

Smart Cities Infrastructures

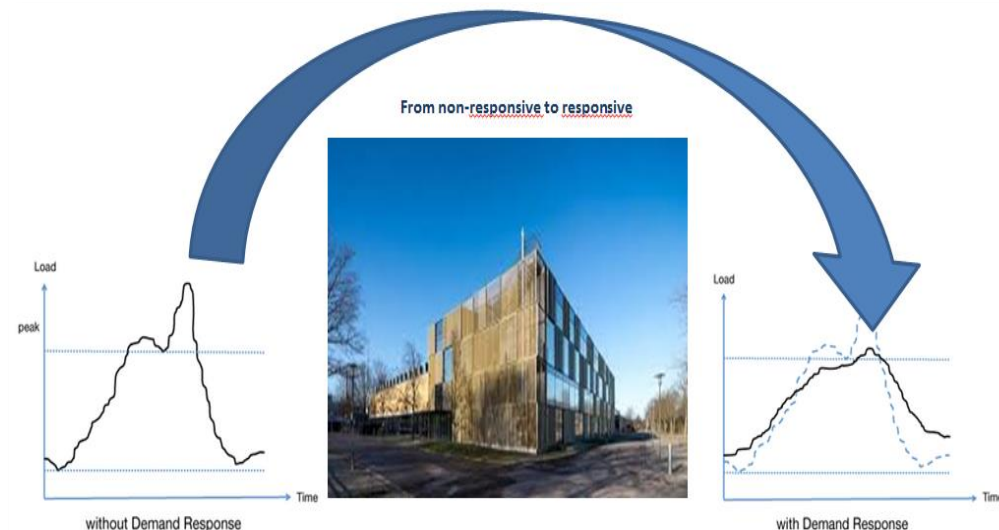
Some glimpse on or research

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With help from:

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DTU Management Engineering

Henrik Madsen
DTU Compute



Cloud'en



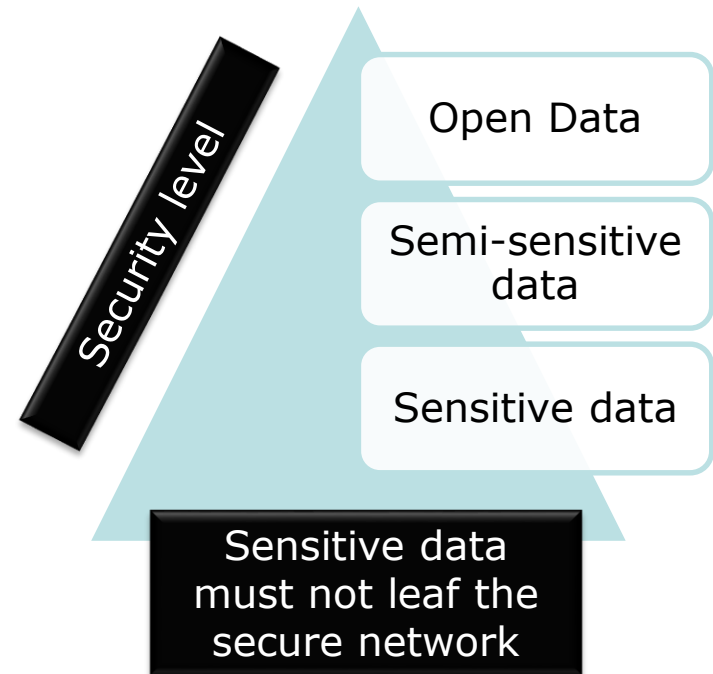
CITIES
Centre for IT Intelligent Energy Systems

