

Professor of Computer Engineering

Faculty of Technical Sciences, University of Novi Sad, Serbia

Email: *malbasa@uns.ac.rs*

Roland Kopetzky

Dr.-Ing, CEO of ennovatis

ennovatis, Dechwitzer Str. 11, D-04463 Großpösna

Email: *r.kopetzky@ennovatis.de*



## Outline

Goals and objectives of demonstrator

Demonstrator location and structure

Calculation of energy savings

Assessment of project impact

Conclusions

## Goals and objectives

Show the outcome of the project to a broad community.

Get practical experience on the usability of the approach in a “real-world scenario” that embraces regenerative energies (wind turbine, solar panel), energy using products and local energy management.

Evaluate the outcomes under realistic conditions.

Prove that all the theoretical assumptions and models produced in SmartCoDe are correct.

Provide a feedback to the models developed so that real-world data can be integrated to finalize the models.

Show to the public that the concept and implementation of SmartCoDe is feasible and thus provide a proof that the budgets of the project are spent for the benefit of the society.



## Specific technical objectives

Prove that SmartCoDe methods for automated energy management are efficient.

Show the benefits of SmartCoDe high resolution energy management.

Show the communication and remote control of EuPs using the SmartCoDe devices.

Demonstrate technical and economic feasibility and benefit of SmartCoDe intelligent energy management.

Quantify possible energy savings due to:

- Classical energy management,
- High resolution energy management,
- Coordination of supply systems,
- Coordination of energy using products, and
- Reduction of peak load.

## Demonstrator location: Buchberg, Austria

Buchberg location includes a building used as restaurant as well as home for a family of five. The building is equipped with a small wind turbine, energy using products and energy management system.

Almersberg site is in addition, it is close to Buchberg and already has some of the needed equipment available.



## Demonstrator structure: Buchberg site

Step 1: Technical Overview – „Consumption Model“

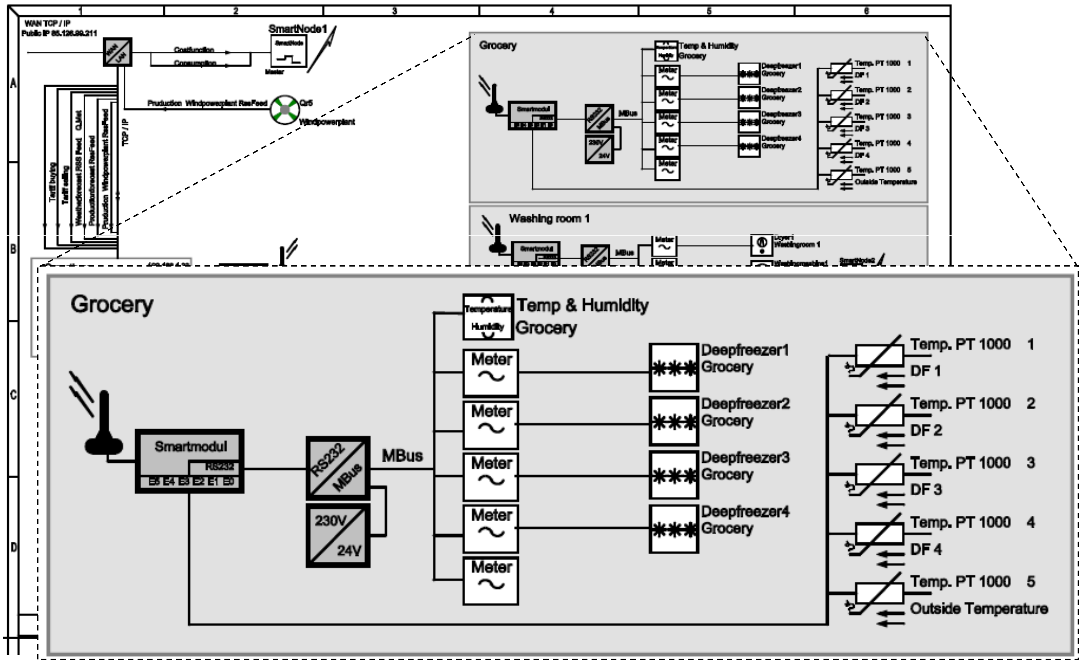
| | Number | Power | Usage Hours | Consumption | Consumption | estimations |
|---|---|---|---|---|---|---|
| **Deepfreezer: summery** | 4 | 0,86 | 3671 | 3.157 | 5,3% | 12 month/a 24 hours/d in use |
| *Whirlpool AFG 6512G* | 1 | 0,2 | 2281 | 456 | 0,8% | *DF1 / 1,25 kWh p d / 503l est: 0,2kW* |
| *Austria Haustechnik GTX 47SS* | 1 | 0,22 | 4480 | 986 | 1,6% | *DF2 / 2,70 kWh p d / 386l* |
| *AHT CC400 Type 807 Eskimo* | 1 | 0,3 | 3772 | 1132 | 1,9% | *DF3 / 3,10 kWh p d / 364l* |
| *Elin GTL 0191* | 1 | 0,14 | 4171 | 584 | 1,0% | *DF4 / 1,60 kWh p d / 180l (est: 1,6 kWh pd)* |
| Washingmashine BSH WM16S750 | 1 | 2,30 | 209 | 480 | 0,8% | estimation 300 washings a 1,6 kWh |
| Washingmashine Miele Meteor 1000 | 1 | 2,40 | 213 | 510 | 0,9% | estimation 300 washings a 1,7 kWh |
| Dryer BSH WDT60 | 1 | 1,50 | 160 | 240 | 0,4% | estimation 150 dryings a 1,6 kWh |
| Dryer Electrolux EDC 5310 | 1 | 4,37 | 150 | 656 | 1,1% | estimation 150 dryings a 4,37 kWh |
| Oven BSH HTSHBP7 | 1 | 3,70 | 81 | 300 | 0,5% | estimation 500 preparations a 0,6 kWh |
| Cooling room | 1 | 0,08 | 8760 | 394 | 0,7% | est. 12 month/a 24 hours/d 60% on duty |
| Restaurant | 1 | 6,00 | 5368 | 32.208 | 53,7% | est. 11 month/a 16 hours/d in use |
| Sigthseeing tower | 1 | 1,80 | 8760 | 15.768 | 26,3% | 12 month/a 24 hours/d est 1,8kW in use |
| Houshold | 1 | 0,50 | 8760 | 4.380 | 7,3% | 12 month/a 24 hours/d est 0,5kW in use |

The analysis helps to understand, which devices and consumers have what part in all over power consumption at the demonstrator.

