By Gorm Bruun Andresen and Smail Kozarcanin from Department of Engineering, Aarhus University Aarhus, Denmark

GRID INTEGRATION OF SOLAR PV AND ELECTRICAL VEHICLES FOR MULTI-APARTMENT BUILDINGS

READY

Smart Cities and Communities

Applied Energy System Analysis

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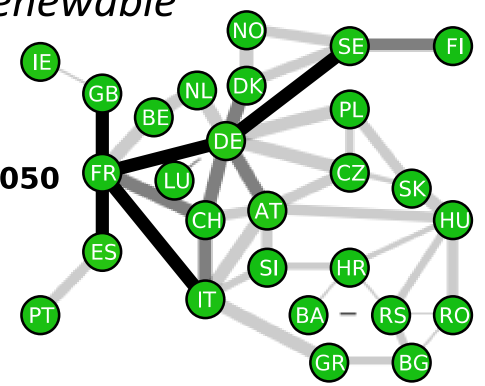
GLOBAL RENEWABLE
ENERGY ATLAS

Weather and climate change

Large-scale energy system analysis

Going fully renewable

2050

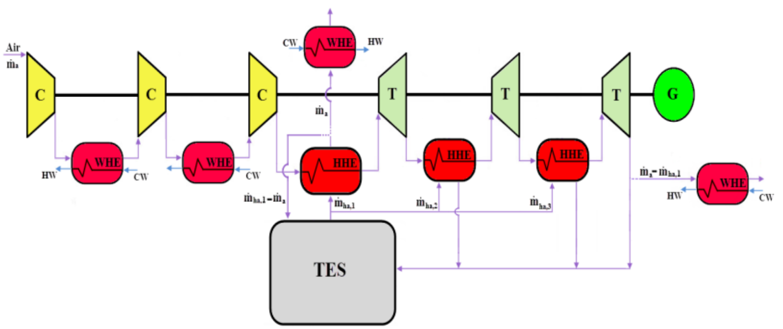


District heating

Aarhus is our lab

Smart energy technology

Developing new technology



G.B. Andresen, September – 2016
gba@eng.au.dk

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Background: PVs and EVs can cause voltage problems in the distribution grids

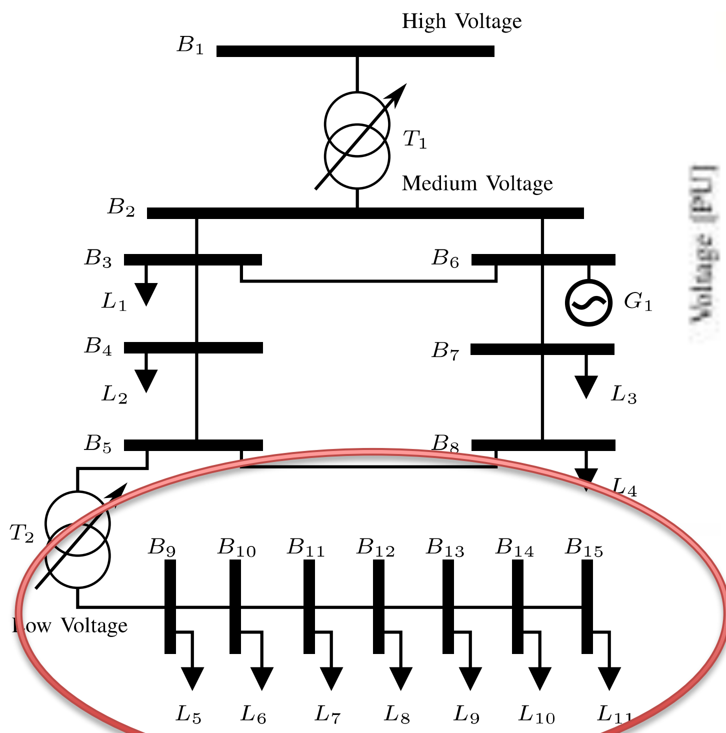
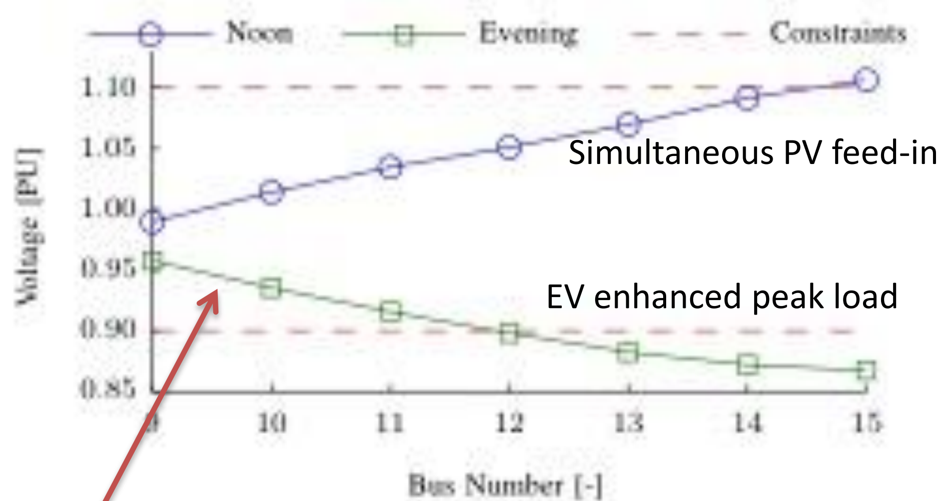


Fig. 8: Grid used for the simulations. The generator on bus 6 (G_1), can be a wind power plant or a solar power plant. L_1 is an aggregated residential grid, L_2 is a commercial load, L_3 is an industrial load, L_4 is an agricultural load and L_5-L_{11} are aggregated residential loads of approx. 20 households. All loads are based on real consumption data.