Demand for Data Services

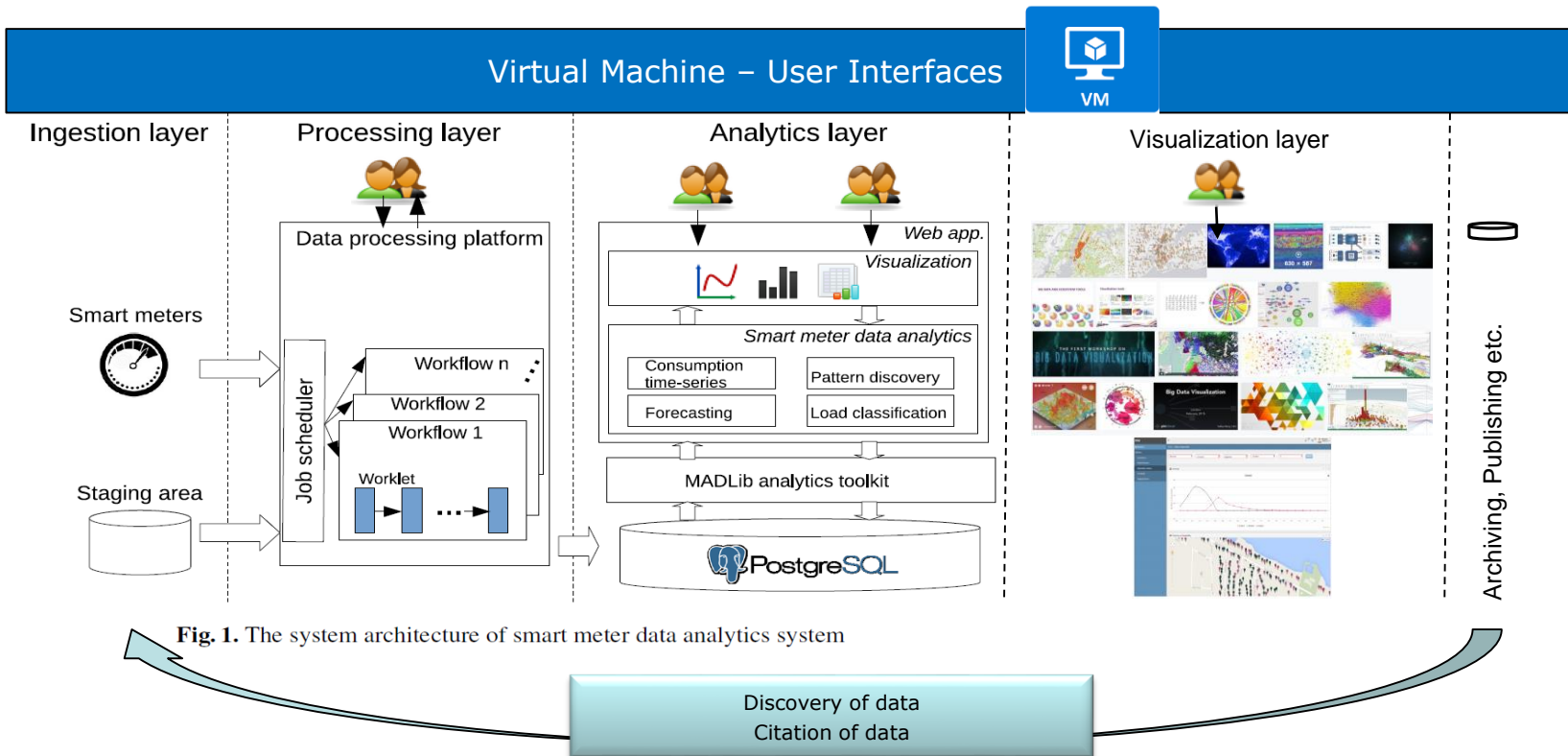
Data
Storage



Computer
Power



CITIES Data Management System



Source: Streamlining Smart Meter Data Analytics (2015) Xiufeng Liu and Per Sieverts Nielsen, DTU (adjusted by Alfred Heller).