It is a kind of „consumption model“ which has to be changed according to the detailed results of the measurement.

# Demonstrator structure: Buchberg site

Step 2: Measurement Concept






# Demonstrator structure: Buchberg site

Energy Management Unit (EMU)

- built in and operative
- connected to the router
- connection to smart module tested

Grocery

- power and temperature measurement in four deep freezers
- room temperature and –humidity are measured
- outside temperature is measured

Washing Room 2 (toilette)

- power measurement for washing machine
- power measurement for dryer
- room temperature measured

## Demonstrator structure: Buchberg site

Main Electrical Distribution

- measurement of the main power meter (EVU)
- power measurement for sightseeing tower
- power measurement for cooling room
- power measurement for restaurant
- power measurement for oven
- power measurement for dryer
- power measurement for washing machine (1st floor)
- room temperature restaurant measured

Wind Power Plant

- connected to the router



## Demonstrator structure: Buchberg site

Step 3: Optimisation Concept

The concept consists of
Energy Management Unit (EMU)

- SmartGridSwitch – simple device for testing user interaction
- SmartCodeNodes – advanced intelligent devices

# Demonstrator structure: Buchberg site



The washing machine in the 1st floor is connected to the SmartGridSwitch with following functions:

- Input one starts the machine immediately.
- Input two: The machine should start within 4 hours.
- Inputs three: The machine should be ready within in the next 12 hours and
- Input four deletes the request.



# Demonstrator structure: Buchberg site

The following devices will be connected with a SmartCoDeNode:

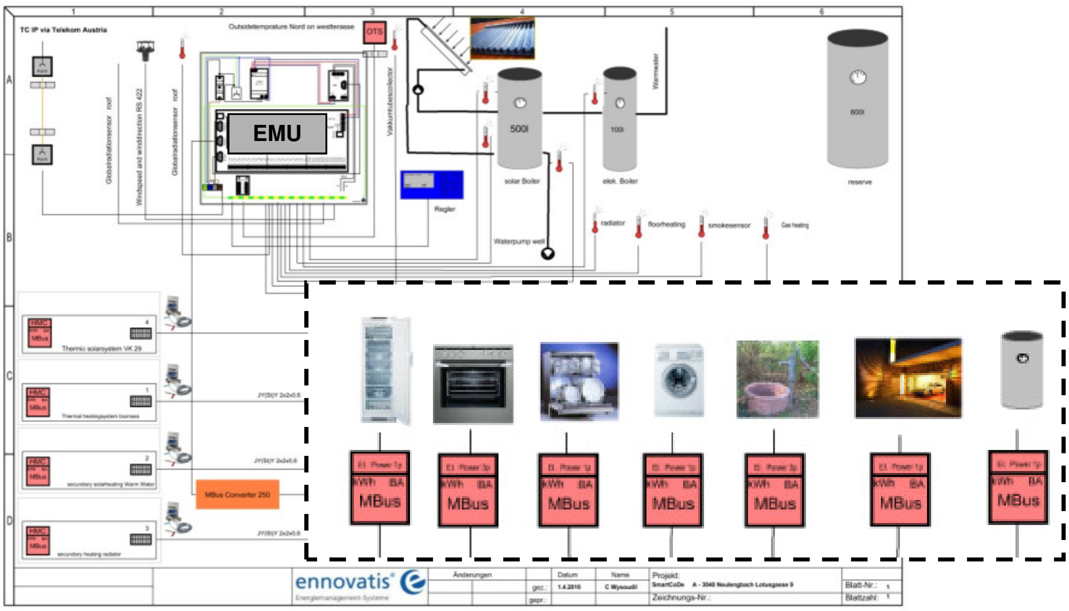
- 4 refrigerators at the grocery
- Washing machine 1 at the Washing Room 1
- Oven 1 at the Restaurant
- Dryer 2 at the Washing Room 2
- Open: Cooling Room
- Open: Automate at the Sightseeing Tower

# Almersberg location



# Demonstrator structure: Almersberg site

Measuring Concept



## Analysis of the measured data

**Demonstrator will be used to:**

- Calculate energy production by local energy production (wind generator and photovoltaic),
- Calculate energy consumption by local energy using products,
- Calculate energy savings compared to the pre-demonstrator energy consumption at the demonstrator site.

**Quantification of possible energy savings due to:**

- classical energy management,
- high resolution energy management,
- coordination of supply systems,
- coordination of energy using products, and
- reduction of peak load.



## Steps to determine energy savings at demonstrator

1. Measure, collect and record baseline data.
2. Install and test the components and the demonstrator as a whole and verify that the demonstrator installation works properly (commissioning).
3. Measure and collect energy and operating data after the demonstrator is installed in a systematic way which is consistent with the baseline period.
4. Calculate the energy savings, report and present all the collected and computed data in a way which is suitable to demonstrate the effect of the demonstrator on the energy savings.

## Calculation of energy savings

The methods which will be used to calculate energy savings are based on the IPVMP protocol (document: „*International Performance Measurement & Verification Protocol (IPMVP*)“, March 2002, www.ipmvp.org.).

Energy saving is the difference among the consumption according to the energy efficiency measures (EEM) and measured during the reporting period and the consumption prior the implantation (baseline period).

Consumption is influenced by different variables like weather, usage or occupancies. It is necessary to have consumption and conditions data prior the implantation of EEM in similar conditions as after the EEM. Also it is necessary to make suitable adjustments for changes in conditions and independent variables.



## Assessment of project impact

The goal of the SmartCoDe project is to provide a solution which will allow manufacturers of energy using products to:

- add energy management functionality,
- with additional features such as remote control, safety and security,
- for very little additional cost,
- and thus enable local entities to participate in the energy market as an intelligent, managed “sub-grid” that can even contribute to a demand side management.

How do we evaluate and assess the overall impact of the project?