Active (smart) control in the distribution grid may be required to alleviate *new* problems caused by, e.g. EVs and PVs.

Local batteries could help here.

R. Pedersen, C. Sloth, G. B. Andresen and R. Wisniewski, "DiSC: A Simulation Framework for Distribution System Voltage Control", *Proceedings of the 2015 European Control Conference*, July 2015.

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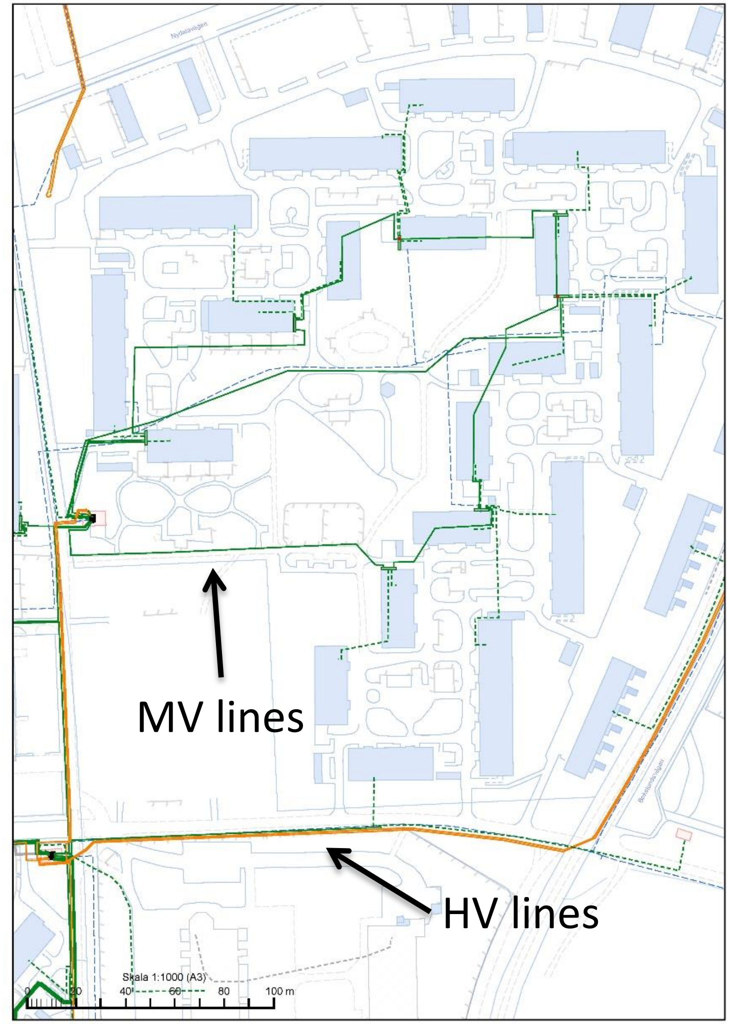
Study cases

Alabastern, Växjö

Bärnstenen, Växjö



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gba@eng.au.dk

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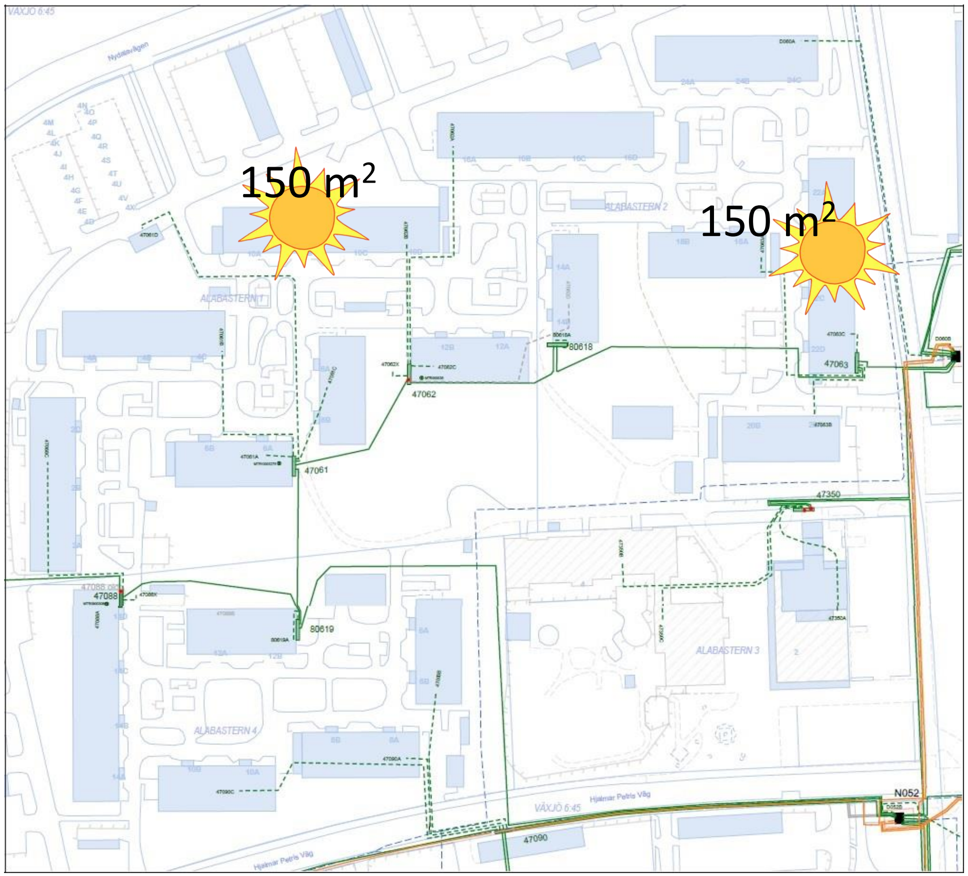
Study cases