Analytics Layer

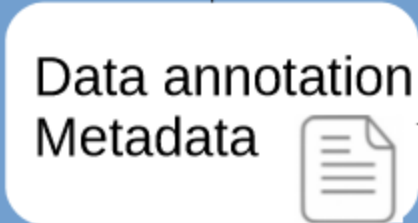
*Analytics
Visualization*



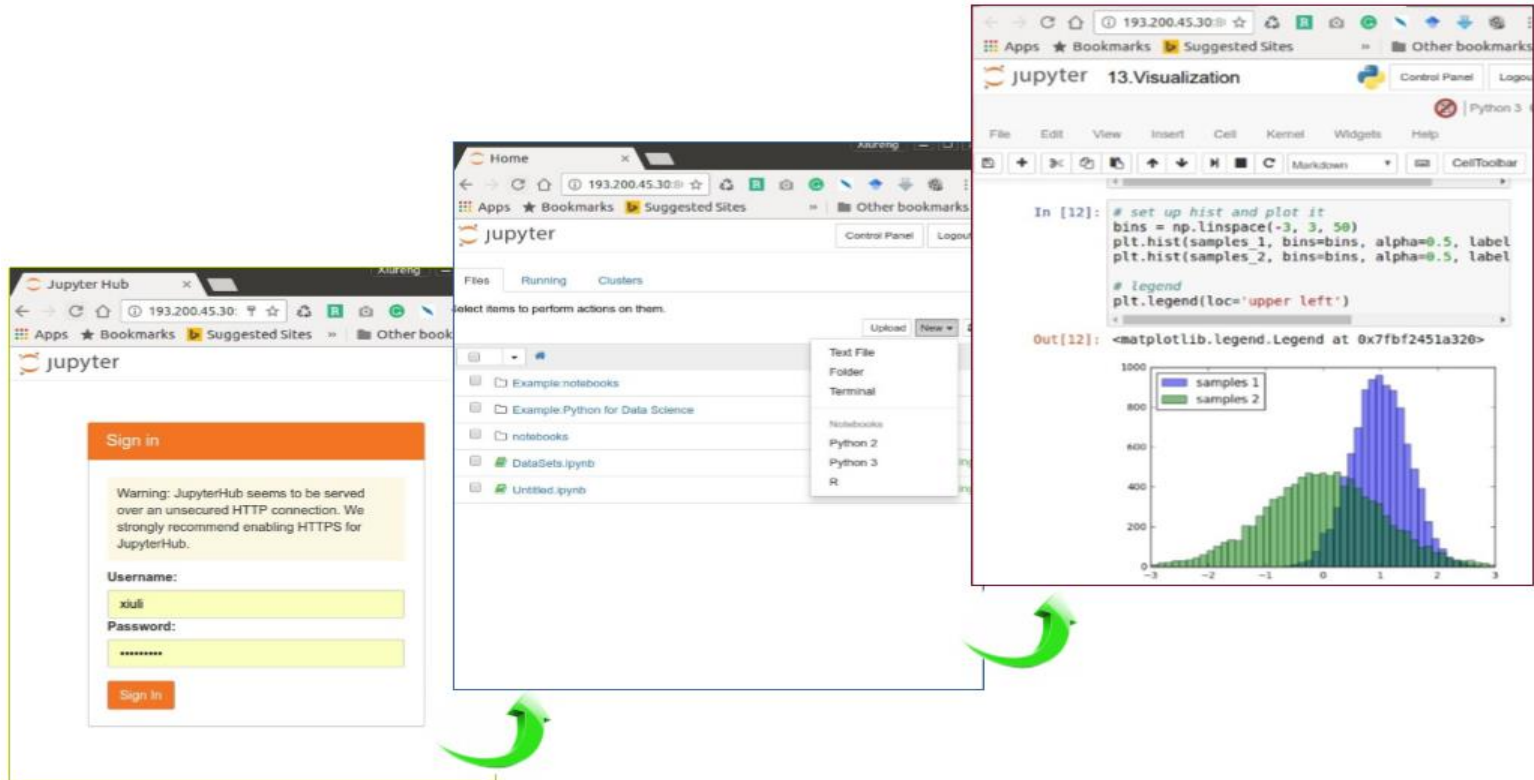
*Multiple users
support*



Data Layer



Data publisher



The image displays a sequence of three screenshots from a JupyterHub environment, illustrating the workflow from login to data visualization.