## Economic feasibility

To assess the economic feasibility of the project we will address several aspects:

- What costs are involved for the different kind of groups (user, equipment provider, energy provider),
- How can invested cost be refund for the different kinds of groups, for example lesser energy costs, market penetration, lesser net load (i.e. lesser peaks probably mean that the maximum net load with which nets are built can be reduced),
- What actually are the benefits apart from energy cost reduction, for example what are community benefits as related to the $CO_2$ reduction.



## Economic feasibility (continued)

We will compare the baseline data with the data collected during the demonstrator operation at the two demonstrator locations, and calculate energy savings due to the local energy production and intelligent energy management.

Energy cost savings will be classified as relative to:

- Cost reduction for buying energy from a third party (for example, the public grid),
- Load reduction for energy out of the public grid,
- Peak load reduction for energy out of the public grid,

## Applicability and usability issues

We will have an external reviewer inputs to prepare, conduct and analyse the applicability and usability of the SmartCoDe solution.

The analysis will be based on monitoring the behaviour of the inhabitants of demonstrator locations to get an understanding how they used the demonstrator equipment and if they are using the suggested methods in an appropriate way.



## Conclusions

We presented SmartCoDe demonstrator concept and structure, as well as how we will use the demonstrator to evaluate energy savings and assess the impact of the project.

Demonstrator is installed at Buchberg, with additional site at Almersberg, both near Vienna, Austria, with wind turbine, photovoltaic panel, energy using products, measurement sensors and SmartCoDe nodes, energy management system in place, and the web site showing the relevant demonstrator data.

In the forthcoming period we plan to use demonstrator to collect data which will be needed for calculation of energy production, consumption and savings.

# SmartCoDe System-in-Package (SiP) Considerations

**SmartCoDe Expert Cooperation Workshop**
**Vienna/Austria 2011-10-12**

Thomas Herndl (Presenter) – IFAT DCGR CRE
Wolfgang Scherr - IFAT DC ATV SC D VI CE
Mario Motz - IFAT DC ATV SC D VI INNO
Josef Haid – IFAT DCGR CCS M
Infineon Technologies Austria AG

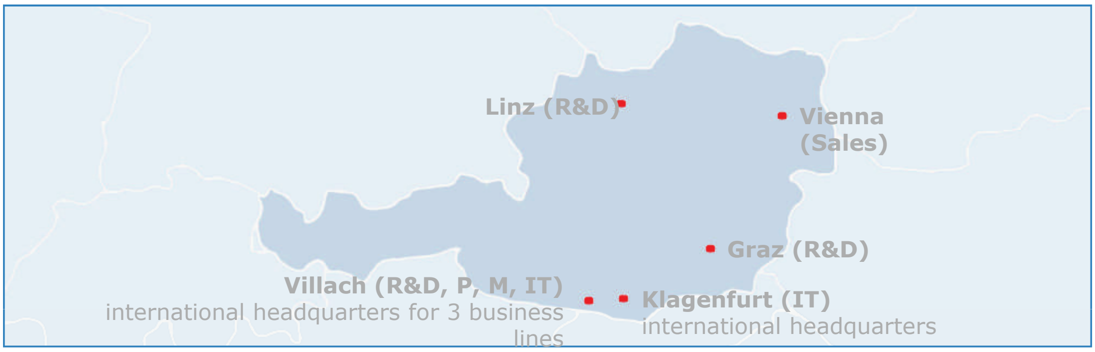
## Content

# Introduction & Scope



## Infineon Austria – Company Overview

### Infineon Technologies Austria AG incl. subsidiaries



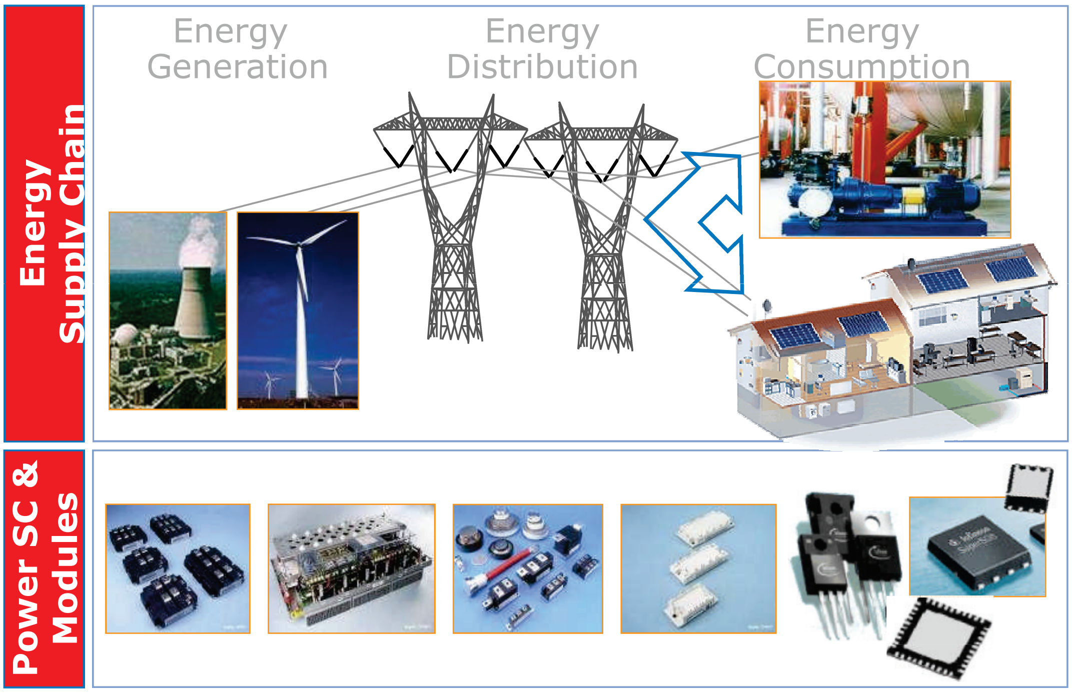


foreign subsidiaries: **Kulim** (Malaysia) **Bucharest** (Romania)