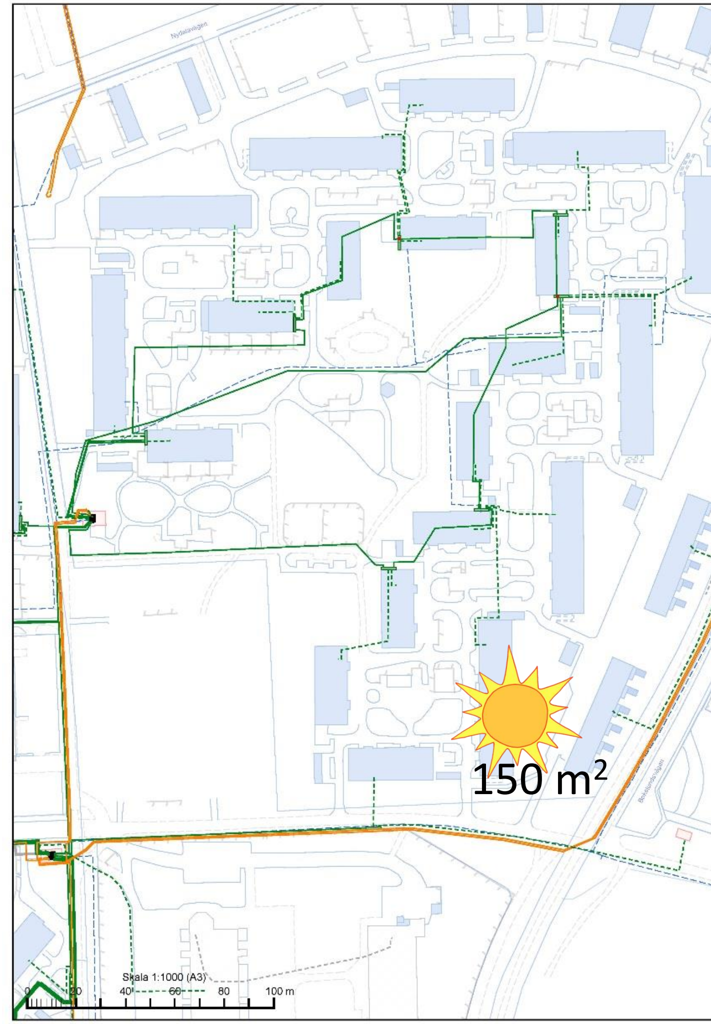
- Actual demonstration -

READY

Alabastern, Växjö



Bärnstenen, Växjö



G.B. Andresen, September – 2016
gba@eng.au.dk

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Solar PV model scenarios

- **No PV:** In this reference scenario the local grid is modeled as it currently is with no solar PV installations.
- **Peak matching:** The roof is partially covered with PV. The degree of coverage is determined such that all generated electricity can potentially be used locally, i.e. peak production is about equals to the demand when it occurs.
- **Energy matching:** The degree of roof coverage is determined such that the annual electricity yield from solar PV matches the total annual consumption.
- **Full roof coverage:** The roof is fully covered with solar PV.

