



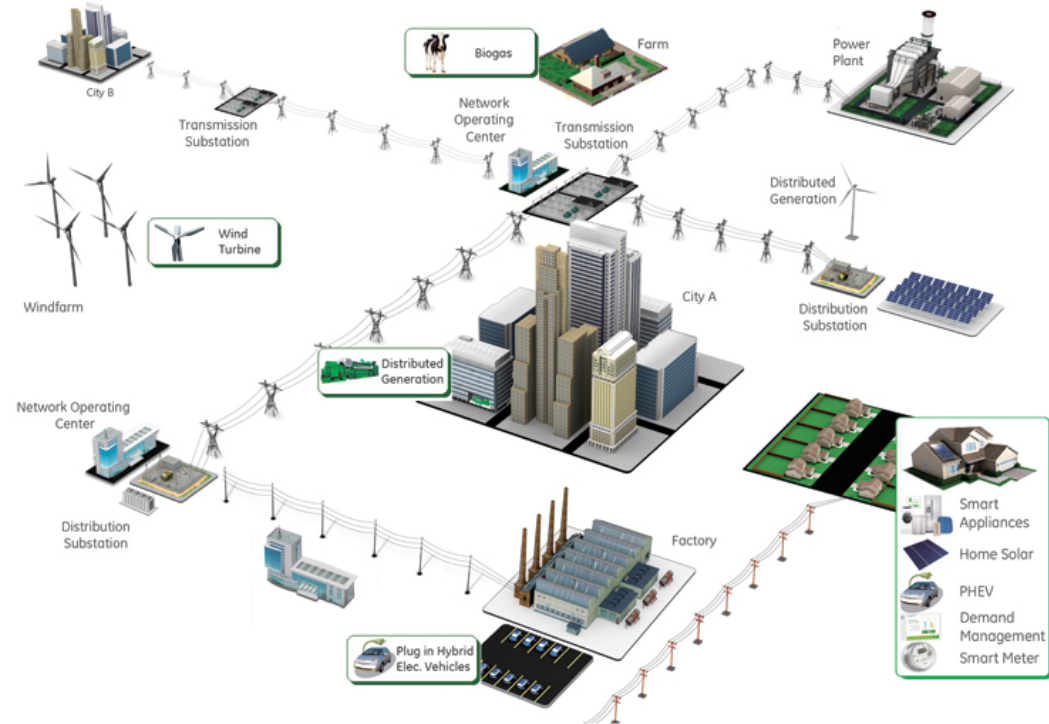
## BIPV : towards the DC nanogrid

Johan Driesen



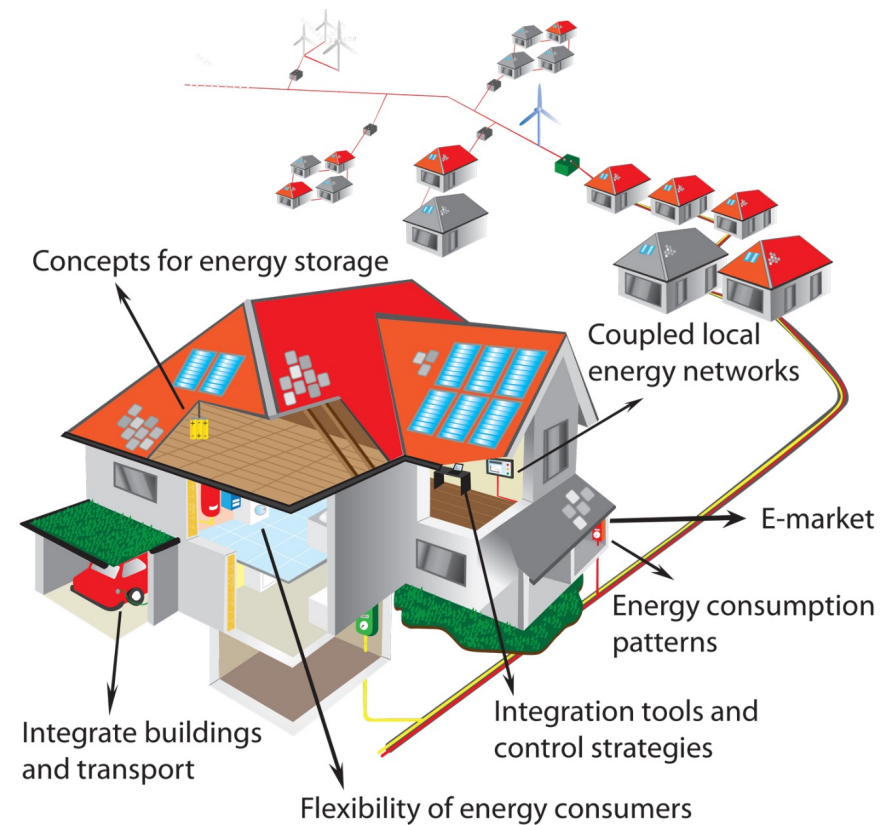


# Smart Grids



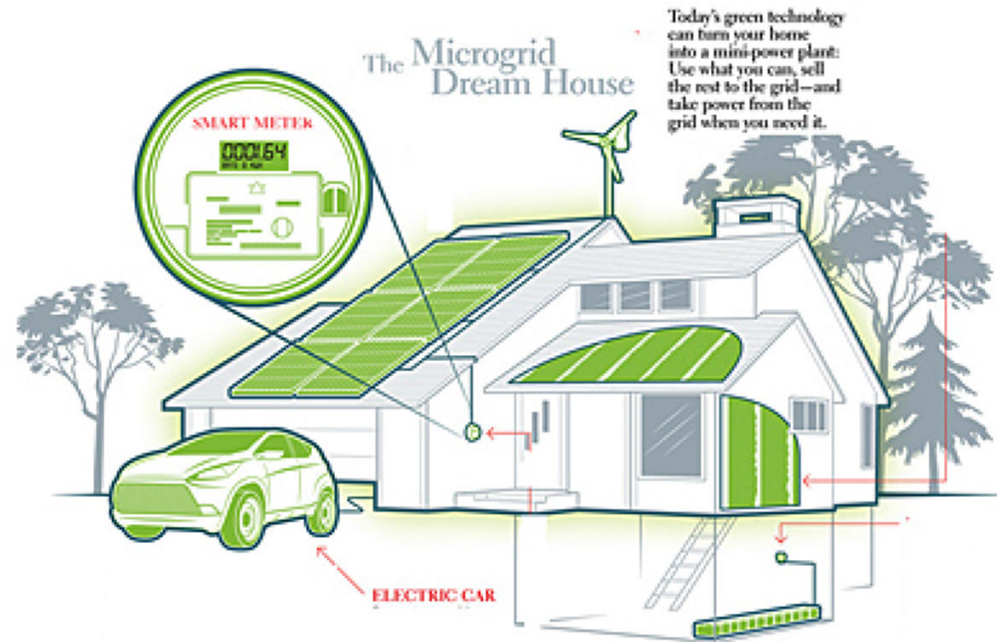
# Rethinking the electricity system

## Smart Energy Systems in Smart Cities



# Rethinking the electricity system

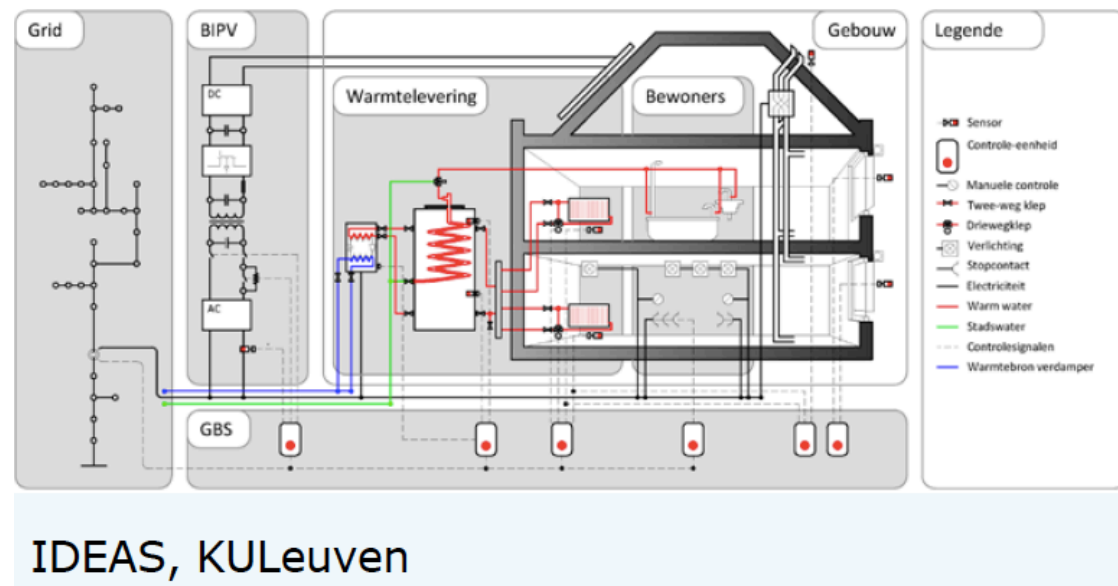