# Environmental Sustainability at Infineon

## Enabling a Sustainable Society: Our Products

**IFX provides products and solutions for the whole energy value chain**

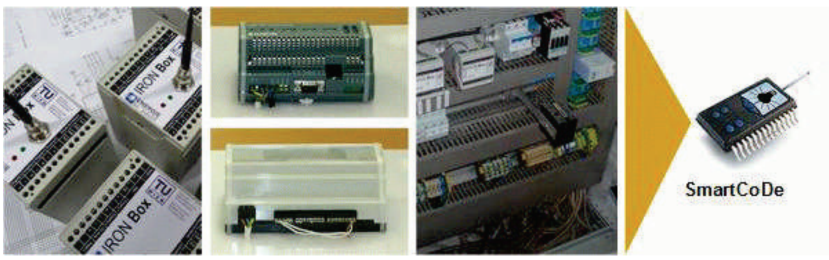





# …Now Going Further to the Energy CONTROL Level

## SmartCoDe Target Module

› Miniaturized wireless networked smart device for power metering and control of energy using products at low costs
  - **Lighting units**
  - **(Home-) appliances**
  - **Intelligent power plug**
  - …

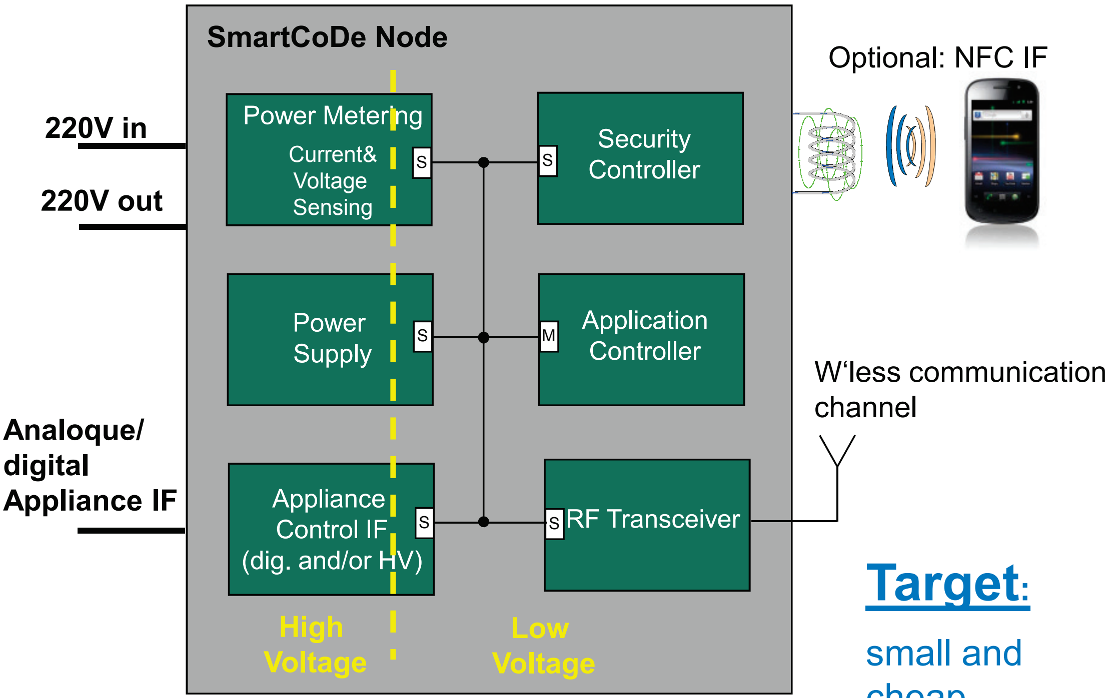


# Application cases to be considered

- Lighting units (**LED**, neon lamps, halogen lamps, bulb, …)
- Appliances control (e.g. fridge, washing machine, ..; with digital or analogue interface)
- Intelligent power plug (Power plug control & metering)
- Smart Metering only (measure, store and report metering information)
- Sensors (temperature, humidity, presence, light level,…)
- Master- resp. Gateway Node (need to also perform SW-centric network management tasks, key management,…)
- ….



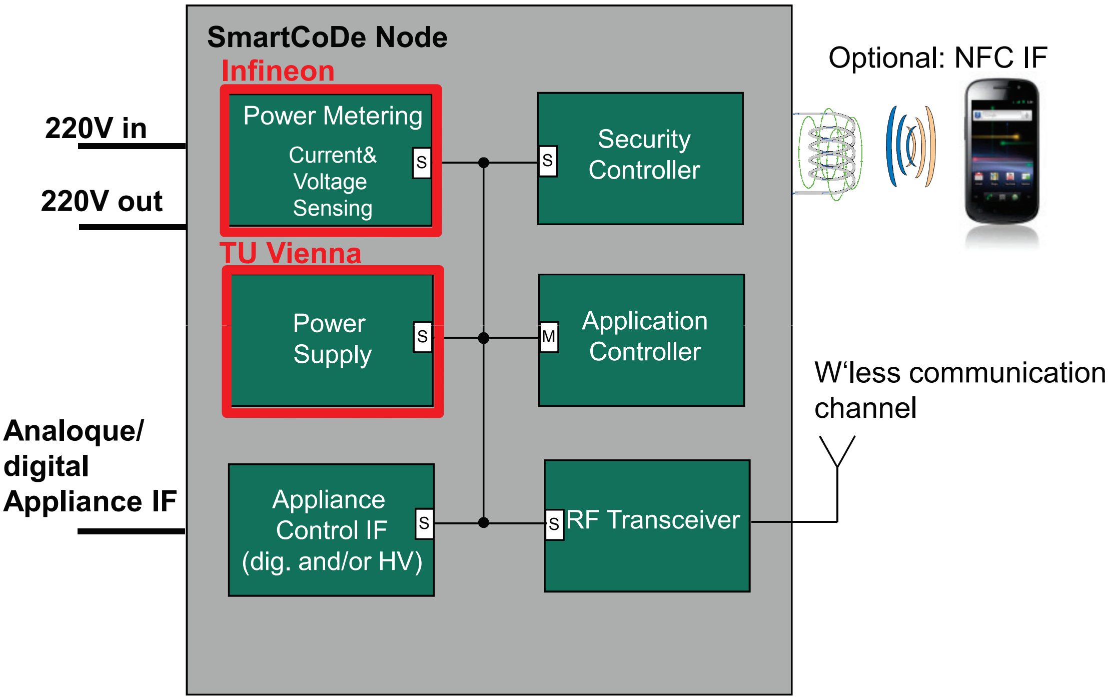
# Basic Functional Blocks of a full functional SmartCoDe Node