Single building vs. All buildings

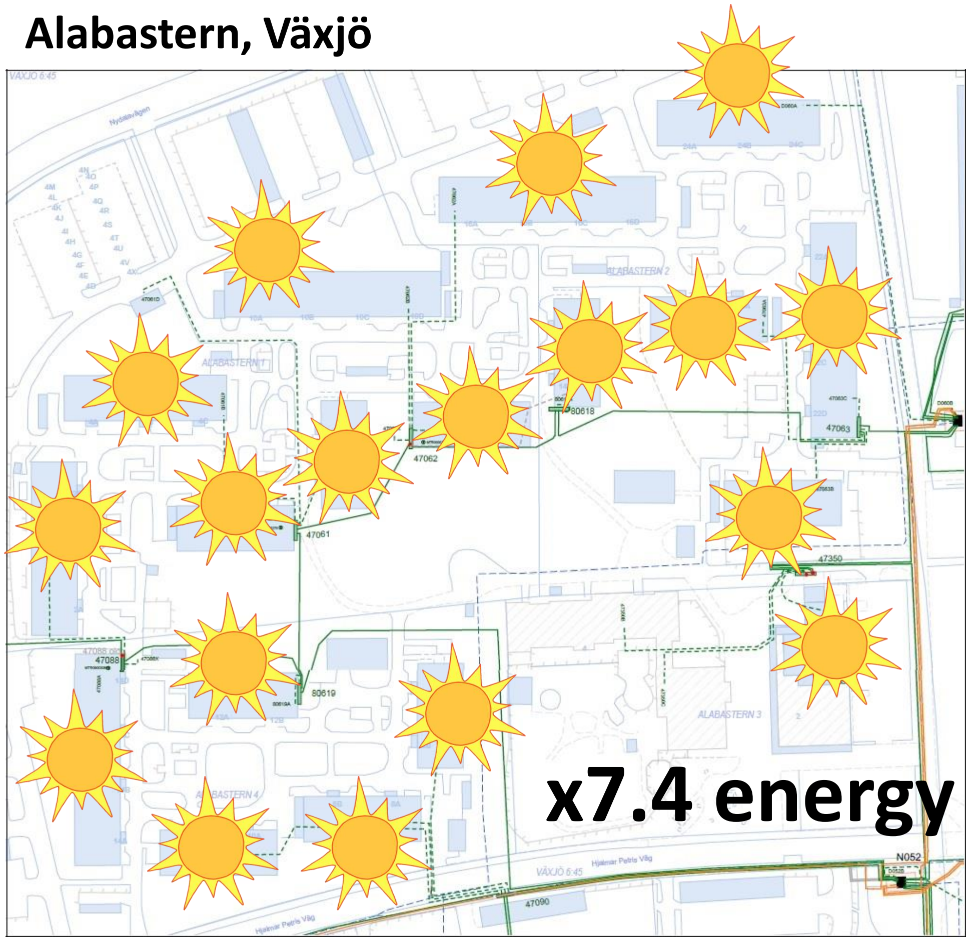
Solar PV model scenarios

		Base case	Summer peak match	Annual energy match	All roof covered
Bärnstenen	**Single building with PVT** Consumption: 91.2 MWh/yr	Area: 0 m^2 Capacity: 0 kWp Production: 0 MWh/yr	Area: 75 m^2 Capacity: 52 kWp Production: 22.1 MWh/yr	Area: 309 m^2 Capacity: 215 kWp Production: 91.3 MWh/yr	Area: 2086 m^2 Capacity: 1,449 kWp Production: 616 MWh/yr
	All buildings with PVT Consumption: 439 MWh/yr	Area: 0 m^2 Capacity: 0 kWp Production: 0 MWh/yr	Area: 7x75 m^2 Capacity: 365 kWp Production: 155 MWh/yr	Area: 1,485 m^2 Capacity: 1,031 kWp Production: 438 MWh/yr	Area: 12,502 m^2 Capacity: 8,682 kWp Production: 3,694 MWh/yr
Alabastern	**Single building with PVT** Consumption: 71.6 MWh/yr	Area: 0 m^2 Capacity: 0 kWp Production: 0 MWh/yr	Area: 75 m^2 Capacity: 52 kWp Production: 22.1 MWh/yr	Area: 242 m^2 Capacity: 167 kWp Production: 71.5 MWh/yr	Area: 1,482 m^2 Capacity: 1,022 kWp Production: 436 MWh/yr
	All buildings with PVT Consumption: 395 MWh/yr	Area: 0 m^2 Capacity: 0 kWp Production: 0 MWh/yr	Area: 8x75 m^2 Capacity: 414 kWp Production: 177 MWh/yr	Area: 1,338 m^2 Capacity: 923 kWp Production: 395 MWh/yr	Area: 9,866 m^2 Capacity: 6,804 kWp Production: 2,915 MWh/yr