## 🌿 Residential (DC) microgrids





# Rethinking the electricity system

🌿 Smart Houses with fully integrated energy systems

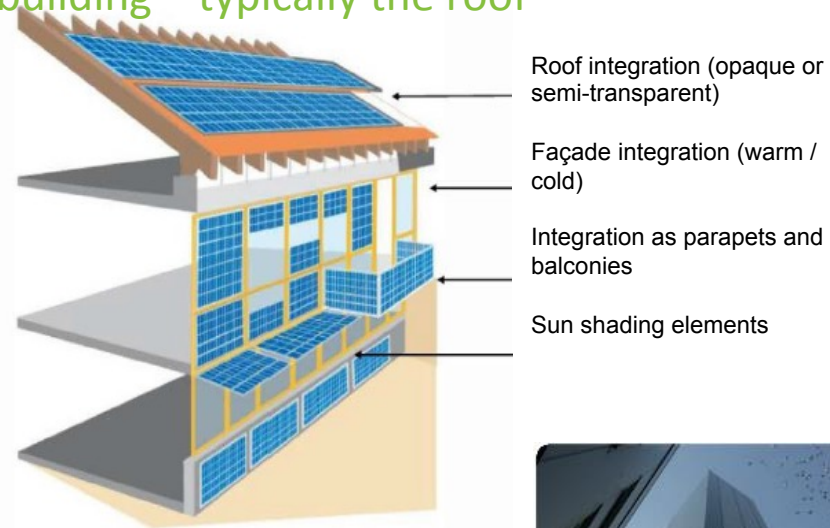


# Building-Integrated-PV potential

🌿 Today: PV modules “added” to the building – typically the roof

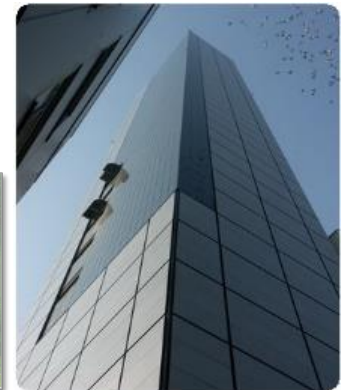
🌿 BIPV = multi-functional use

- ✦ As building component
- ✦ To generate electricity



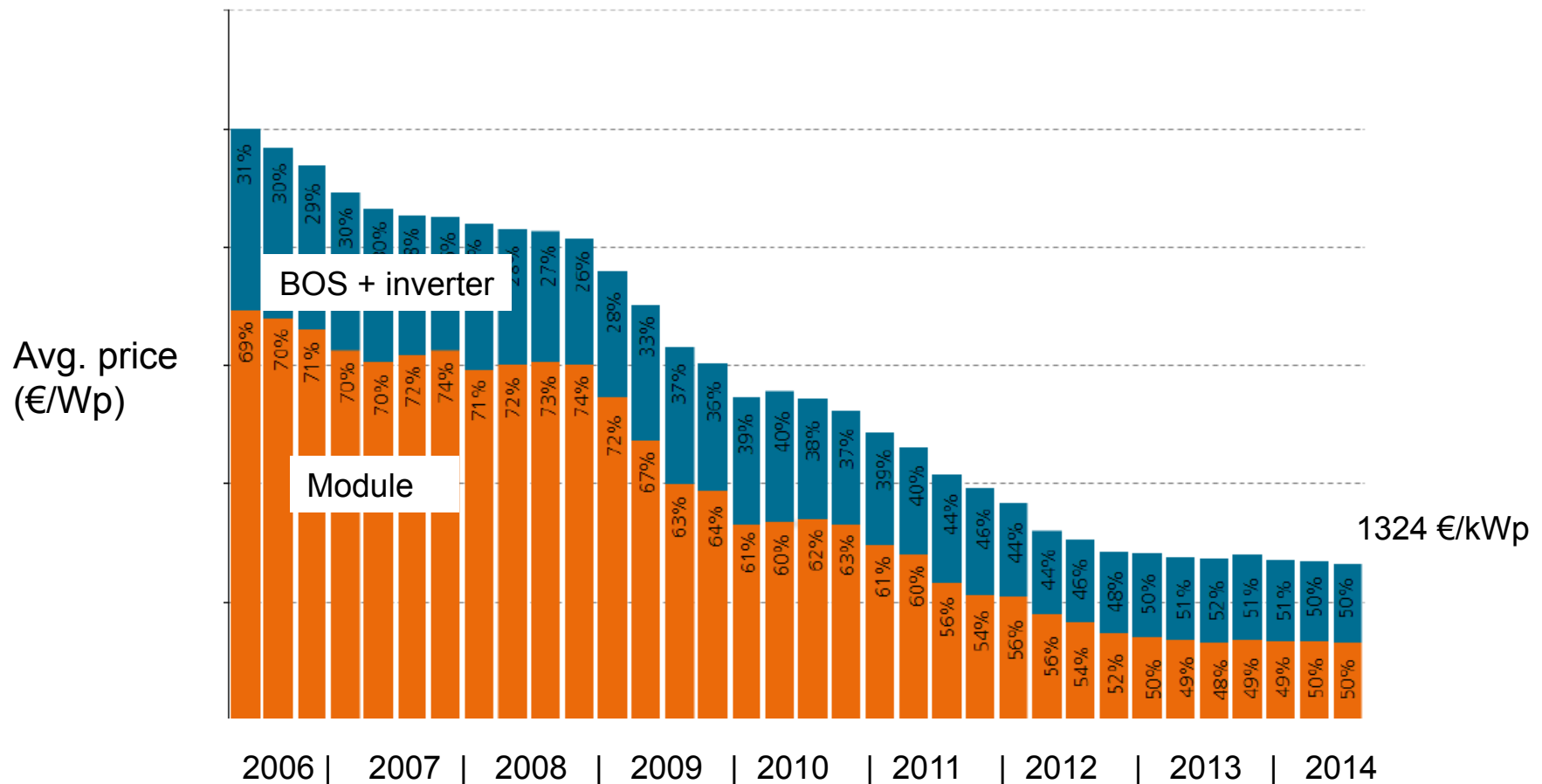
🌿 What will drive BIPV ?

