Dr. Johan Driesen

Download Presentation

Power Electronics as the Enabling Technology for Sustainable Energy

TECHNICAL SESSION 5

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About the Speaker

- Professor KU Leuven, Belgium
- MSc & PhD KU Leuven
- Postdoc at Imperial College (London) & UC Berkeley (US)
- Research topics: power electronics, renewable energy, electrical storage, smart grids, electric vehicles, energy policy
- Programme director international MSc in Energy @ KU Leuven
- Active in EnergyVille research center

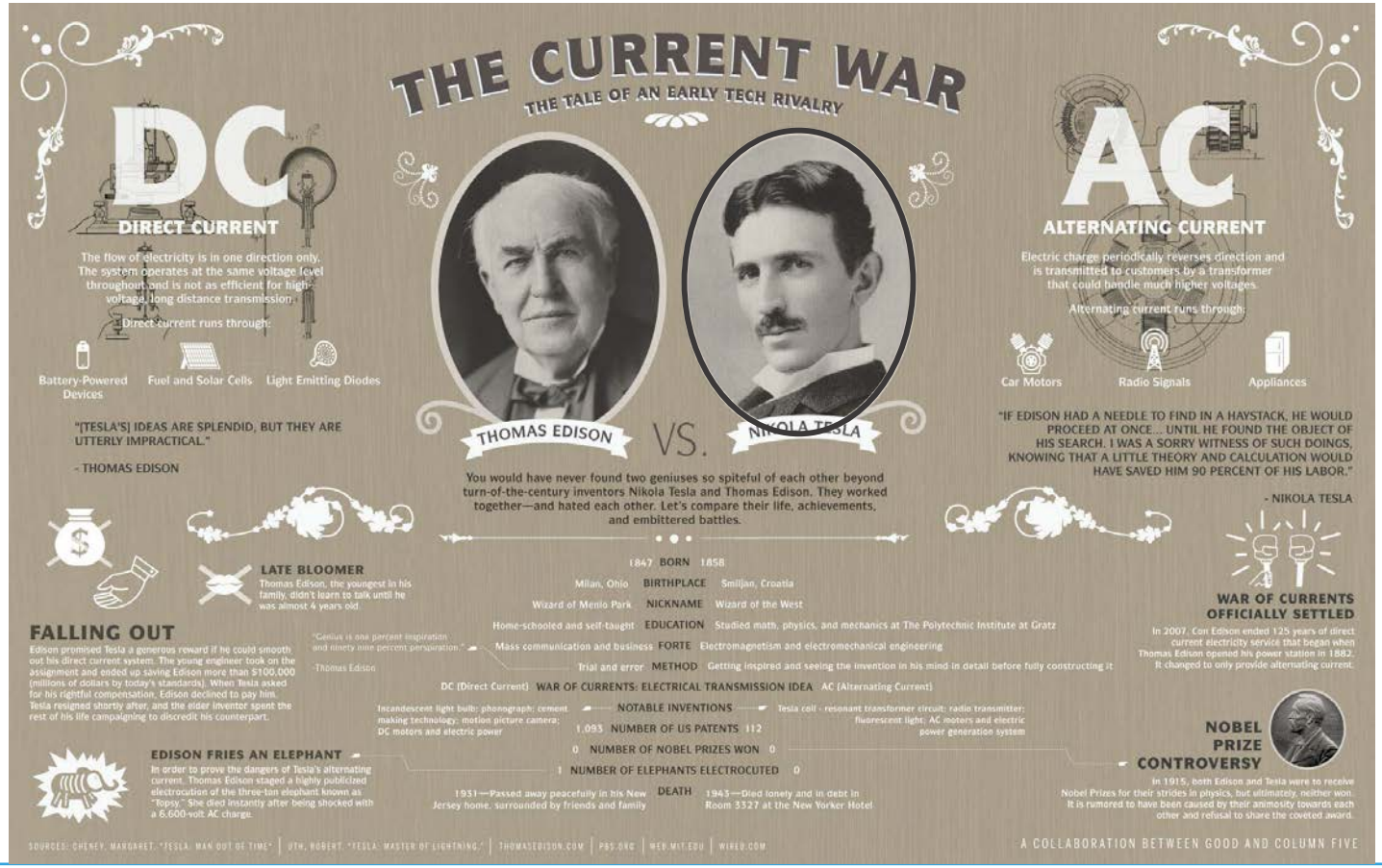
Overview

- From microgrids to smart grids
- Power electronics: a breakthrough technology
- Power electronics for renewables
- The role of batteries
- Rethinking the power system