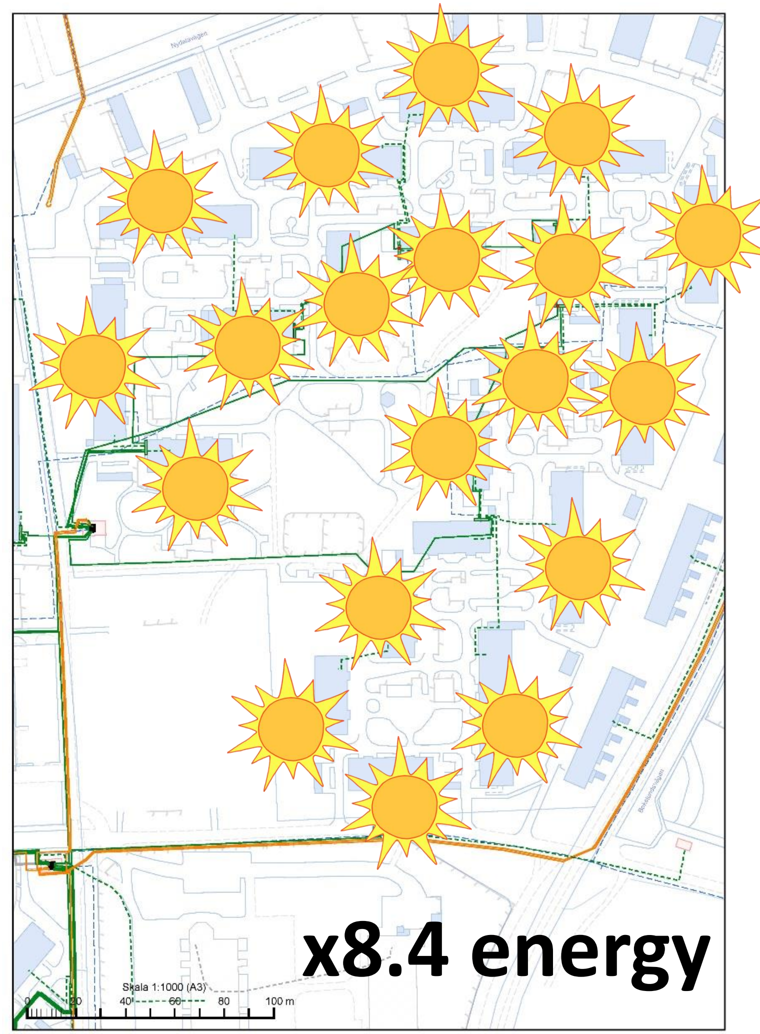
Study cases

- All roof covered -

Alabastern, Växjö



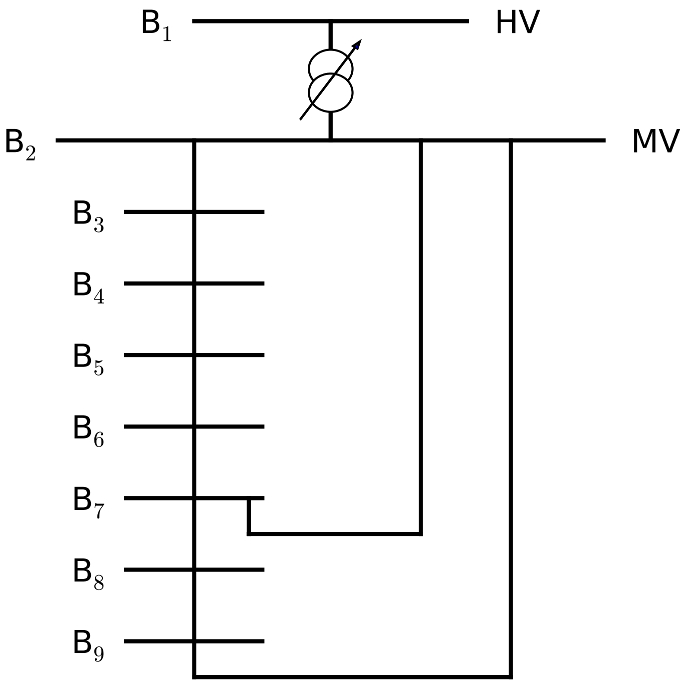
Bärnstenen, Växjö



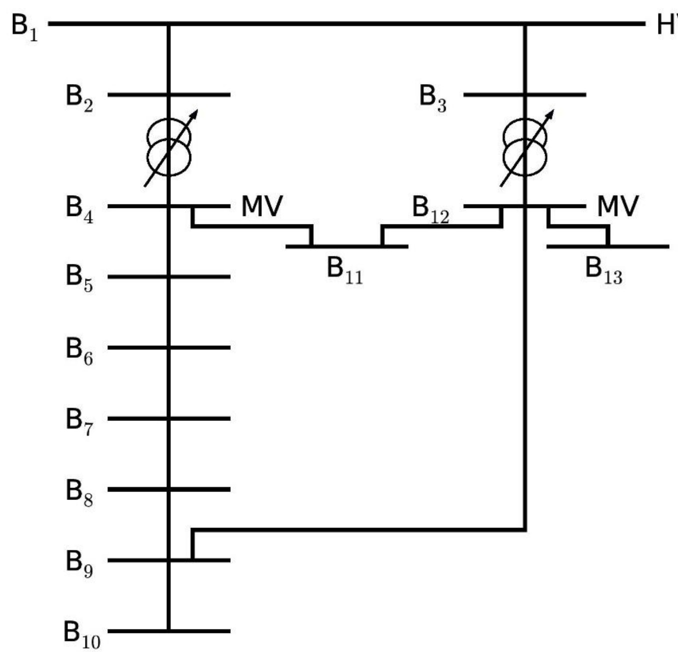
DiSC model

A Newton-Rapson power flow solver is used to determine the non-linear currents and voltages differences between the individual busses in the network.