Left Screenshot (Login): Shows the JupyterHub login page. A warning message states: "Warning: JupyterHub seems to be served over an unsecured HTTP connection. We strongly recommend enabling HTTPS for JupyterHub." Below the warning, there are input fields for "Username" (containing "xuli") and "Password" (masked with "*****"), and a "Sign In" button.

Middle Screenshot (File Browser): Shows the JupyterHub file browser interface. A context menu is open over the "Untitled.ipynb" file, listing options: "Text File", "Folder", "Terminal", "Notebooks", "Python 2", "Python 3", and "R".

Right Screenshot (Code Execution): Shows a Jupyter notebook cell with Python code for histogram generation and a legend. The code is as follows:

```
In [12]: # set up hist and plot it
bins = np.linspace(-3, 3, 50)
plt.hist(samples_1, bins=bins, alpha=0.5, label='samples 1')
plt.hist(samples_2, bins=bins, alpha=0.5, label='samples 2')

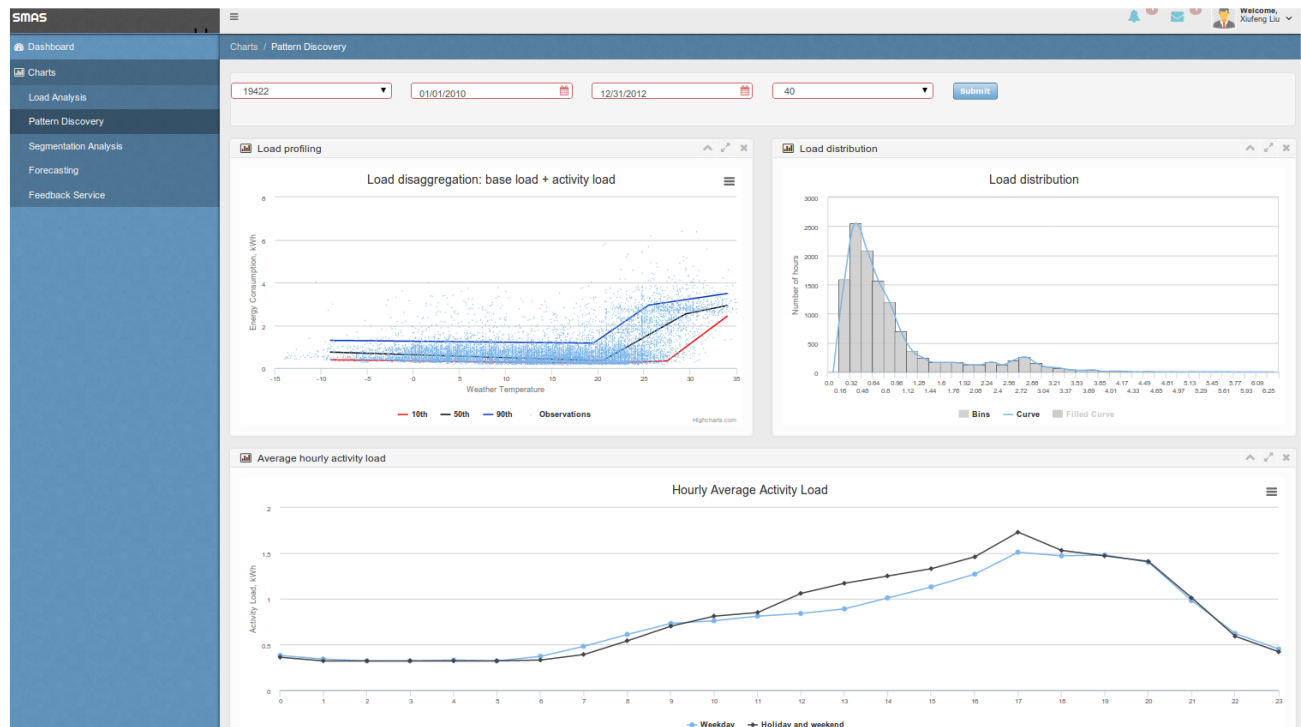
# legend
plt.legend(loc='upper left')
```