**Target:**

small and cheap

# Key Components developed throughout SmartCoDe



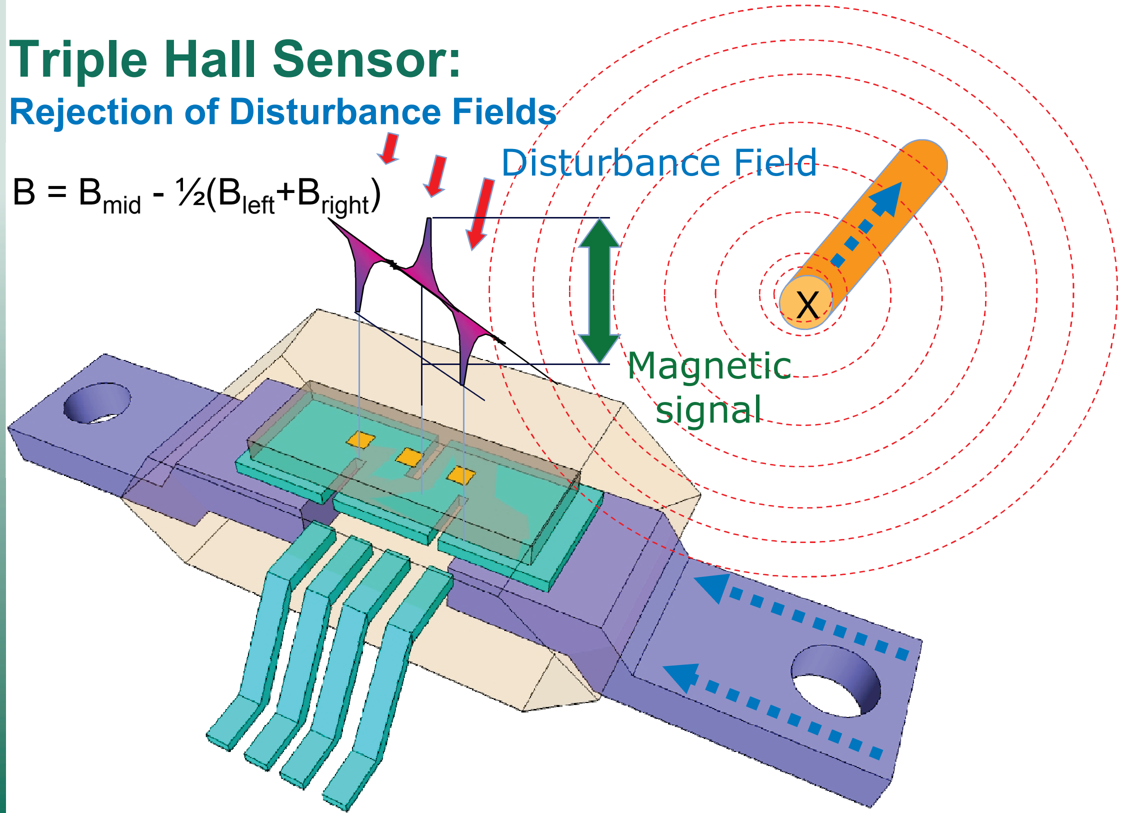



# Key element: Current (Power) sensing

# Triple Hall Sensor:

## Rejection of Disturbance Fields

$$B = B_{mid} - \tfrac{1}{2}(B_{left}+B_{right})$$



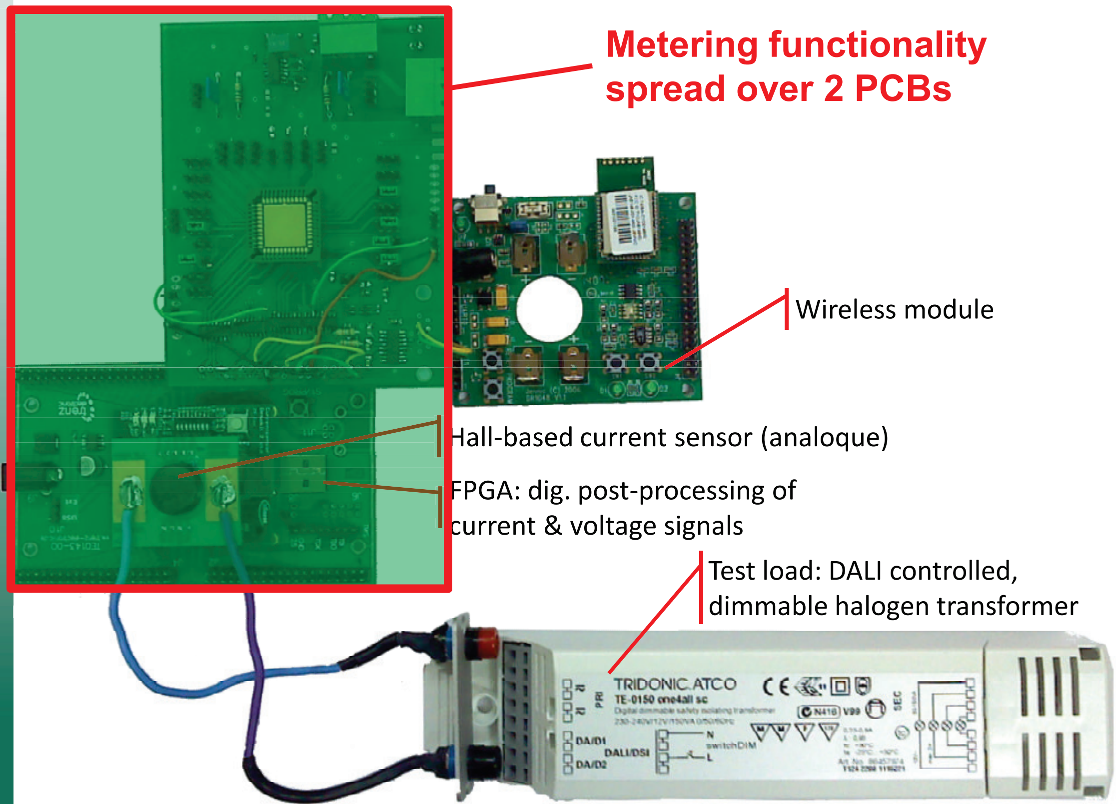