- ✦ Façade-integration of PV for tall NZEB-compliant buildings  
*potential market > 100 GW/yr*
- ✦ PV-roofs with improved esthetics
- ✦ Lower overall cost (building + PV)



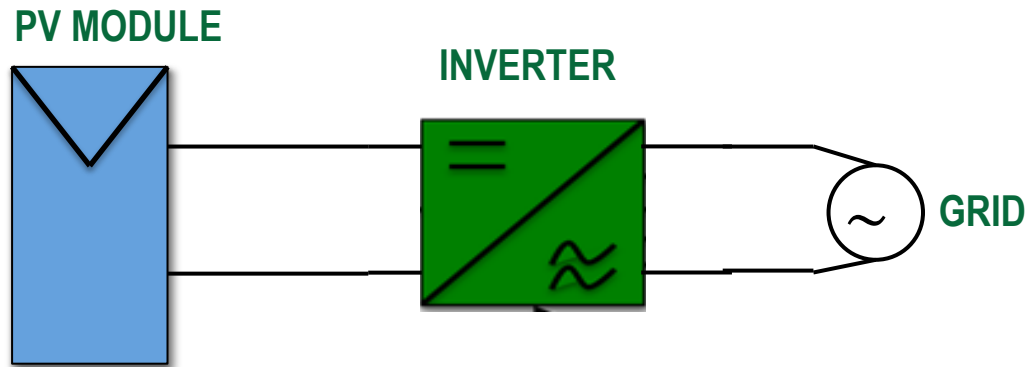
# Price of inverter and balance-of-system (BOS): also decreasing but not so fast as modules

10...100 kWp PV rooftop systems in Germany



Source: Fraunhofer ISE

## Energy losses ? Also at system level !

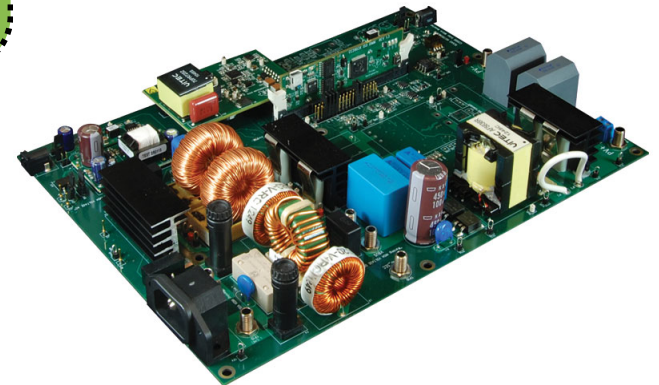
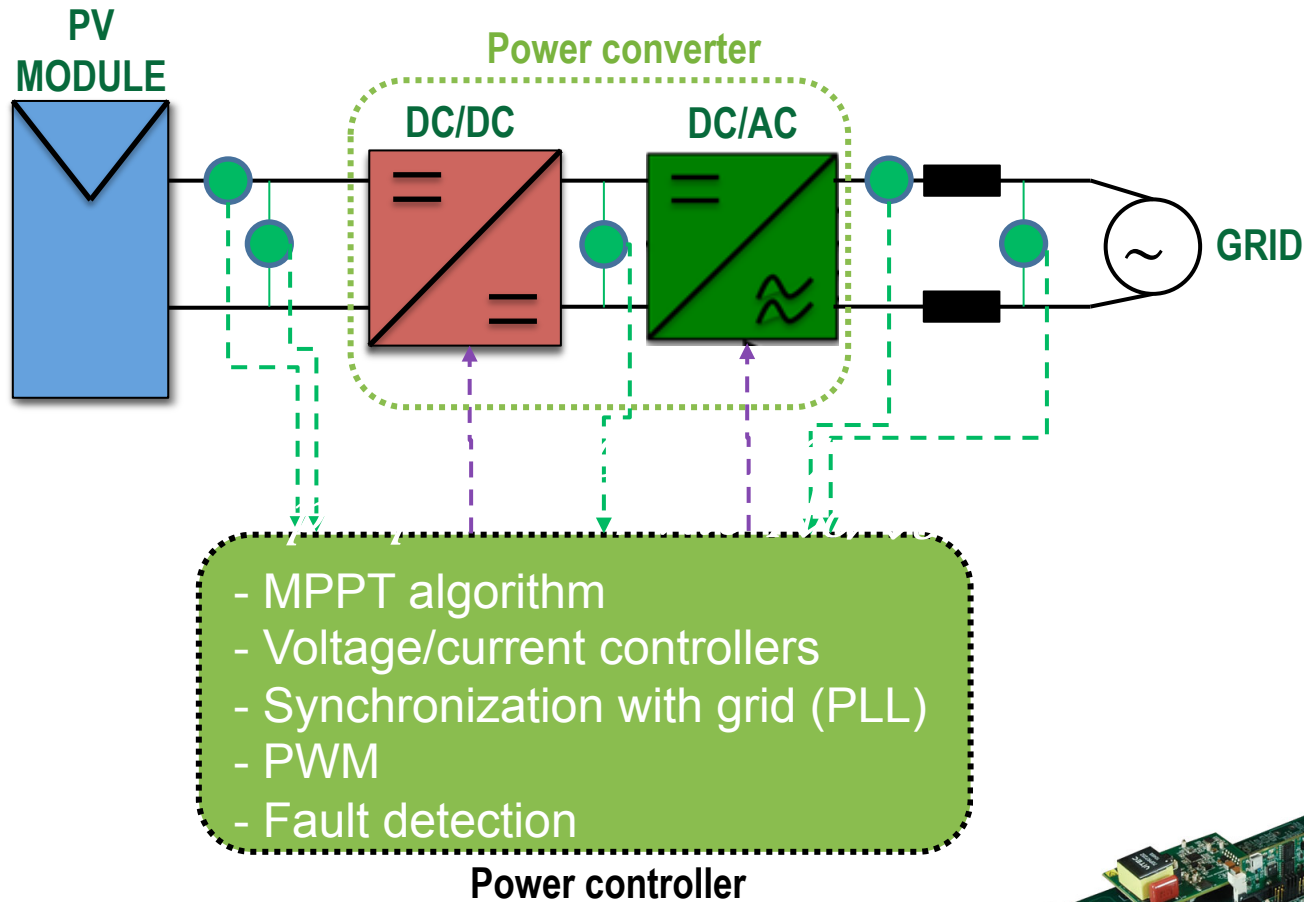


Wiring	Any cables have some resistance and therefore more losses.
MPP	Ability of the MPP tracker to consistently find the maximum power point.
Inverter	Inverter efficiency
Mis-sized inverter	If the inverter is undersized, power is clipped for high intensity light. If it is oversized, the inverter's efficiency will be too low for low intensity light.
Transformer	Transformer losses in case electricity has to be connected to a high-voltage grid.