The output of the cell is a histogram plot showing two overlapping distributions: "samples 1" (blue bars) and "samples 2" (green bars). The x-axis ranges from -3 to 3, and the y-axis ranges from 0 to 1000. A legend in the upper left corner identifies the two series.

Værktøjet muliggør



- visualisere og analysere af data



Application Examples



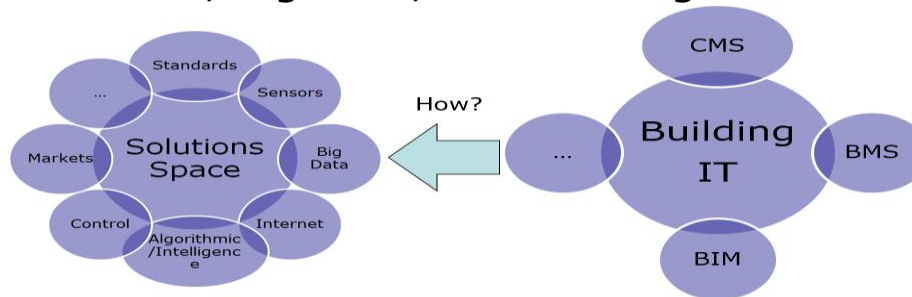
Thermal Systems & Buildings

- Flexibility



Aggregation models (districts, cities, regions ...)

- IT, sensors, automation, big data, data management



- Thermal Energy for Smart Cities

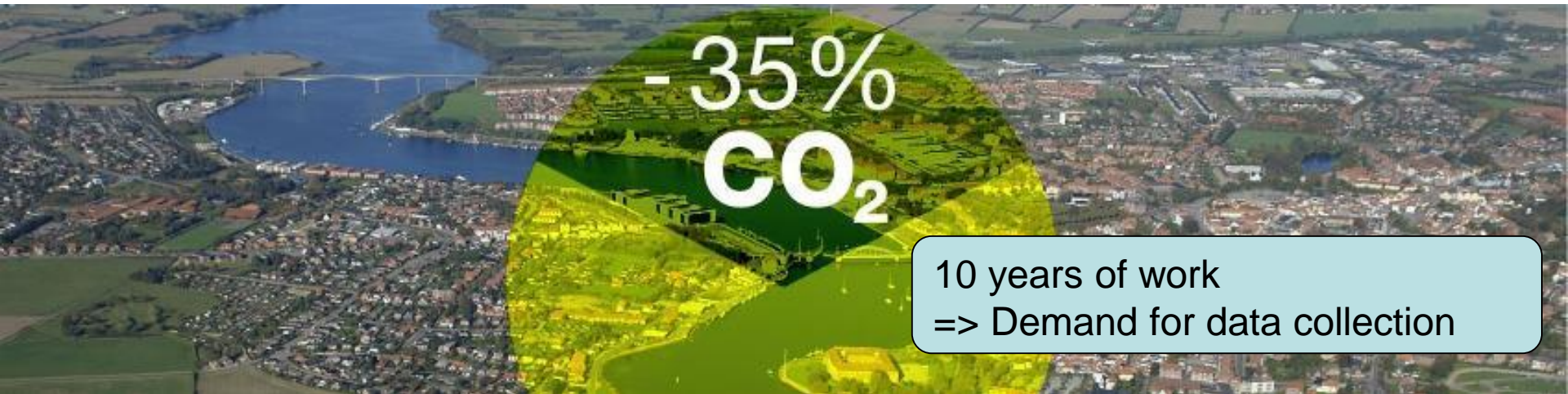
- District Systems Heating/Cooling/
- Central Solar
- Seasonal thermal storage