# Dual Hall Sensor:

## Differential principle

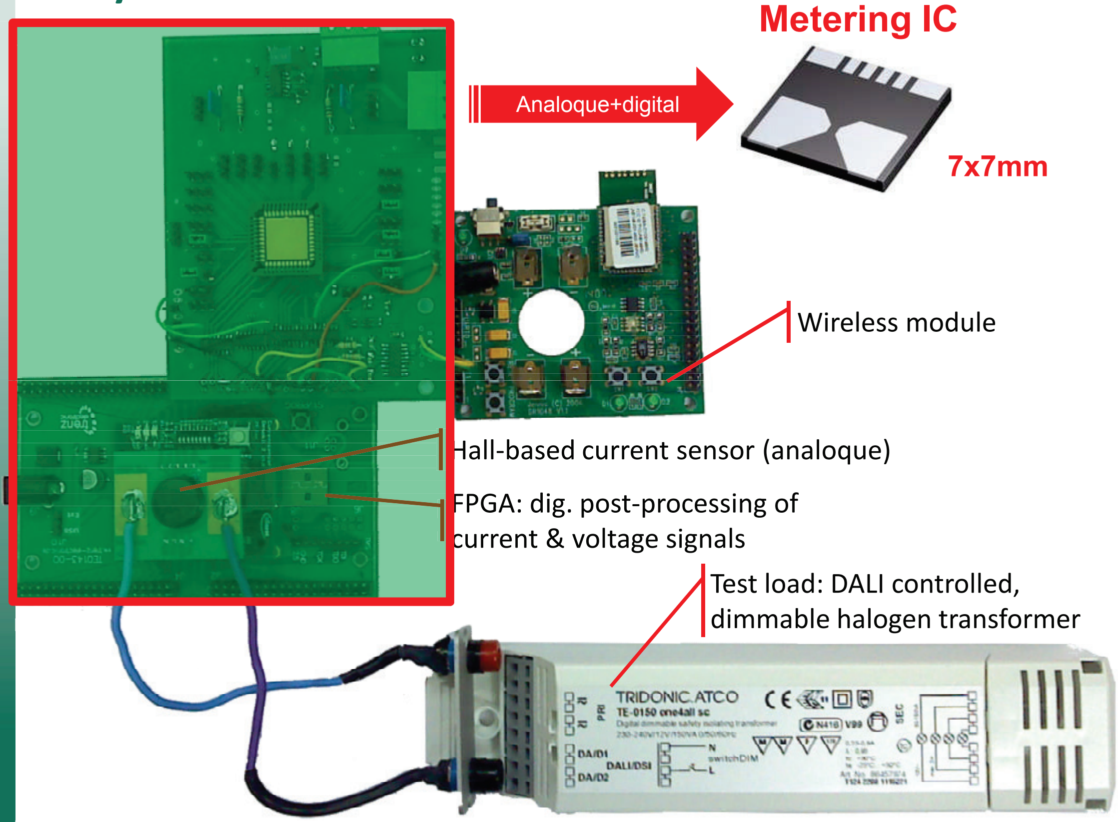
$$B = B_{left}-B_{right}$$



# 1. First functional Demonstrator (year 1)



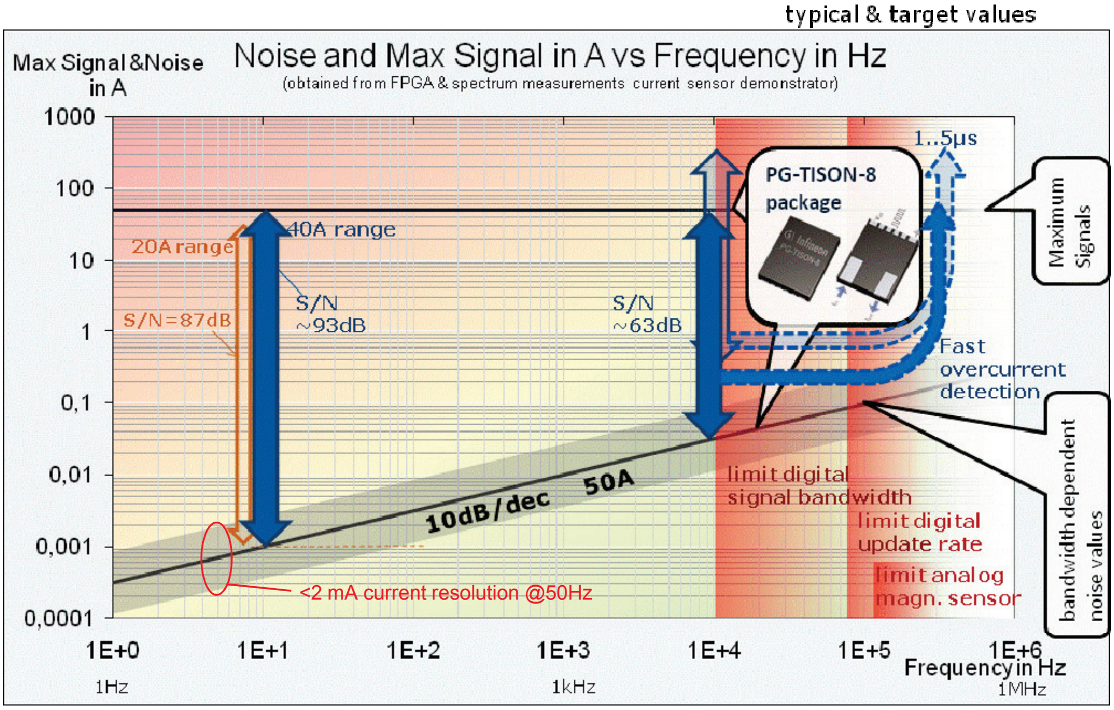
# Metering Sensor: First fully integrated samples now ready for test