Bärnstenen



Alabastern



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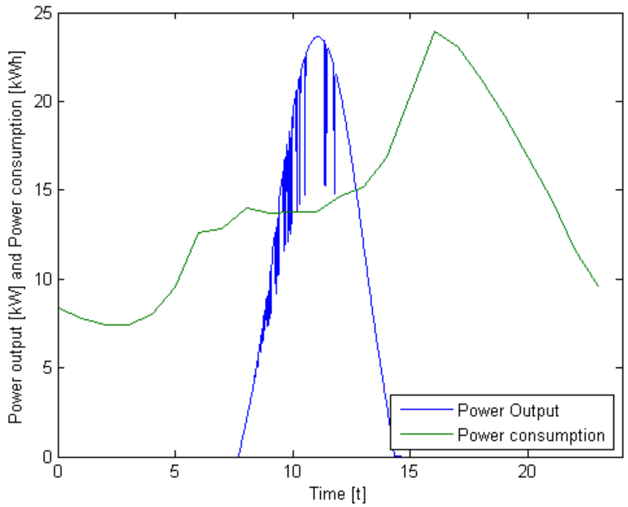
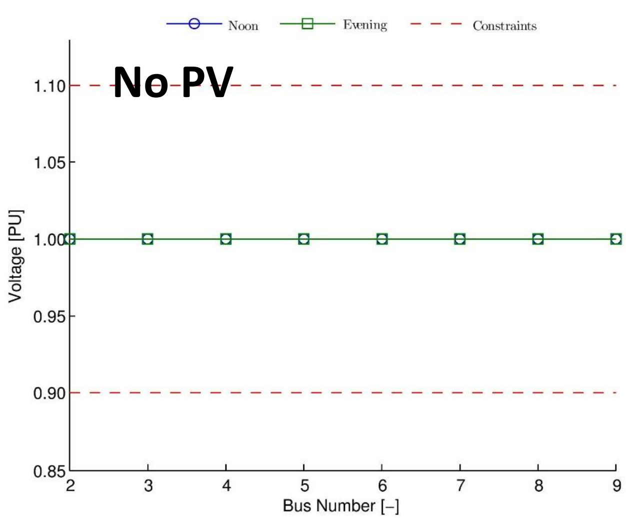
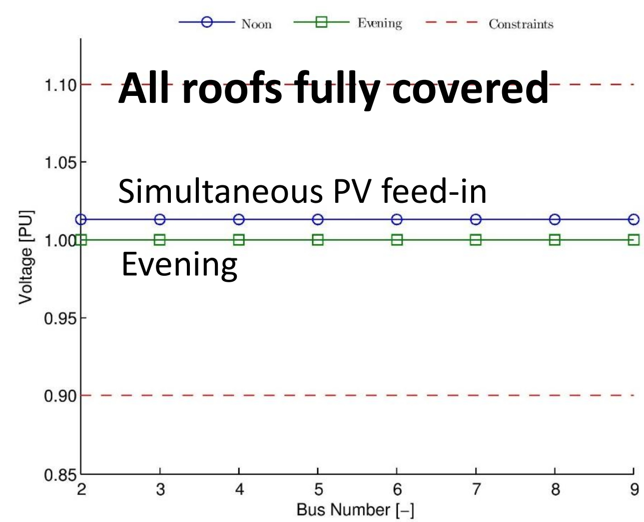
Results – Bärnstenen



Key finding: Minor overvoltages during midday in the most extreme scenarios.

(similar results for Alabastern)





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gba@eng.au.dk

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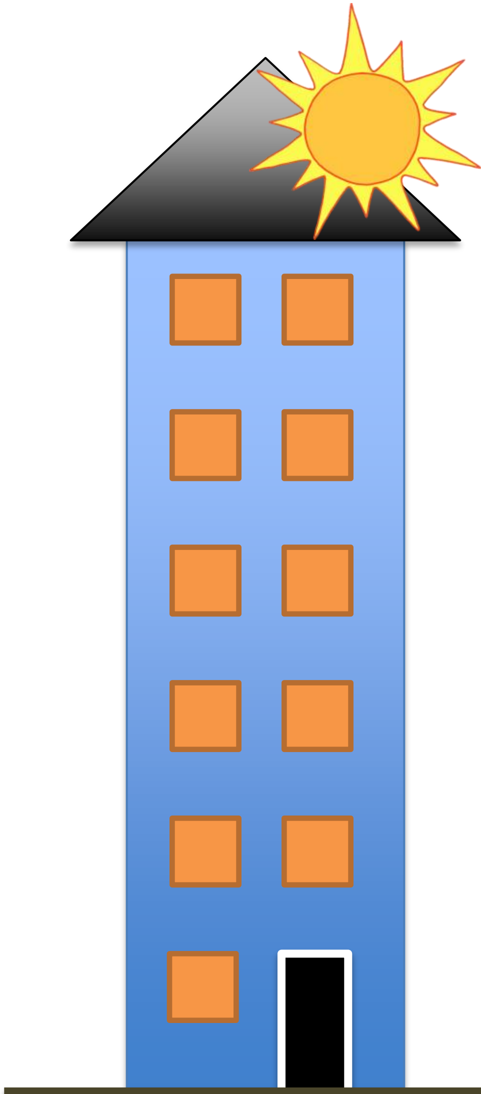
Maximum overvoltages

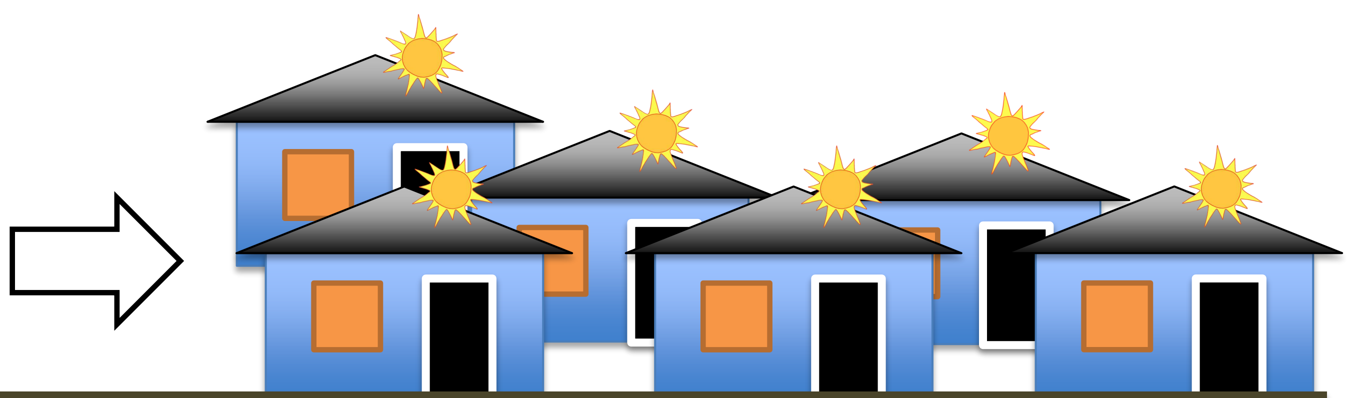
		Base case	Summer peak match	Annual energy match	All roof covered
Bärnstenen	**Single building with PVT**	Maximum overvoltage: **0 V**	Maximum overvoltage: **0 V**	Maximum overvoltage: **5 V**	Maximum overvoltage: **45 V**
	All buildings with PVT	Maximum overvoltage: **0 V**	Maximum overvoltage: **12 V**	Maximum overvoltage: **33 V**	Maximum overvoltage: **274 V**
Alabastern	**Single building with PVT**	Maximum overvoltage: **0 V**	Maximum overvoltage: **0 V**	Maximum overvoltage: **2 V**	Maximum overvoltage: **16 V**
	All buildings with PVT	Maximum overvoltage: **0 V**	Maximum overvoltage: **7 V**	Maximum overvoltage: **15 V**	Maximum overvoltage: **110 V**