Sønderborg CO₂ accounting automation)

54 buildings



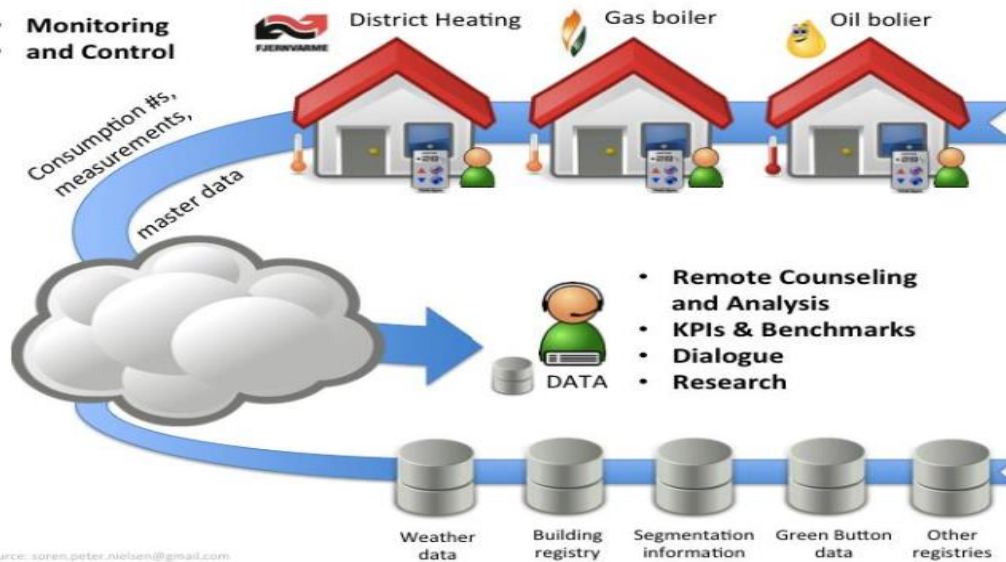
- Hourly data, collected every day to the cloud
- Made ready for usage with different time scales
- Open Access data set(s)