# Noise & Dynamic Range of Current Sensor Section

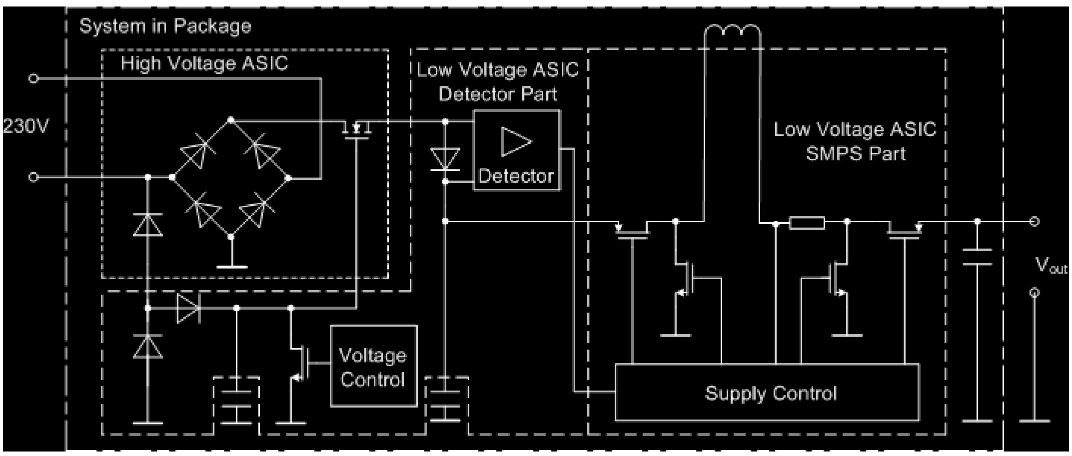
typical & target values



# Power Supply



# SmartCoDe Power Supply
# SMPS based, with detector and capacitive startup



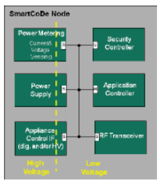

- No clumsy components
- Low count of external passives
- High efficiency

Development ongoing

# Discussion: Partitioning SiP/SoC

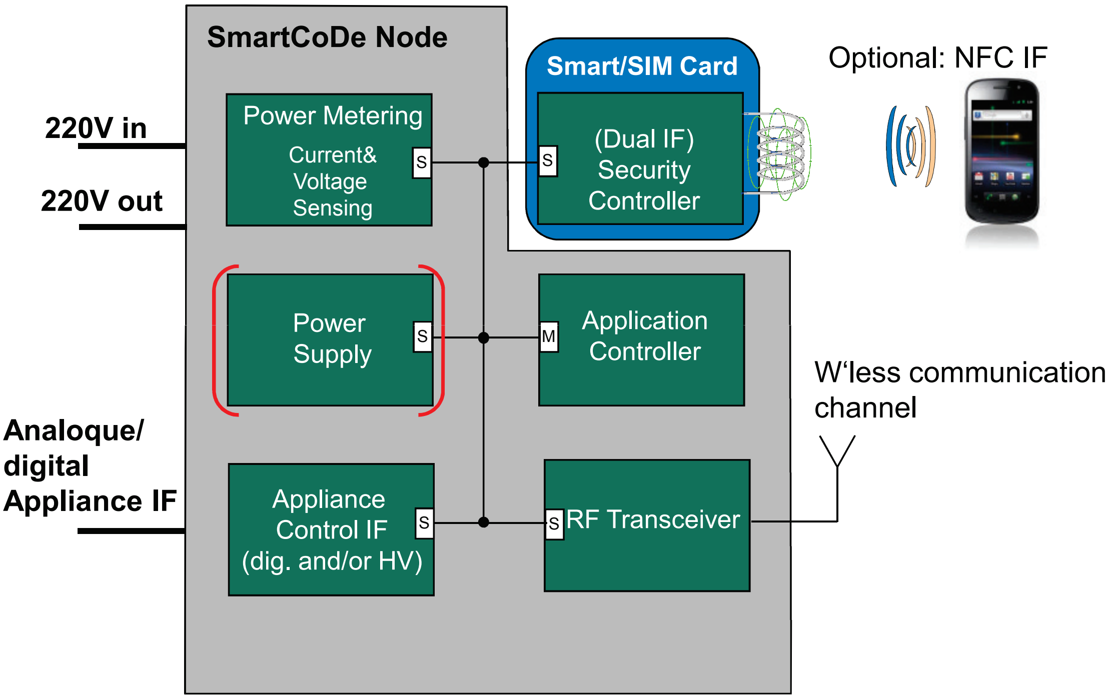


## SoC or SiP ?



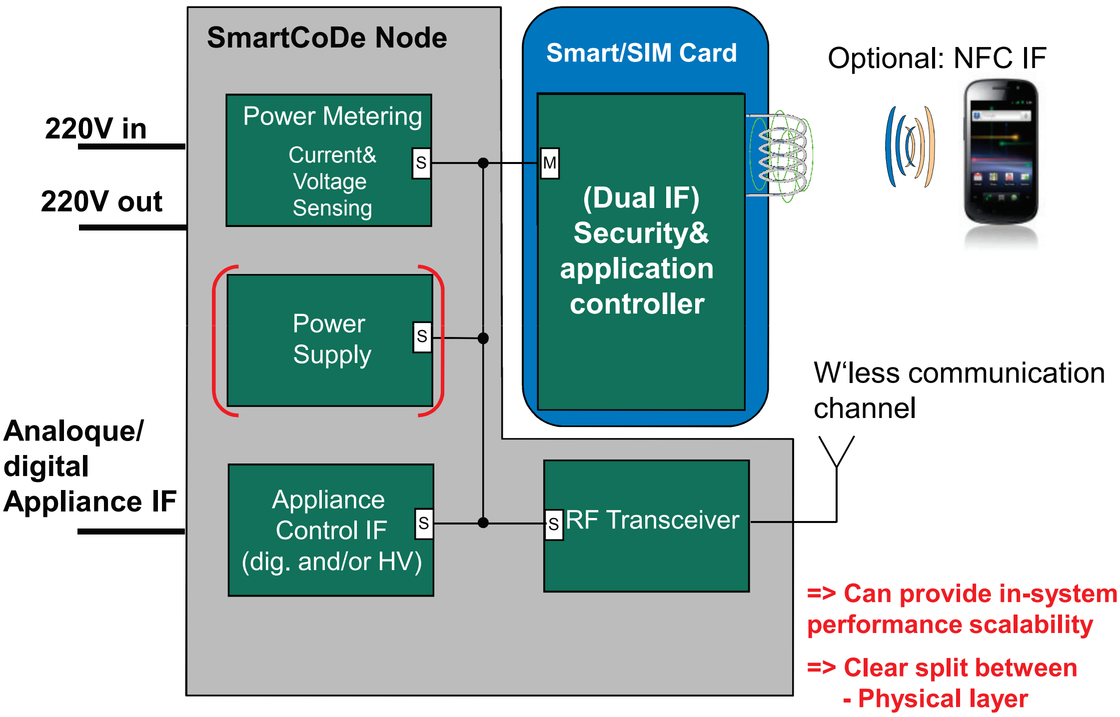

- SoC:
  - Integrating CMOS technologies can implement almost all functions on single chip, with some external passives
  - Optimize chip-area, reduce assembly- and logistic costs
  - Pays off only for highest volume
  - Could be long term target once standardizing issues are clearly settled
- SiP:
  - Can use different, “best fitting” semiconductor technologies and specific process optimizations
  - Due to low number of component-I/Os and interconnects in a SmartCoDe node this does not add significant costs:
    - **no multi-layer substrates/PCBs required**
    - **Could apply cheap sub-packaging**
      - **e.g. SMD only to make use of homogeneous assembly line**
      - **cope with heterogeneous reliability/hermeticity requirements**
    - **low risk of yield drop**
  - Mid-term target: chip embedding/eWLP => keep value chain in wafer fab
    - **paves the way towards a true integration of frontend- and backend-processes. It streamlines the manufacturing process undergone by a highly heterogeneously integrated device, like a SmartCoDe module, from silicon start over assembly, packaging, testing and shipment.**

# SmartCoDe Partitioning Option 1





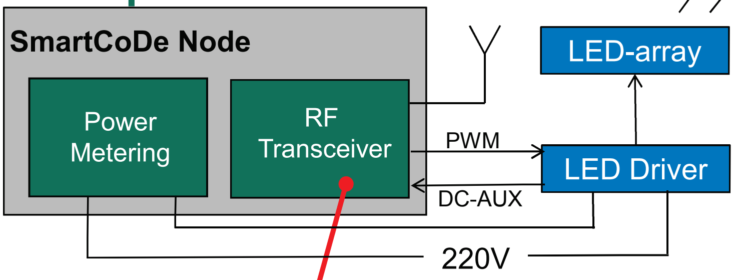