Introduction

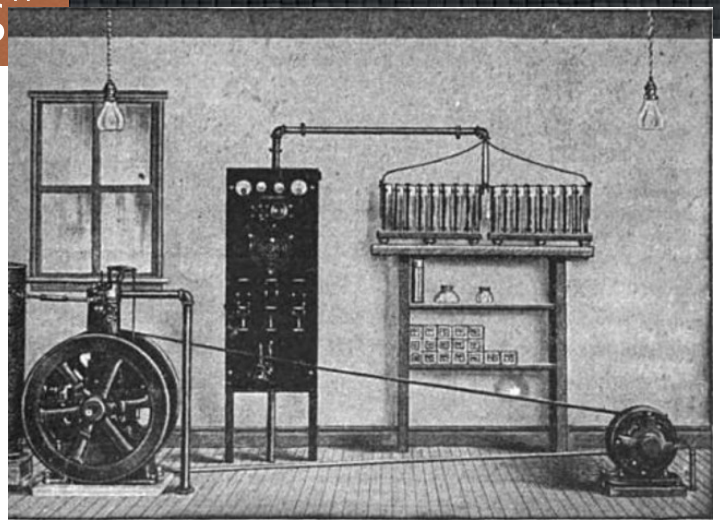
From microgrids to smart grids

Edison vs. Tesla: how “modern” electricity started



The first networks = “(DC) microgrids”

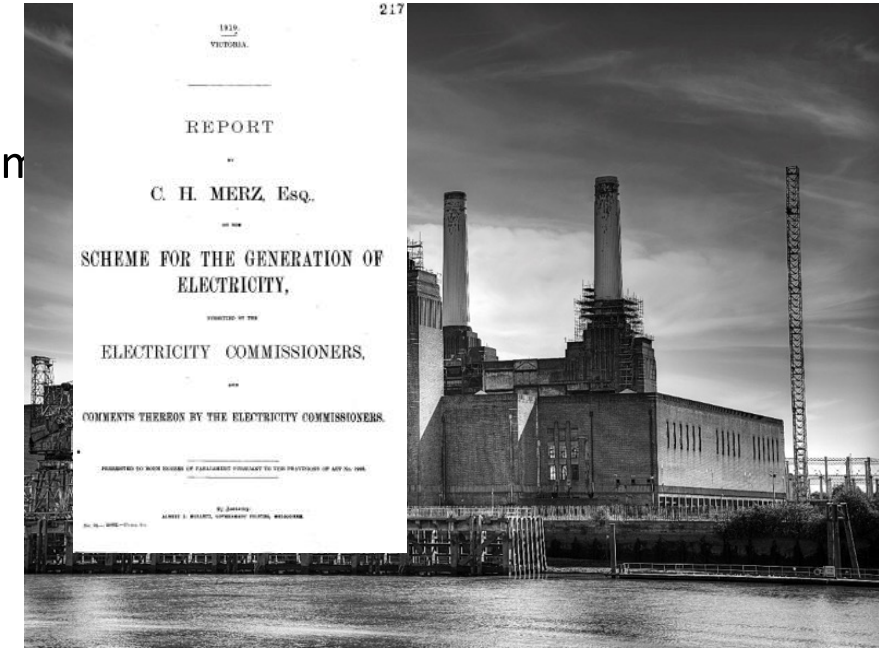
- Small isolated autonomous grids
  - Mainly DC technology
  - Local generator + lead-acid batteries
  - Serving lights & drives



- Around 1900: more electric cars than combustion vehicles

Switching to AC power, dominating 20th century

- AC power allowed longer distances
- 50/60 Hz became standard
- Electricity:
  - Made the work place safer & healthier (drives)
  - Caused less fires (no candles, gas light)
  - Initiated emancipation of women (electrification of hom
- Central power plants
  - Large hydro
  - Large thermal (coal)
  - Large (industrial) loads
- Large-scale grid interconnection
  - Balancing over larger system
  - Spread reserves