Middelfart data

144 Single family houses

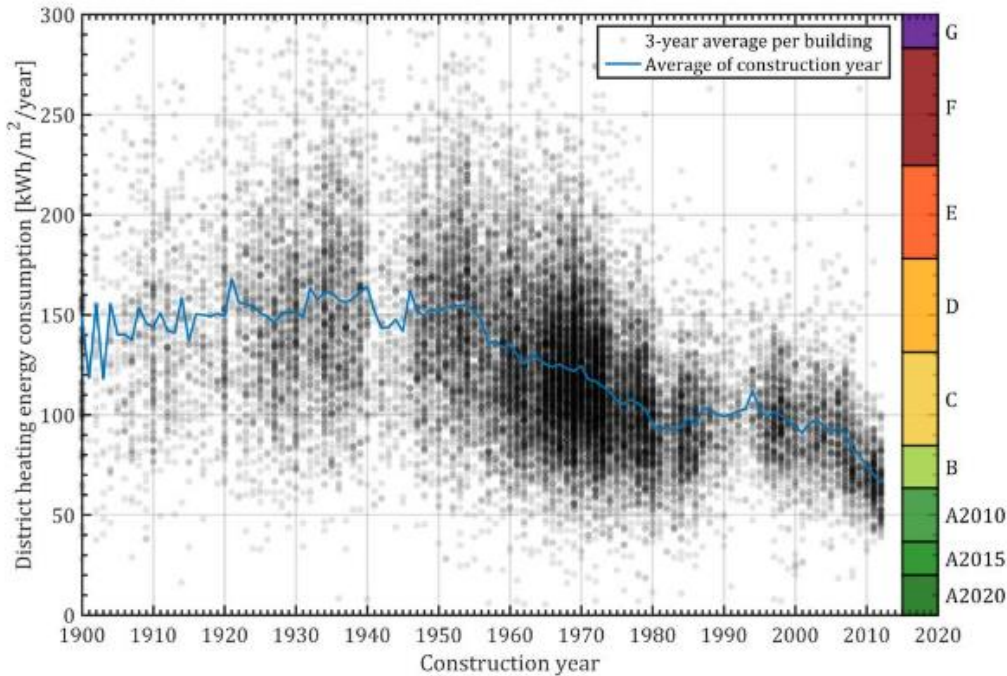
- **Monitoring and Control**



Consulents available to help

Source: soeren.peter.nielsen@gmail.com

Århusdata - Enfamiliehuse



- Statistiske data
- 1 måling pr. år (afregning)
- Visualisering

Viden springer frem af sig selv ...



Yearly data
=> Demand for data collection

Aiming at City level modelling

- BOTTOM-UP
- Work by Panagiota Gianniou, DTU Civil Engineering
- Types of buildings
- Summarizing towards districts and cities
- Uncertainties, how to handle stochasticities
 - In the building construction
 - Systems
 - Users
 - On the district level
- TOP-DOWN
 - Modelling in planning tools

DTU Technical University of Denmark
DTU Civil Engineering
Department of Civil Engineering

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Approach to Aggregation of Building Energy Demand and Building Typology to be applied to Smart Cities

The concept of Smart Cities

Over the half of the global population is now living in urban settlements. Homo sapiens became *Asmo urbico* (Grinmond, 2007). In Europe the corresponding percentage is approximately 80 % (IEA). Forecasts indicate that urban areas will rapidly increase in the future, while the energy demand in cities will triple by 2050 and it would be impossible for the existing infrastructures to provide such demand (McDonald, 2008). A drastic measure against such trend is "smart cities", which holistically includes all aspects of an entire urban system.

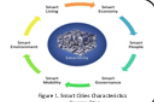


Figure 1. Smart City Characteristics (Source: [1])

Emphasis on building stock

Nowadays, buildings represent the largest sector in the EU in terms of final energy consumption, with a 40% share of the total European energy requirements. For this reason, building stock can play a significant role in the stabilization of the whole energy system. Moreover, buildings provide one of the largest cost-effective opportunities for energy savings. At the same time, the improvement of their energy efficiency can significantly contribute to lower GHG emissions as a part of climate change mitigation strategies, which are top priorities in almost all European governmental agendas.

Do buildings have any potential contribution to mitigate the fluctuation of energy demand considerably and in which way?

Why residential buildings specifically?

Buildings within an urban area constitute complicated structures able not only to consume but also to store (generate energy). The utilization of structural and operational components, such as embedded in building envelope thermal masses and smart scheduling for cooling/heating, respectively, could significantly contribute to system's flexibility. Therefore, buildings are expected to have a key role in the future energy networks.

It was decided to emphasize on the residential stock, since it counts for 70% of the European buildings' floor area.

Aggregation

One main prerequisite towards the optimization of Smart Cities' energy performance, is the determination of their energy demand. Although significant effort has been placed on the calculation of individual buildings' energy demand, new ways have to be investigated that trace large numbers of buildings as clusters or entities and estimate their energy demand as a whole.

How building energy demand can be determined at aggregated level, streets, neighborhoods or whole cities.

Numerical methods

- Simplest calculation of summing all energy demands up
- Weighting factors

$$E = \sum_{i=1}^n (E_{i,j}) \cdot W_{i,j}$$

where i is the building or building type

Proposed weighting factors: share of floor area with respect to the total floor area

Statistical models

- Regression models for short-term heat load forecasting

Urban Simulation Tools

- Parallel processing of individual building energy simulations, while considering the neighboring buildings in terms of shading, wind blockage etc.

E.g. *Umy Cities*

Archetype modeling

- building typologies and databases
- creation of representative example buildings for every category/type and use these for aggregating energy demands instead of using thousands of buildings in cities.