# SmartCoDe Partitioning Option 2




=> Can provide in-system performance scalability

=> Clear split between
- Physical layer
- Abstract layer / computing platform

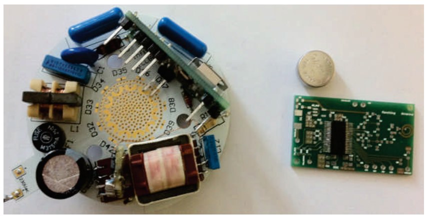
# Example of a „minimum“ system configuration: LED Lamp control




Infineon Smart TRX (prototype from EU funded project. „CHOSeN“):
includes RF-FE, BB, AES crypto acceleration, programmable
iSM for MAC-acceleration & simple protocols/applications

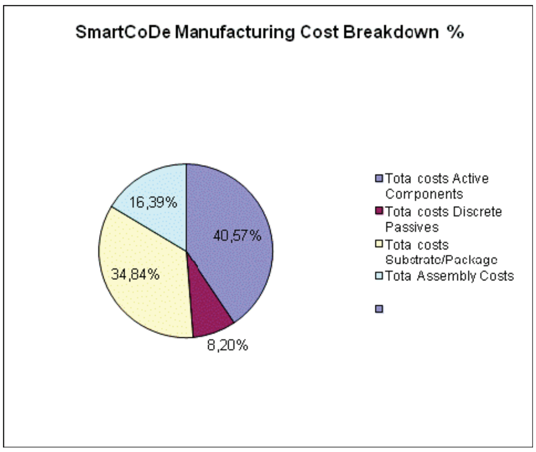
⇒ not all applications might require all functional units

⇒ due to the high number of light sources in buildings a highly optimized approach is particularly interesting

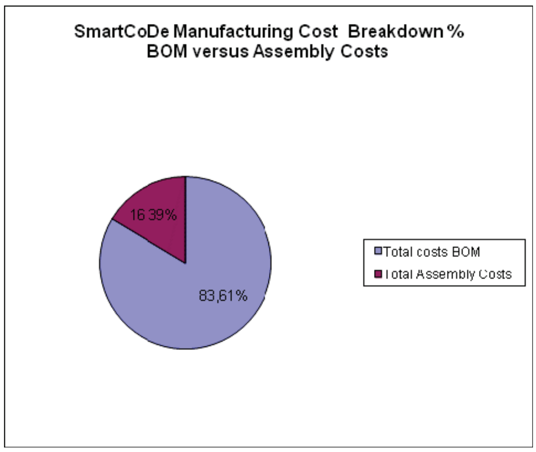




# Initial SmartCoDe HW Node Cost Indications




- Total costs: < 5€ possible (based on full functional node)
- Lower costs possible if not all functions are required or when striving for higher single chip integration (costs are BOM dominated)



## Possible Cost Optimizations

- Costs dominated by
  - **active components**
  - **substrate/packaging**
- Means for Optimization
  - **cost drop over the years**
    particularly for eWLP once mature, homogeneous Frontend/Backend fabs are set in place
  - **higher single chip integration (of heterogeneous functions; e.g. usage of CMOS integration technologies)**
  - **tailoring/optimization to specific (killer-niche) application**
  - **digitally intensive approaches (digital logic shrinks best)**
  - **different feature variants (w/wo security, power supply, metering)**



SmartCoDe An affordable technology for everyone…

Tent lights off !

Thank you for your attention…

**Never stop thinking**