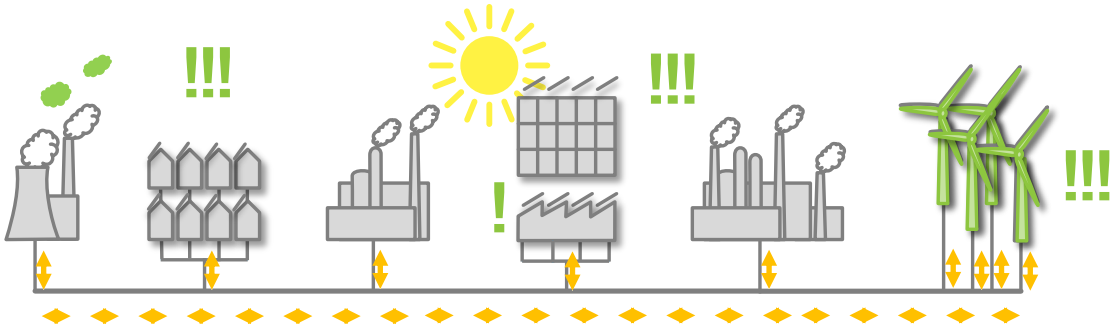


21st century: Energy Transition

- In

- The rest of the world…
  - Still 840 Million people without power
  - China: transition towards less pollution
  - US: transition thanks to (fracking) gas and cheap renewables
  - Local renewables cheapest source for developing nations