Building typologies serve the need for a wider and more macroscopic assessment of building stocks. The current necessity to evaluate the behavior of several building types in order to determine whether and to what extent they can contribute to more flexible energy demand.

<p>Building typologies relies on parameters such as:</p> <ul style="list-style-type: none"> Energy performance Use of building Age of construction 	<p>Secondarily:</p> <ul style="list-style-type: none"> Existing ventilation and heating/cooling systems Existing Energy systems Renovations and potential energy retrofitting
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Flexibility

Building stocks may have a significant contribution to a grid's flexibility. Thermal mass integrated in buildings constitutes a means of storing a significant amount of heat. Several building elements could contribute to such way of heat storage and the amount of heat collected depends on the heat capacity of each one of them ("smart" materials integrated in the building envelope, hot water tanks, appliances etc.). For instance, in the case of an outside-insulated building envelope, a material with a satisfactory specific heat capacity (JK) implemented in the wall assembly, could postpone heating or cooling for a significant period of time without affecting the indoor thermal comfort of the building. Thus, if the building is excess pre-heated/cooled within the comfort range of the room temperature prior to a shutdown of heating/cooling it is possible to prolong the shutdown period. This phenomenon acts as an indirect load shift for the grid and could be proven considerably effective for the mitigation of peak loads in energy demands.

Perspective of the project

The above-mentioned aggregation and classification ways are to be implemented on a real case of a small city in Denmark.

The main results of the study will be applied to future buildings according to realistic predictions upon their performance.

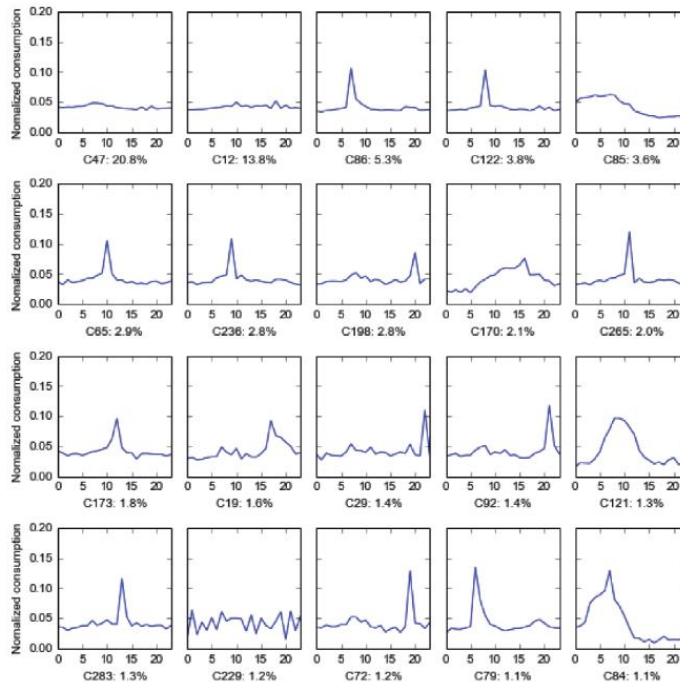
100% Climate Neutrality by 7th October 2015, Sønderborg, Denmark

Aarhus data

1.000 > single family houses

50.000 building in all (e-meters)

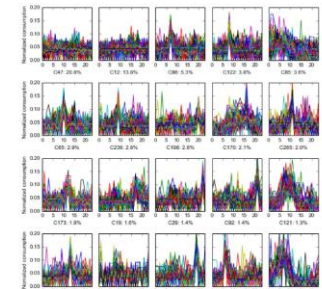
Results



Top 20 clusters

- A first experience
- Cautions
 - Be critical

Results



IoT what's the fuzz?



Building automation

- ... cloud supported
- ... by prediction
- ... by consultant support
- ... online

Source: <http://www.computerworld.dk/art/234247/herkan-du-spinde-guld-paa-internet-of-things-der-ligger-milliarder-gemt-i-disse-omraader>