Usually economical compromises are made

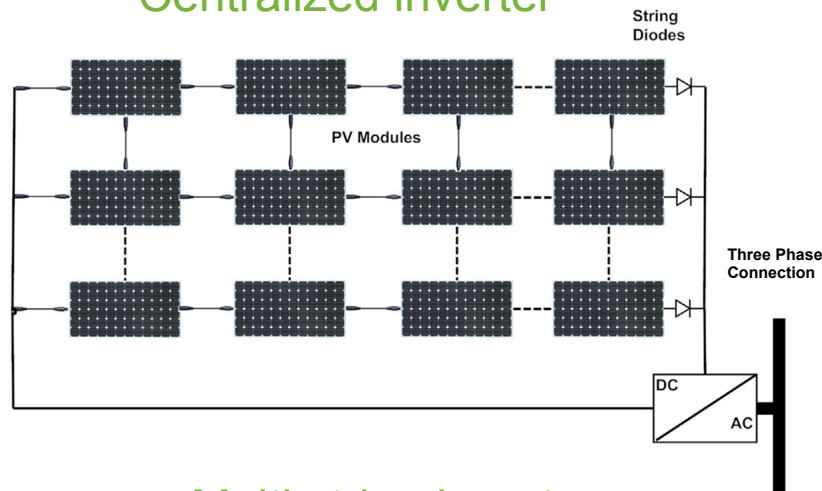


# From DC module to AC grid

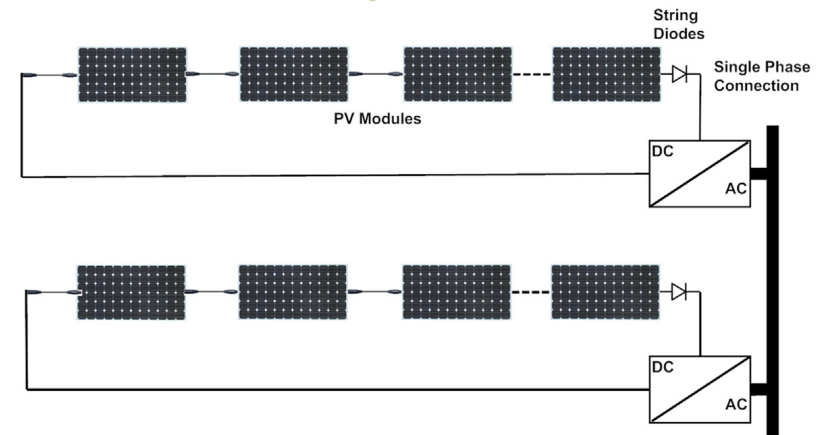


# PV Inverter configurations

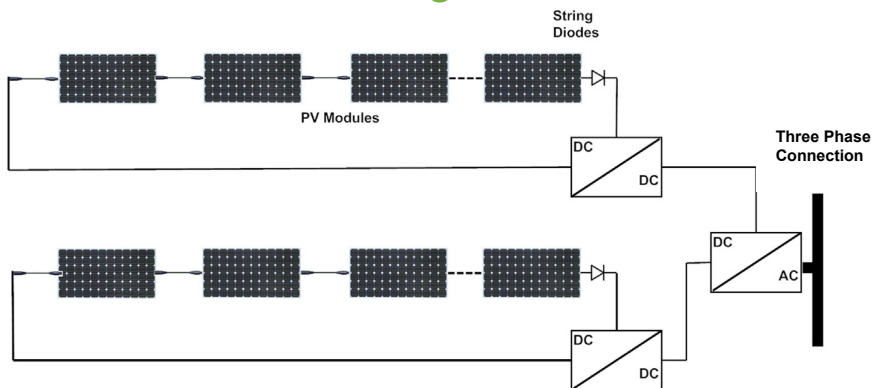
## Centralized inverter



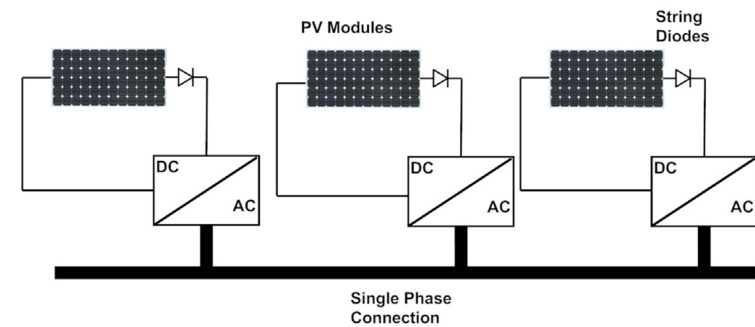
## String inverter



## Multi string inverter



## Micro-inverter



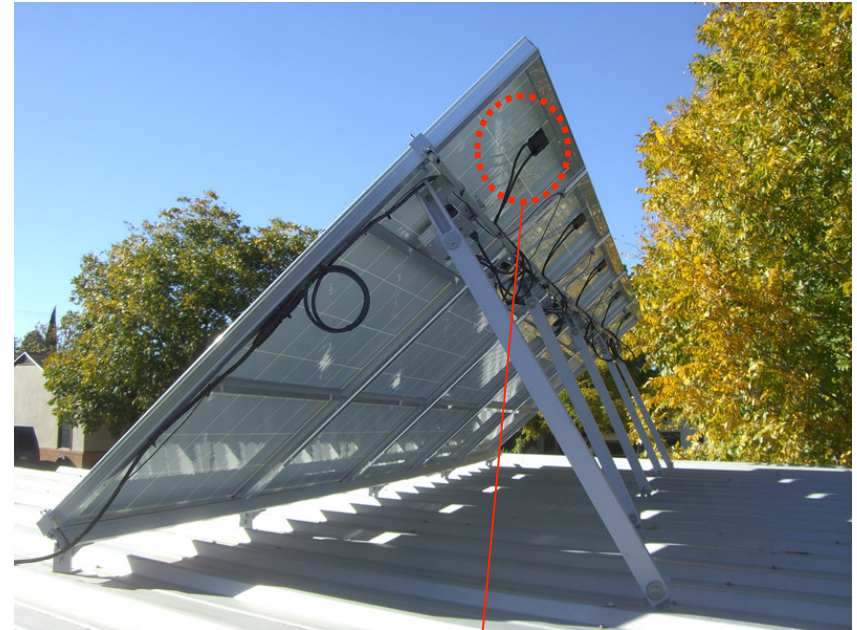
# Micro-Inverters

## Application/features:

- Module level power conversion
- Easy to install
- Better performance under shading conditions, different inclination/orientation
- Solution for BIPV market
- Data for every PV module

## Challenges:

- Price
- Efficiency
- Cable losses
- Lifetime
- Temperature issues

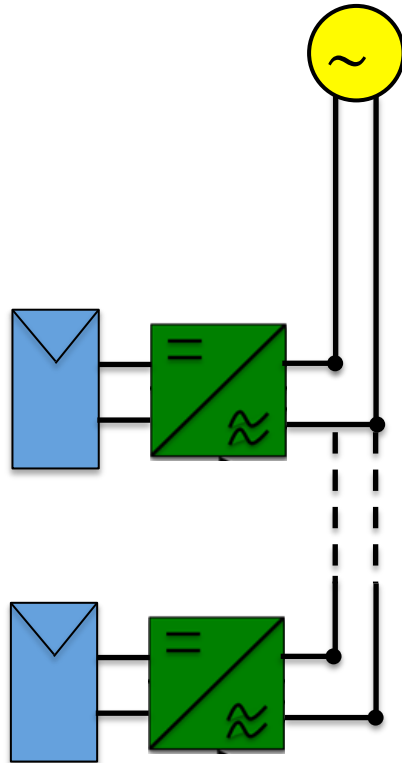




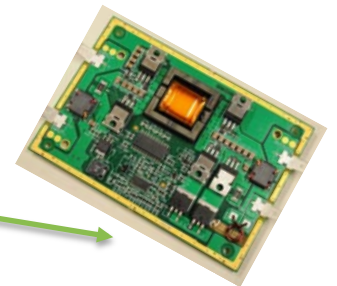
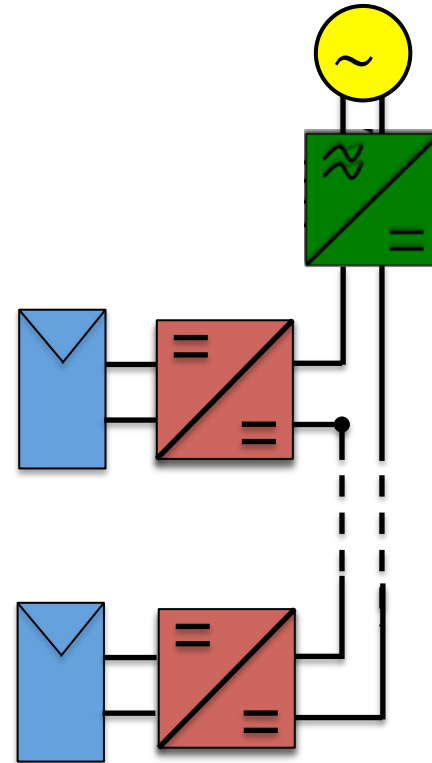
# From Micro-Inverters to Power optimizers

- A power optimizer is a DC/DC converter connected to each PV module
- Replaces the traditional solar junction box