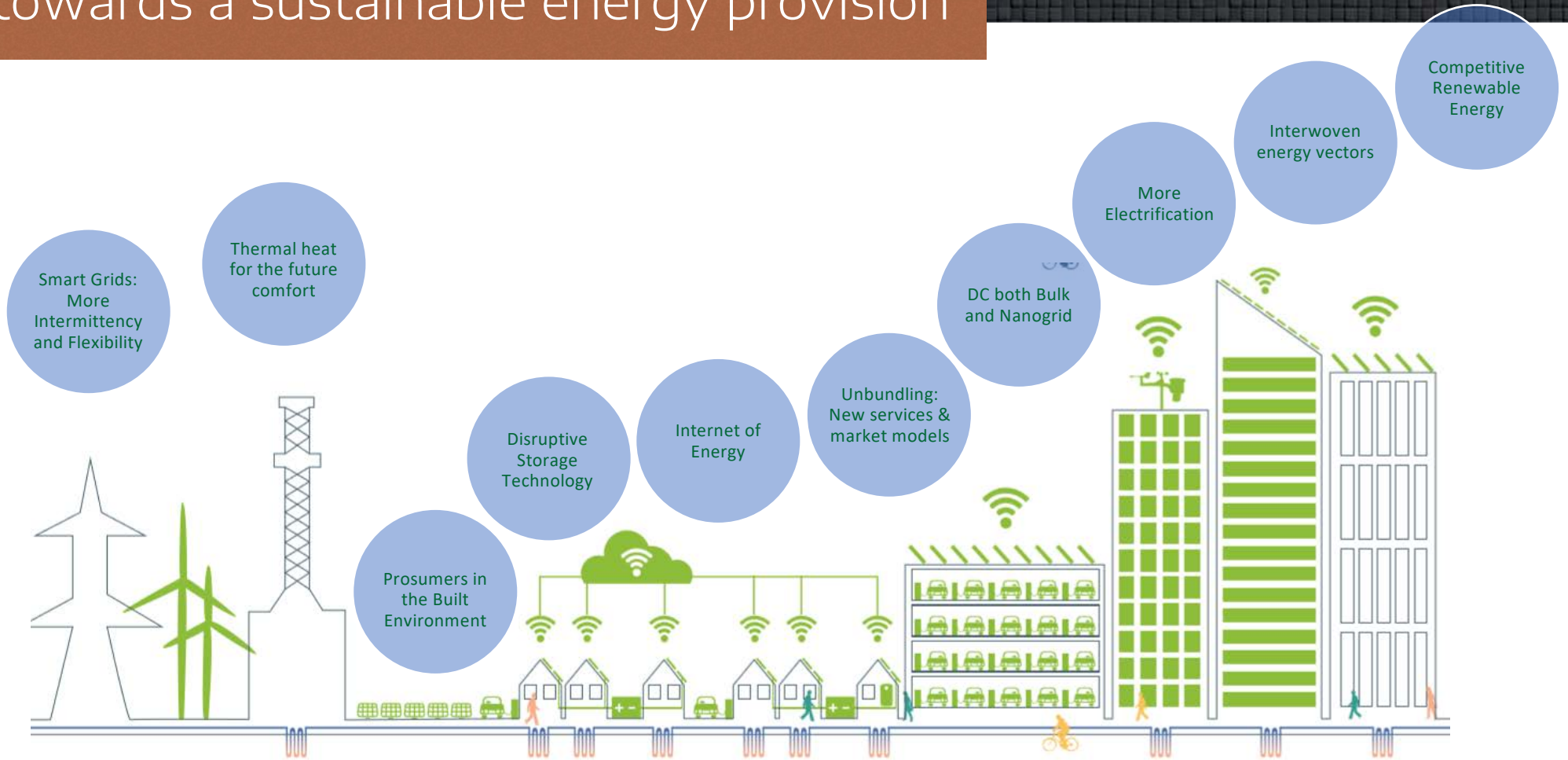
Challenges for the electricity system



- Demand drives generation ↔ Generation drives demand
- Bidirectional flows
- Techno-economical puzzle:
  coordinated grid actions with all the players involved