The most extreme overvoltages can easily be handled in the 20 kV MV grid, but the would not be acceptable in the 400 V LV grid.

Splitting up multi-apartments



By splitting up one multi-apartment building into individual dwellings the solar PV goes from being **parallel** connected to **serial** connected in the LV grid.



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gba@eng.au.dk

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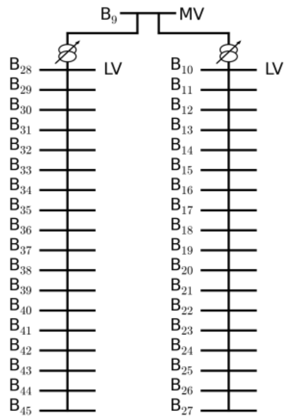
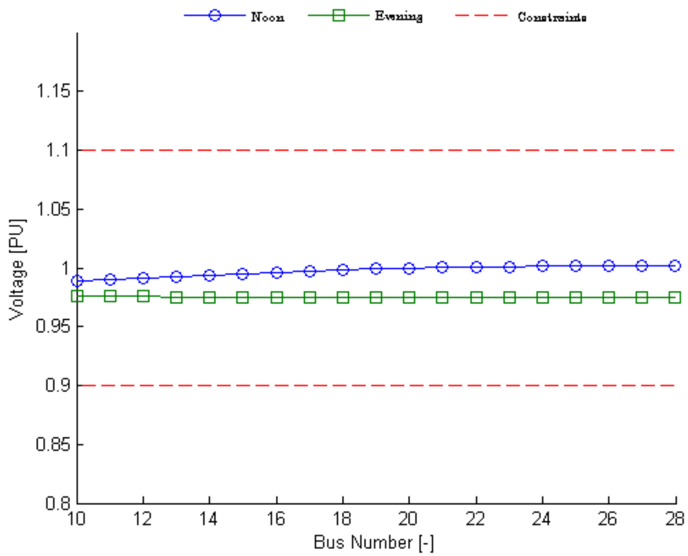
Splitting up multi-apartments

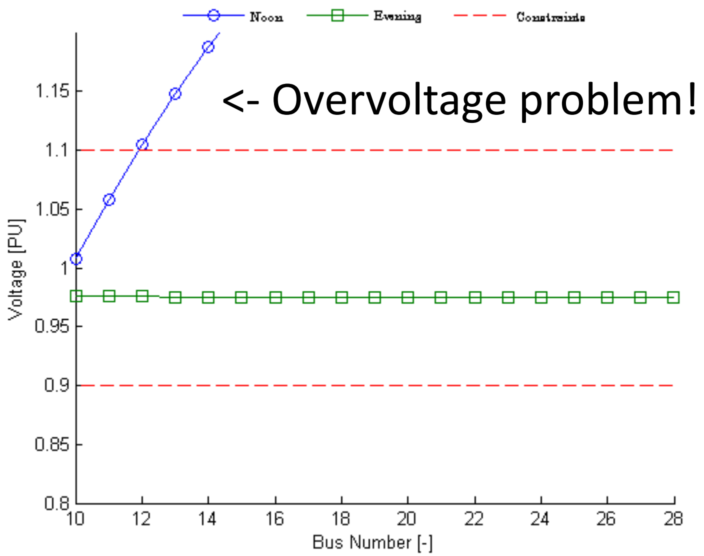


For the split apartments, we observe the same voltages problems that has been reported by many other studies.

Annual energy match



All roofs fully covered



Large-scale @ High voltage

Medium-scale @ Medium voltage

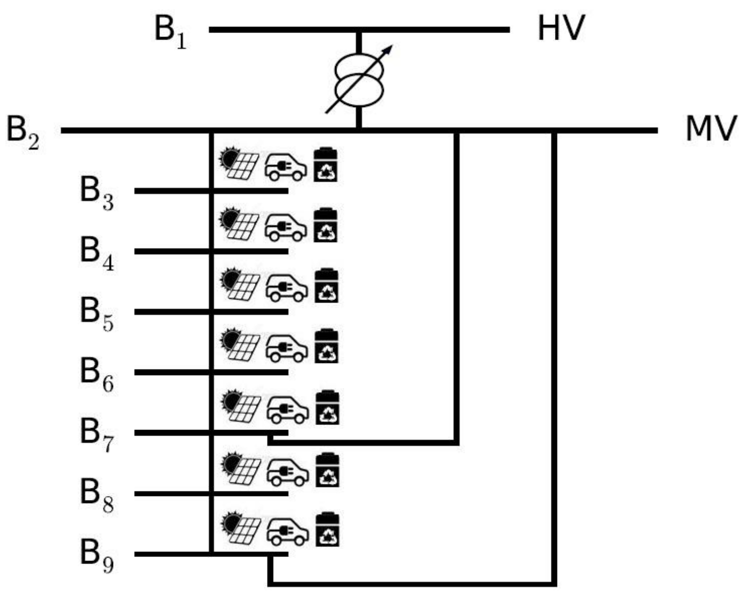
Small-scale @ Low voltage

Why not do it cheap and easy?