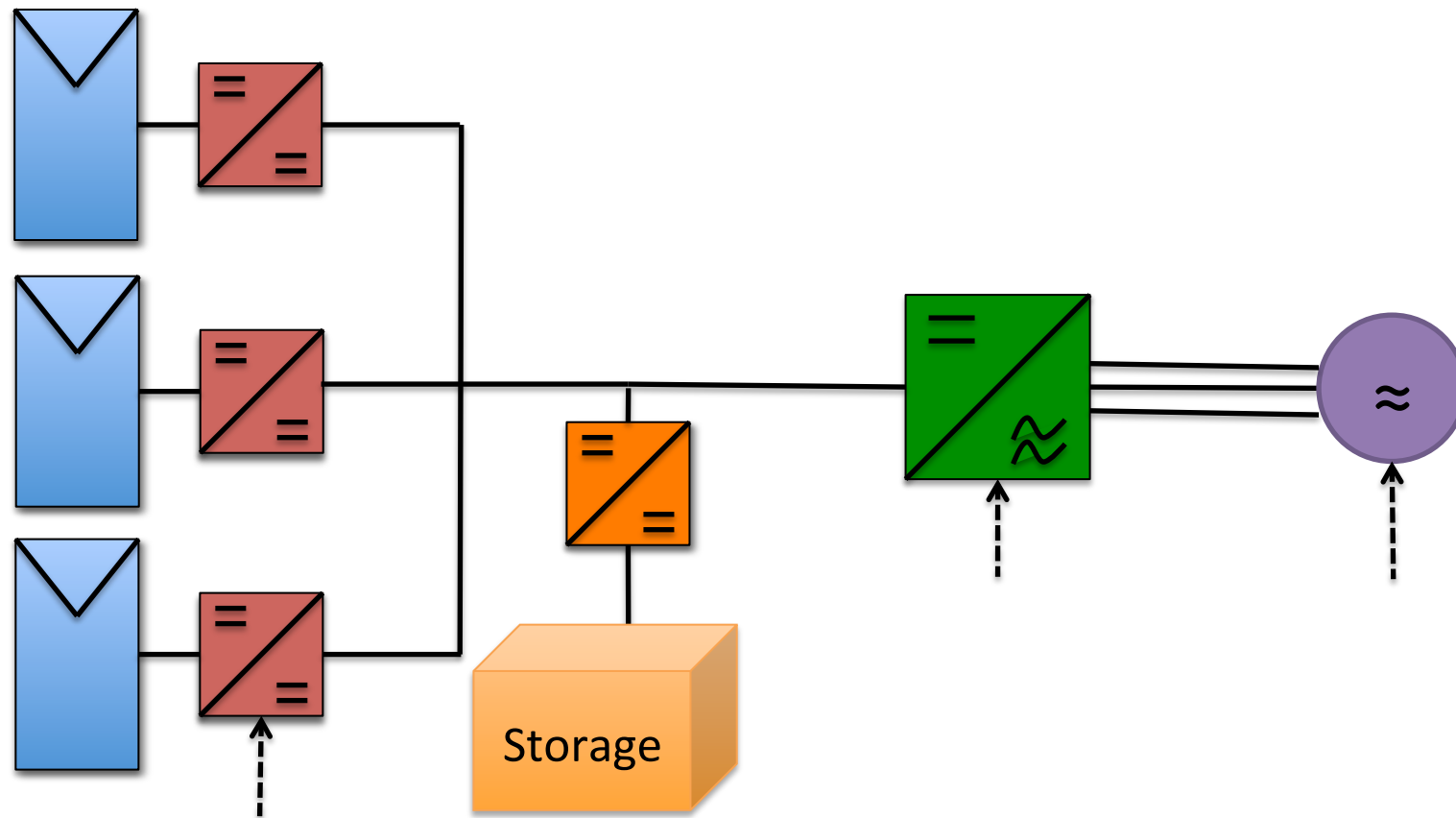
Micro-inverters



Power optimizers



Or ... parallel alternative?



🌿 high boost, but more robust + trend towards DC-grids

# Next challenges for PV power converters

## Power semiconductor technology:

- ☐ Higher switching frequency
- ☐ Increased power density
- ☐ Higher working temperatures
- ✓ New materials (SiC, GaN)
- X But some issues (driving, EMC, passives,...)

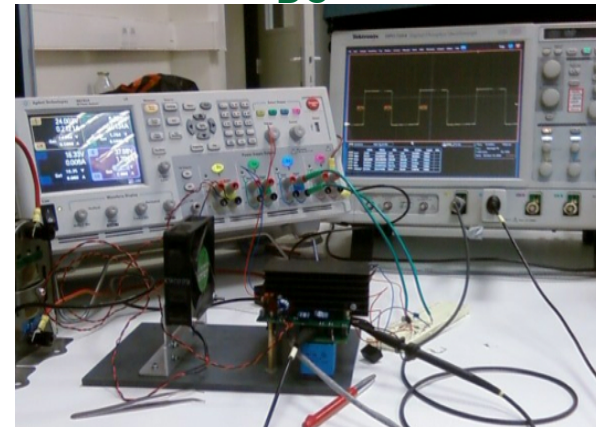
## Smart features

- ☐ Multiple MPPT trackers
- ☐ PFC capability
- ☐ Enhance monitoring
- ☐ Integration of storage
- Full digital control (uC, DSP, FPGA,...)