From a classic model…

...towards a sustainable energy provision

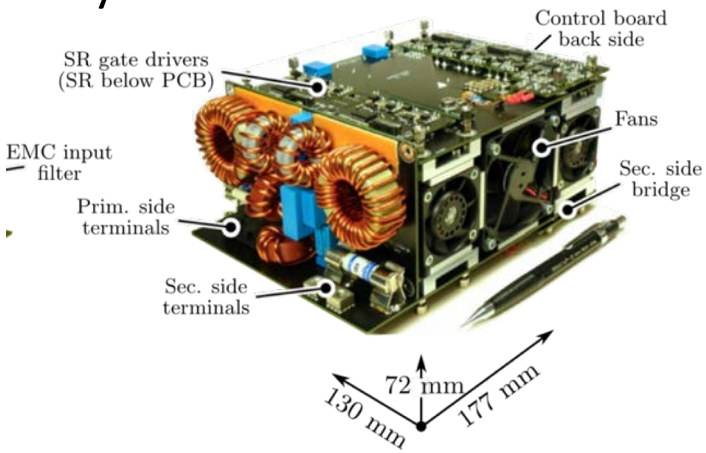


Power electronics

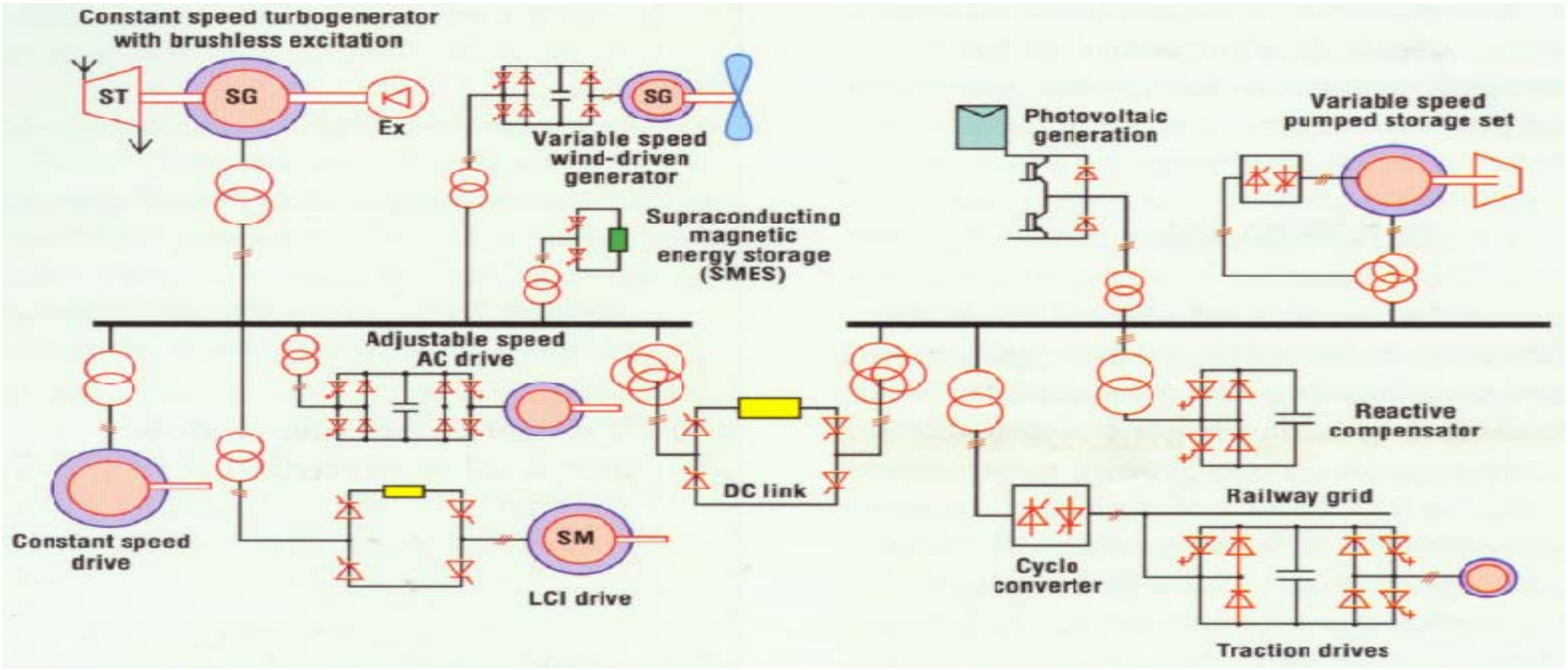
breakthrough technology

Power electronics definition

- Power electronics (PE) is used to convert electrical energy to an alternative form
  - Different voltage, current, # phases, frequency
- Comparison with ICT
  - In ICT-electronics voltage, current and frequency is used to transfer information
  - in power electronics energy is converted, so efficiency is key
- Circuits
  - analogue in priniciple
  - the energy often gets ‘digitally modulated’
  - EMC problems