WHERE TO BUILD SOLAR PV

Adding EVs and ESs

- **One EV per. apartment:** Each apartment in the residential area owns an electric vehicle with a battery capacity of 20 kWh that charge once per day. With 400 EV's the consumption is 2920 MWh/yr.
- **One EV and ES per. apartment:** An extra (old) EV battery is added per apartment.

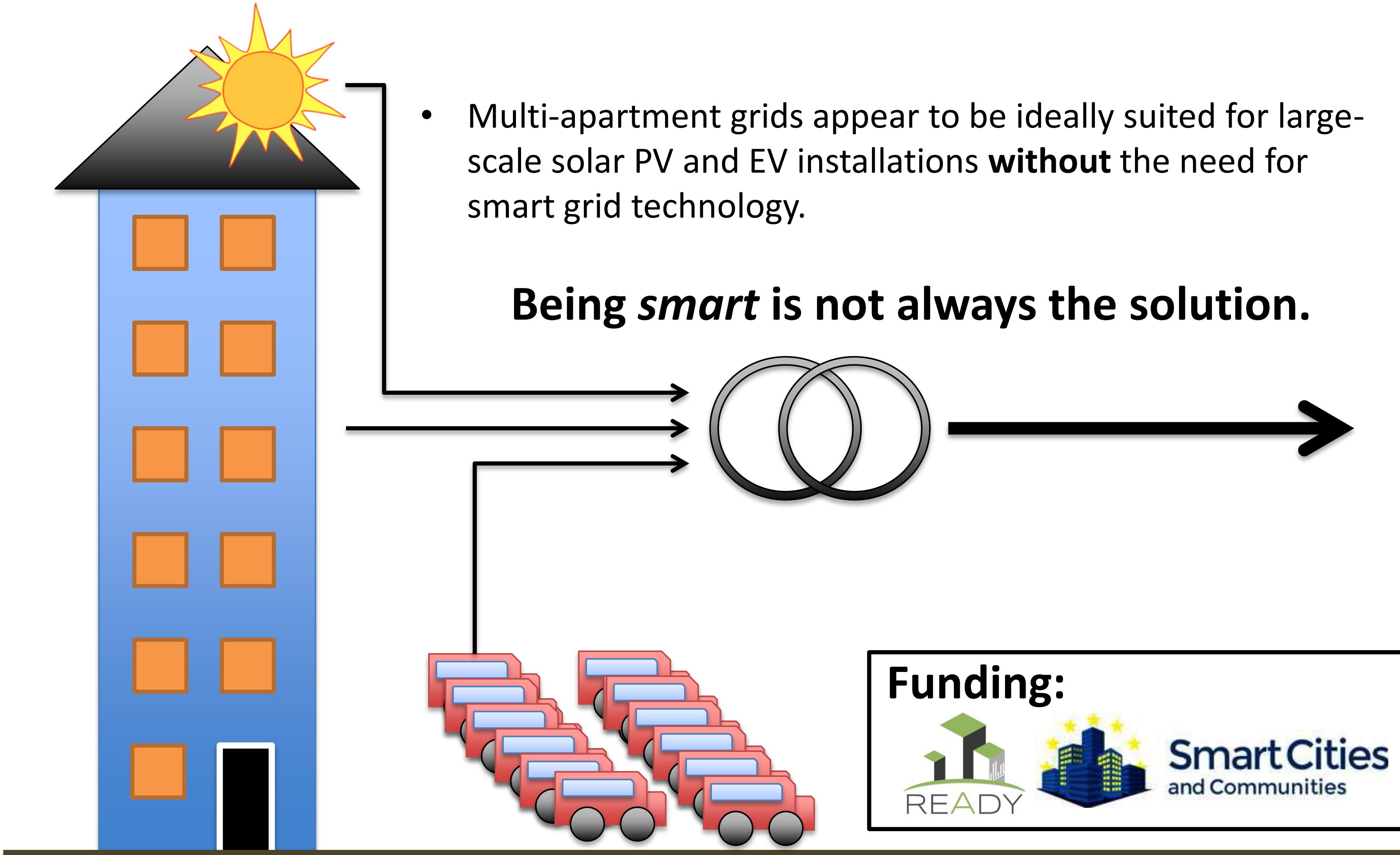


Key finding: Because we are dealing with multi-apartment buildings PV, EVs and ESs are added directly at the MV-to-LV transformer. As a consequence all voltage issues are easily handled.

Thank you for your attention!

- Multi-apartment grids appear to be ideally suited for large-scale solar PV and EV installations **without** the need for smart grid technology.

Being *smart* is not always the solution.



Funding:

READY

Smart Cities and Communities