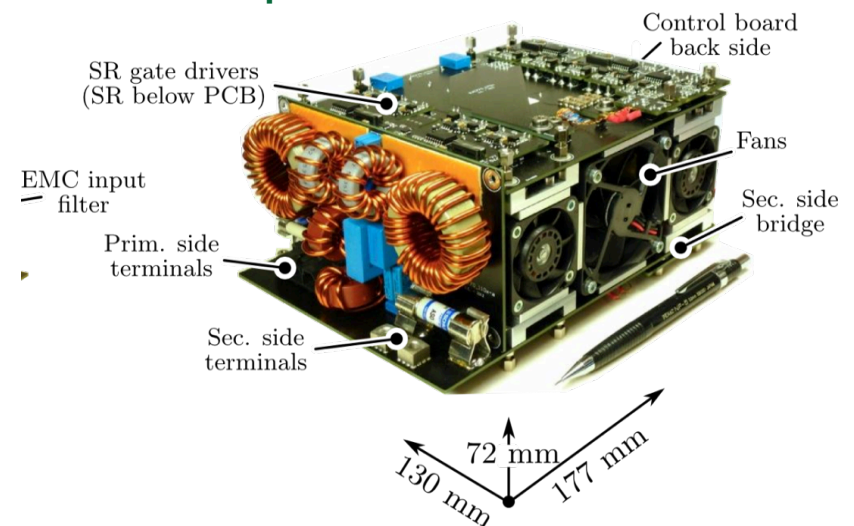
## Longer lifetime

## Reliability

### GaN high-boost DC/DC

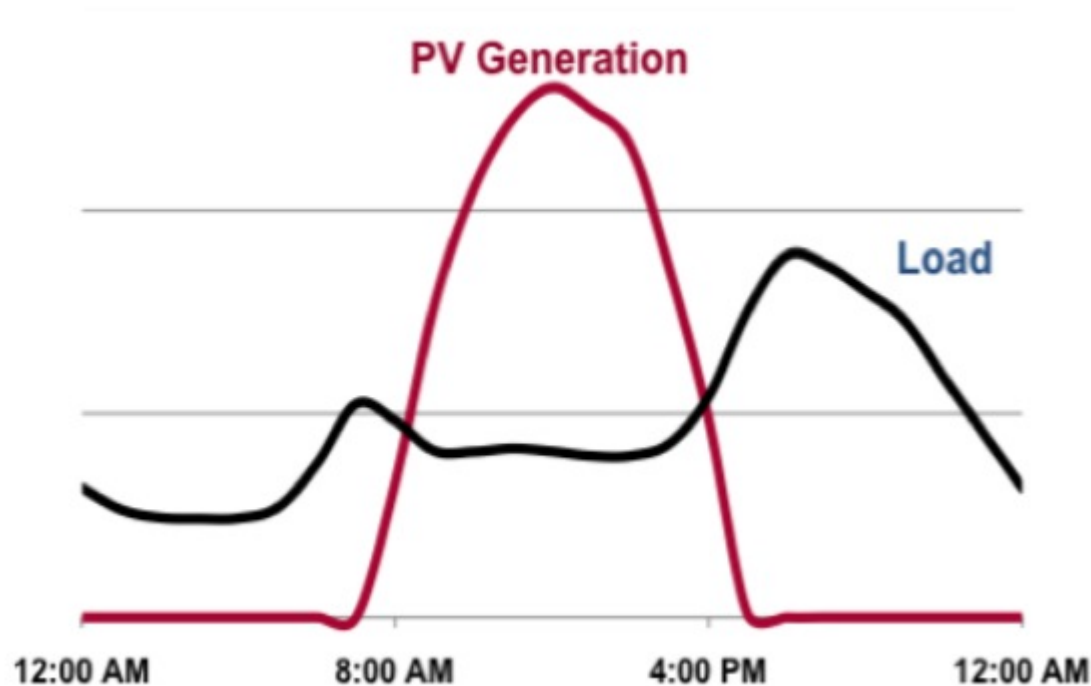


### Ultra compact resonant DC/AC interface



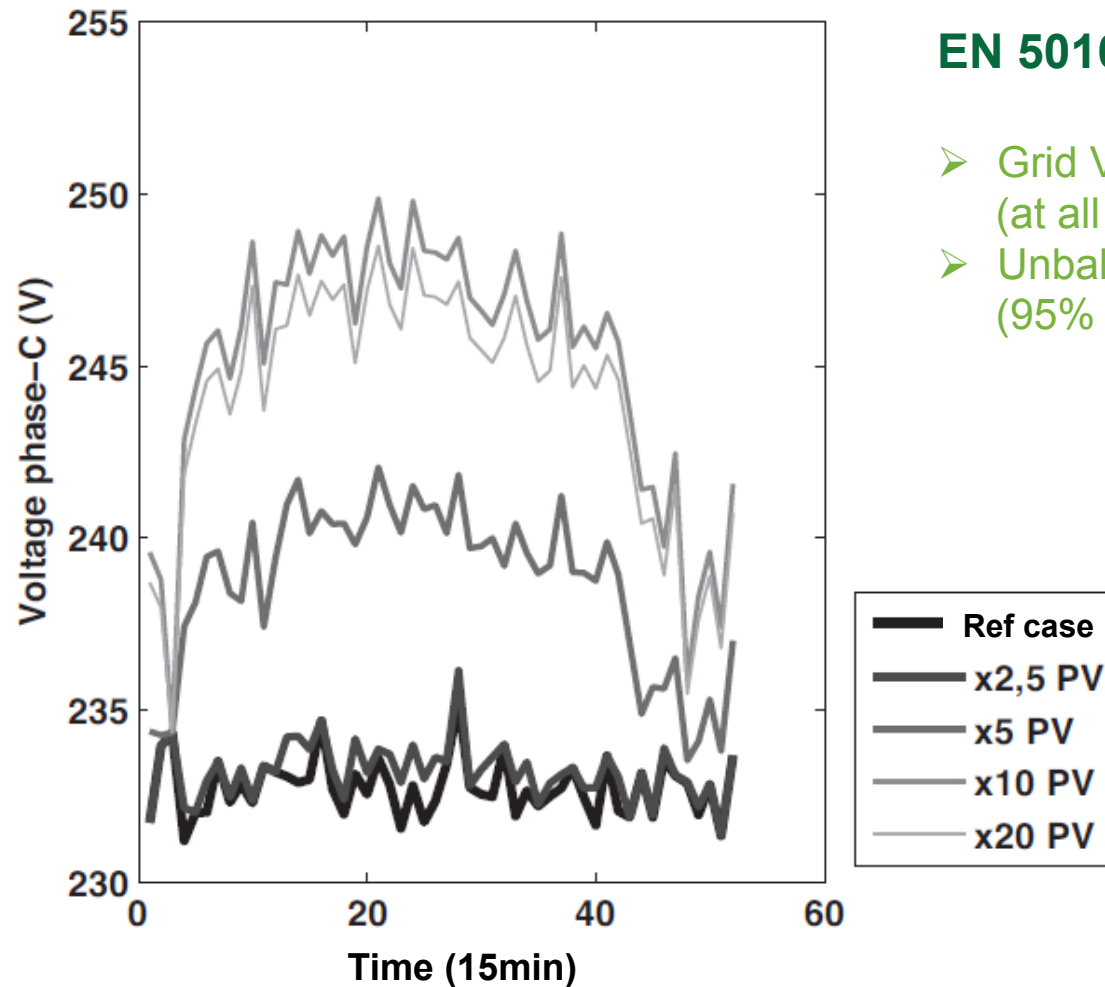
## Problem: local injection of PV power

- 🌿 PV injection does not coincide with the consumption peak



Source: [solarpowerworldonline](http://solarpowerworldonline)

## Excess of PV power can result in overvoltage in your local feeder

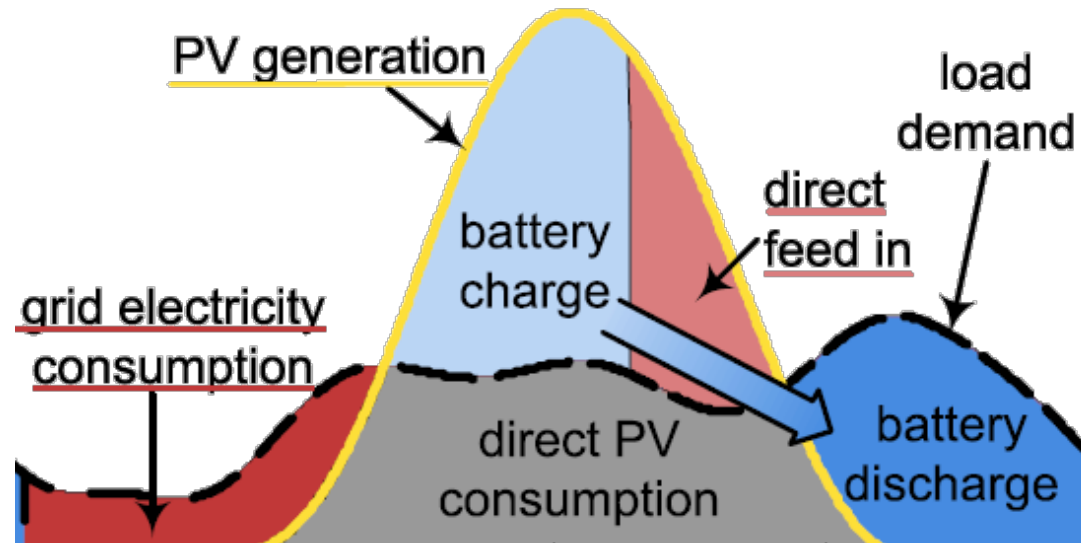


### EN 50160 standard:

- Grid Voltage < 230V  $\pm$ 10% (=253V) (at all times)
- Unbalance between phases <  $\pm$ 2% (95% of time)