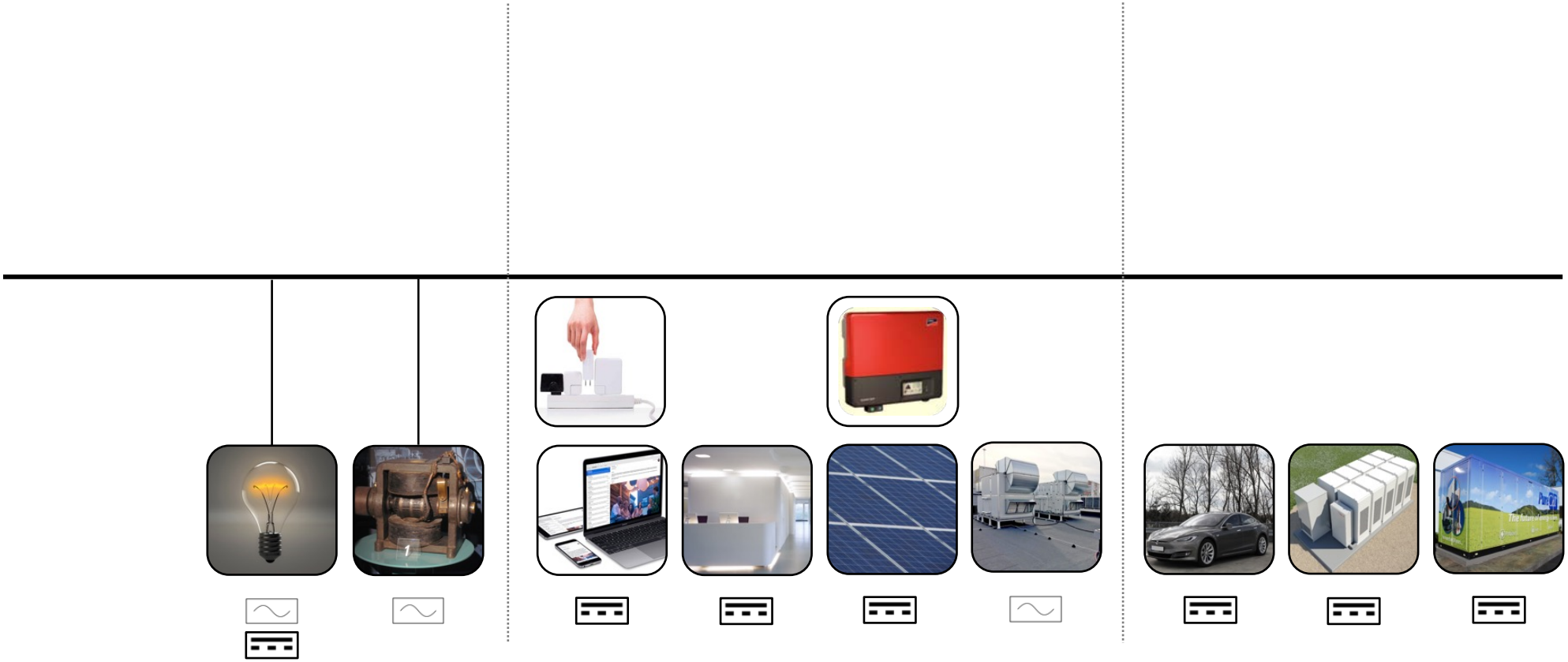


(current) power electronic dominated grids

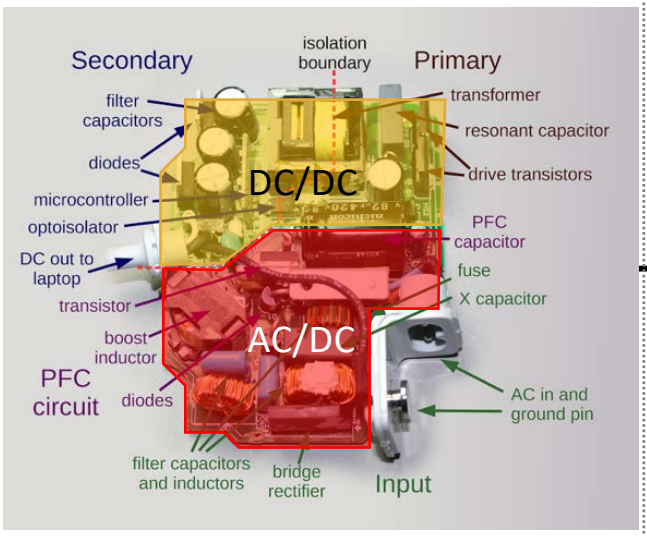


Source: KEMA

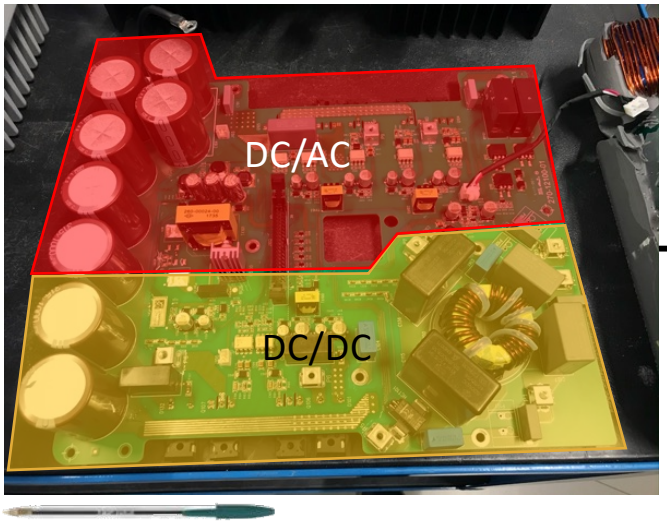
Omnipresent power converters

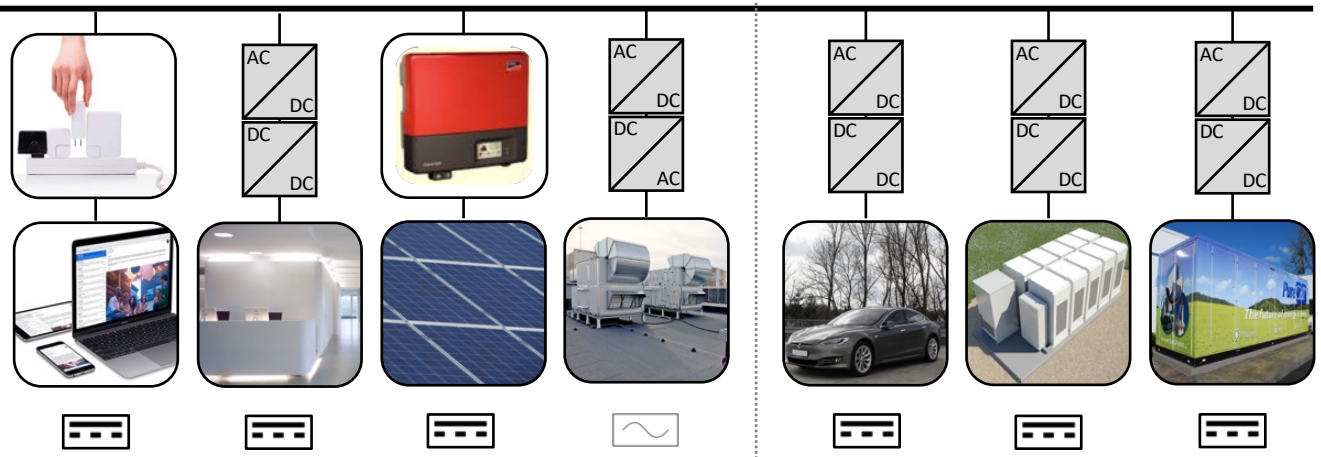


AC/DC power supplies

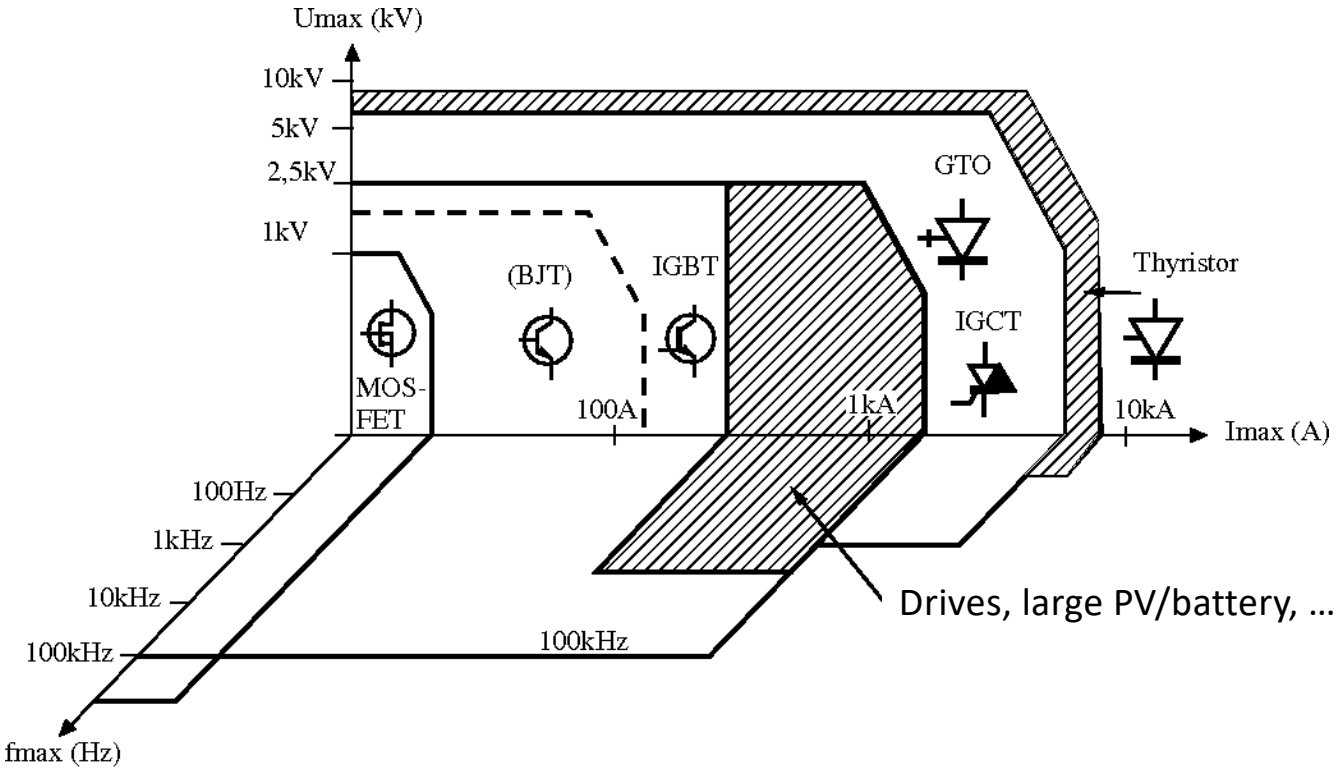


DC/AC Photovoltaic Converters

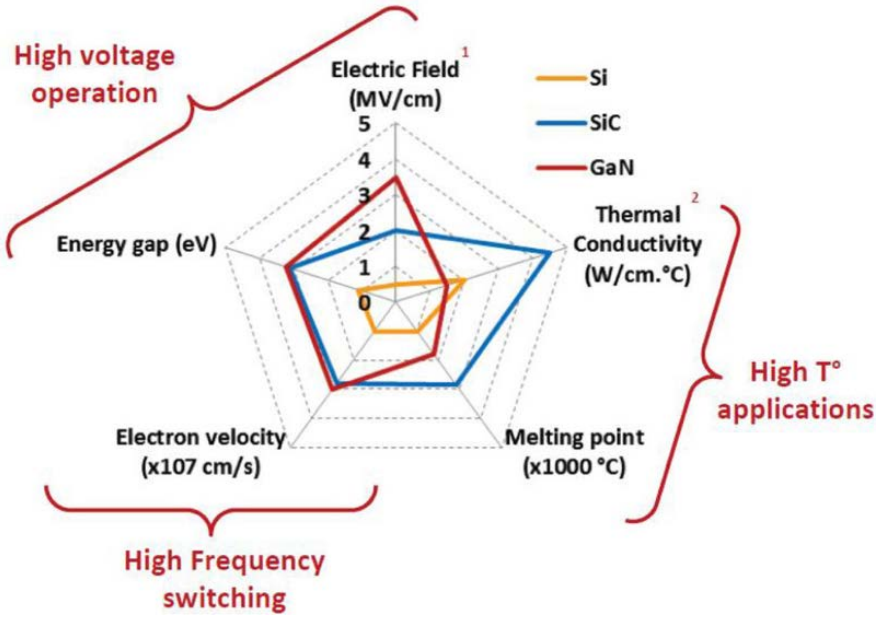


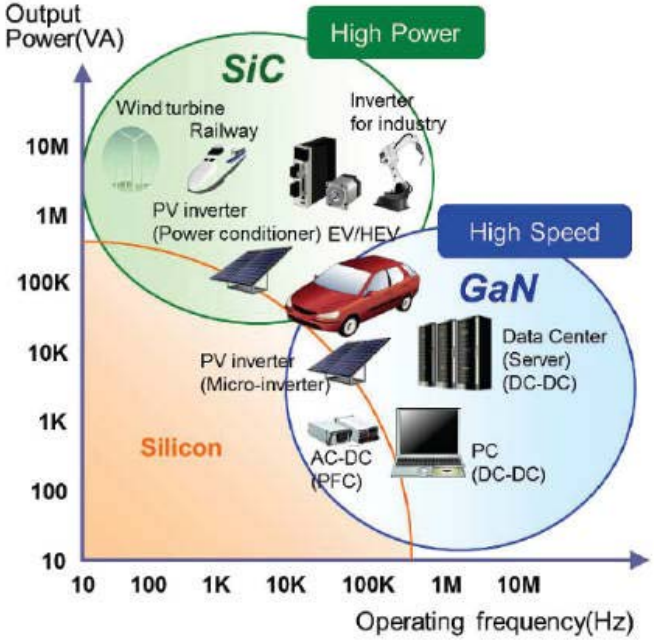


Currently available PE components