Large PV penetration can violate voltage standard, especially in rural areas

## Solution = storage ?



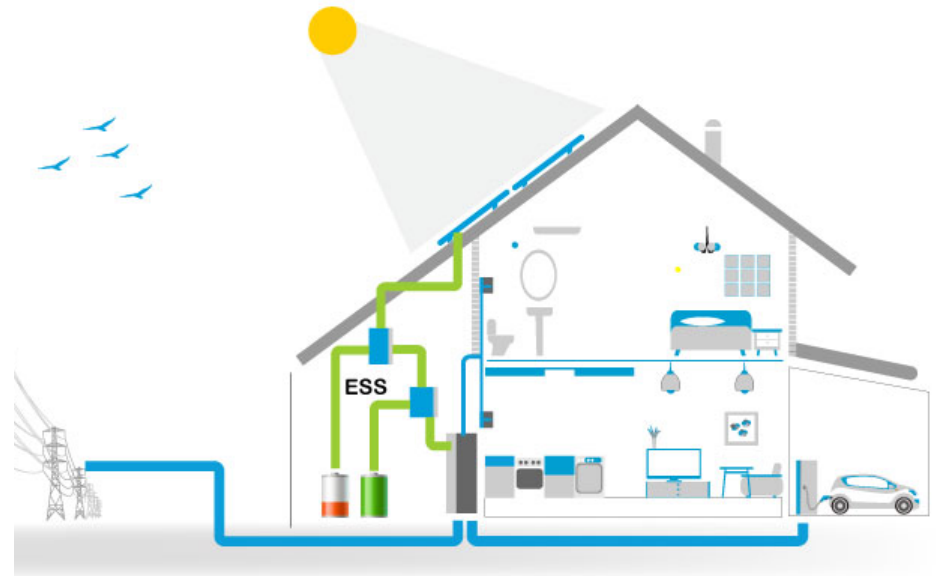
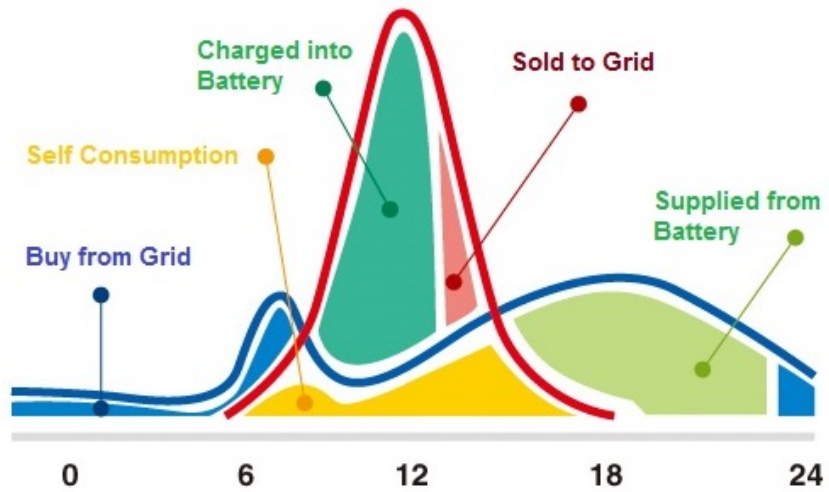
### Drivers for storage

- ✦ Peak shaving (grid support)
- ✦ Balancing
- ✦ Feed-in tariff
- ✦ Electricity cost
- ✦ Stand-alone operation



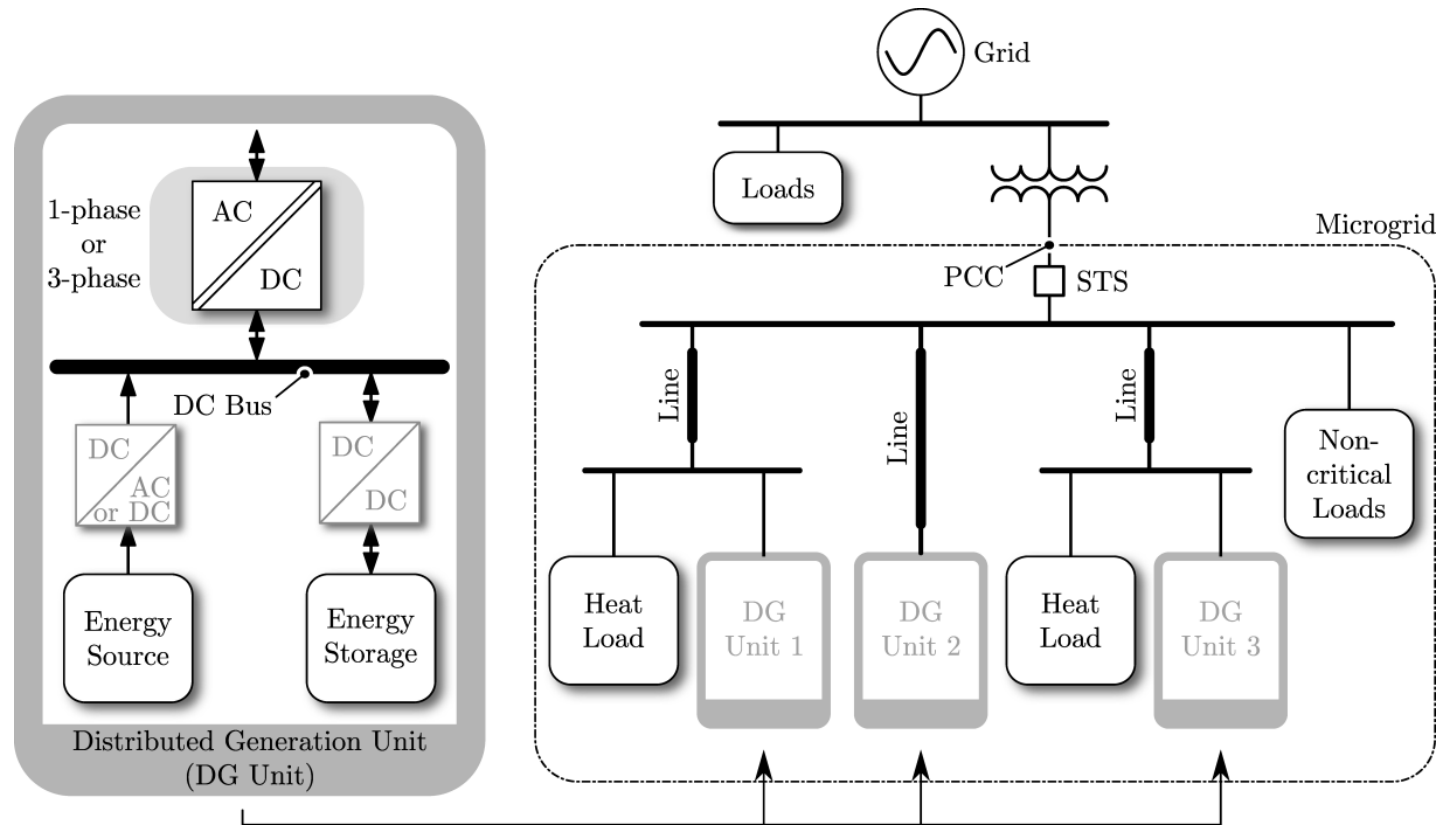
Product Line	Automotive	Residential	Commercial
Power/Energy	310 kW / 85 kWh	5 kW / 10 kWh	200 kW / 400 kWh+

## Why storage is needed... in every house



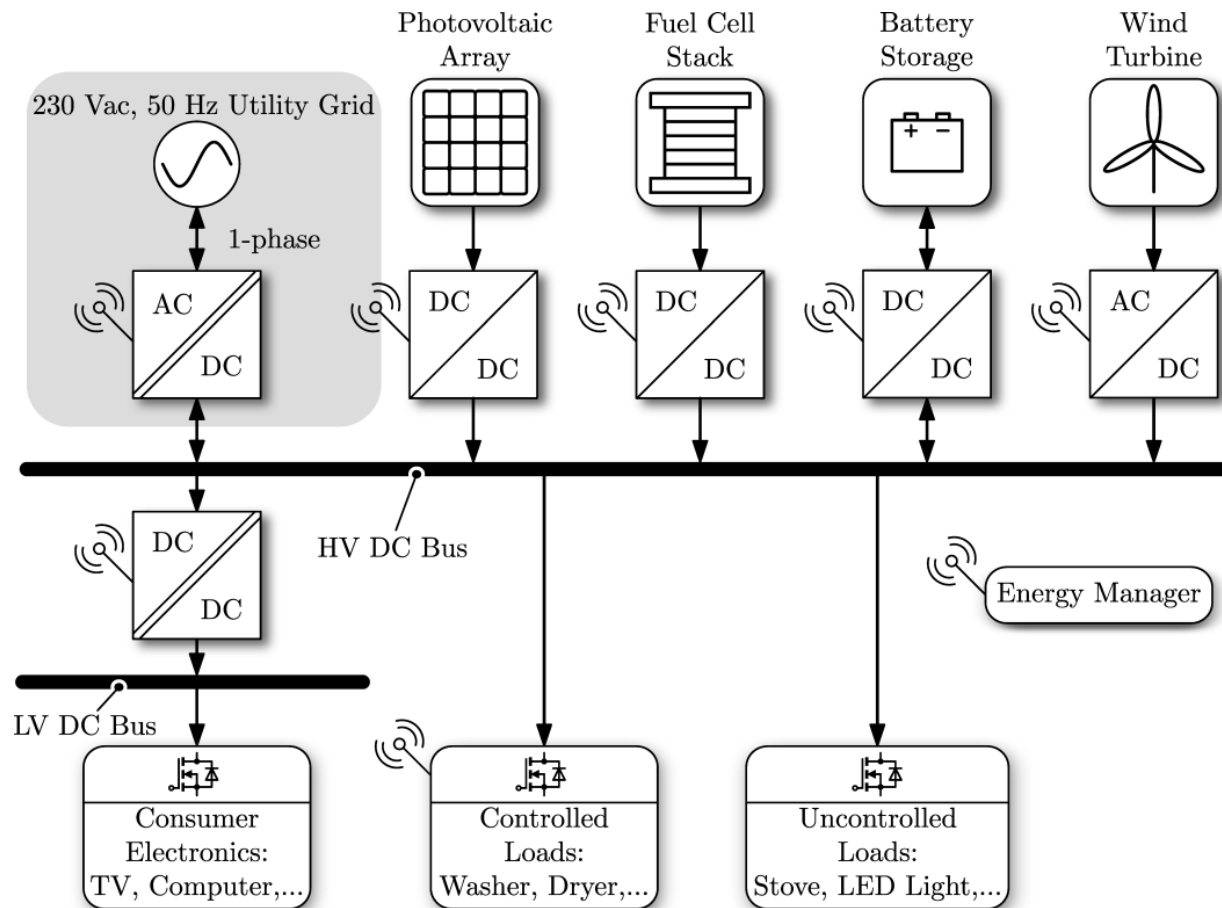


## Next step: From Tesla's AC grid...



- Many AC/DC – DC/AC conversions
- Many DC loads (e.g. LED lighting, Electric Vehicle charging)

# The return of ... the DC grid ?



Especially for (new) buildings, districts ...

Challenges: cabling, connectors, protection, ...

# What would Edison think of all this?

## THE CURRENT WAR

THE TALE OF AN EARLY TECH RIVALRY

### DC

#### DIRECT CURRENT

The flow of electricity is in one direction only. The system operates at the same voltage level throughout and is not as efficient for high-voltage, long distance transmission.

Direct current runs through:

- Battery-Powered Devices
- Fuel and Solar Cells
- Light Emitting Diodes

### AC

#### ALTERNATING CURRENT

Electric charge periodically reverses direction and is transmitted to customers by a transformer that could handle much higher voltages.

Alternating current runs through:

- Car Motors
- Radio Signals
- Appliances

**THOMAS EDISON VS. NIKOLA TESLA**

**DC (Direct Current) WAR OF CURRENTS: ELECTRICAL TRANSMISSION IDEA AC (Alternating Current)**

**EDISON FRIES AN ELEPHANT**

In order to prove the dangers of Tesla's alternating current, Thomas Edison staged a highly publicized electrocution of the three-ton elephant known as "Topsy." She died instantly after being shocked with a 6,600-volt AC charge.

**WAR OF CURRENTS OFFICIALLY SETTLED**

In 2007, Con Edison ended 125 years of direct current electricity service that began when Thomas Edison opened his power station in 1882. It changed to only provide alternating current.

**NOBEL PRIZES**

In 1915, both Edison and Tesla were to receive Nobel Prizes for their strides in physics, but ultimately, neither won. It is rumored to have been caused by their animosity towards each other and refusal to share the coveted award.

**Keeping the balance...**

SOURCES: CHENEY, MARGARET, "TESLA: MAN OUT OF TIME" | UTH, ROBERT, "TESLA: MASTER OF LIGHTNING." | THOMASEDISON.COM | PBS.ORG | WEB.MIT.EDU | WIRED.COM

A COLLABORATION BETWEEN GOOD AND COLUMN FIVE

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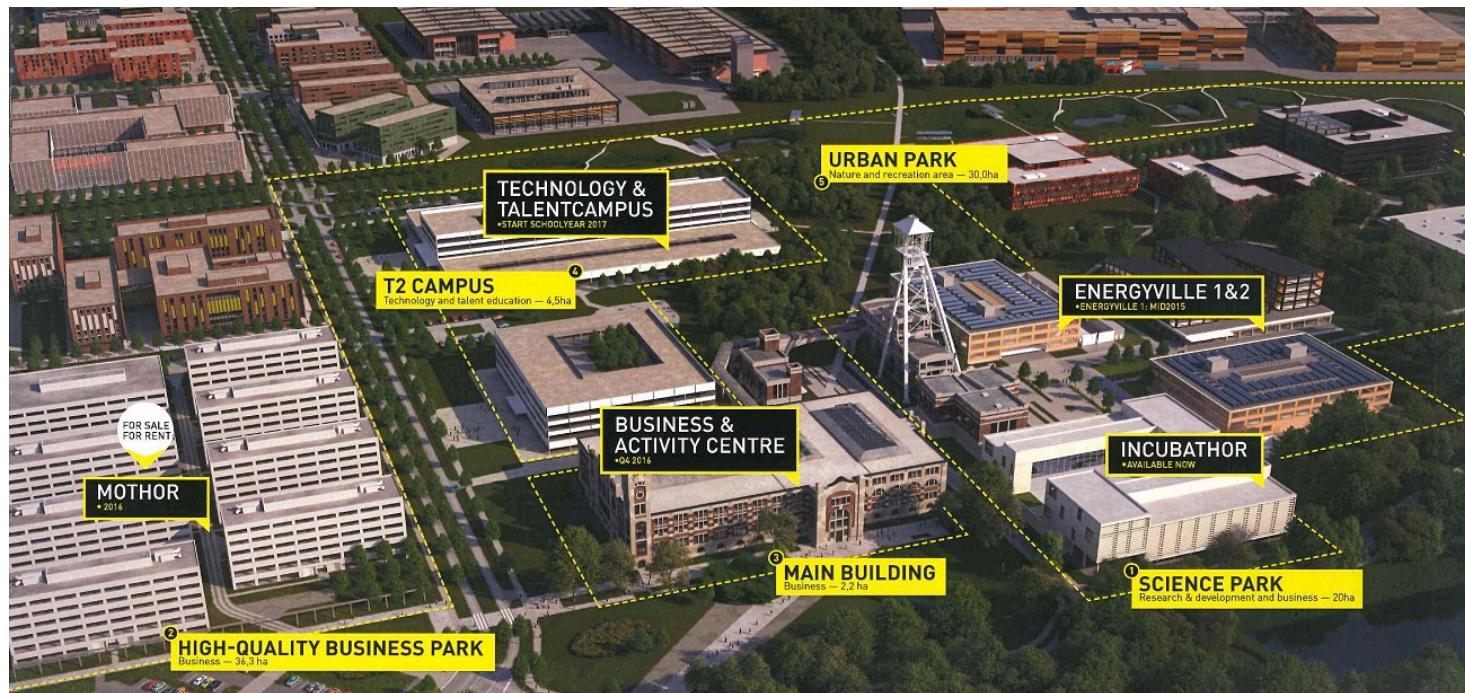
# Labs

- 🌿 Battery Testing Lab
- 🌿 Home Lab
- 🌿 Smart Grid  
Infrastructure Lab
- 🌿 Thermo Technical  
Lab
- 🌿 Medium Voltage  
Lab
- 🌿 PV Metrology Lab
- 🌿 Matrix Lab





## Embedded in an eco-system







More info?

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