What “new”semiconductor material fits best?





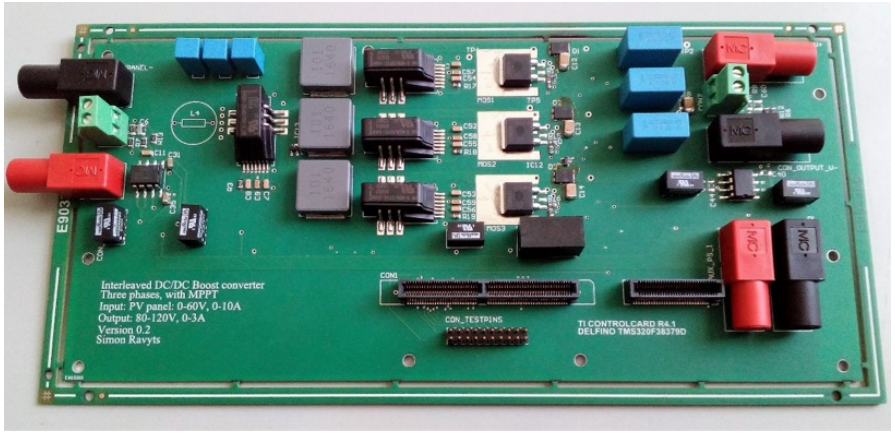
SiC for high power voltages (>1kV) with high current
= niche market

GaN on Si for high frequency at midrange voltages (<1kV, up to 100A)
= mass market

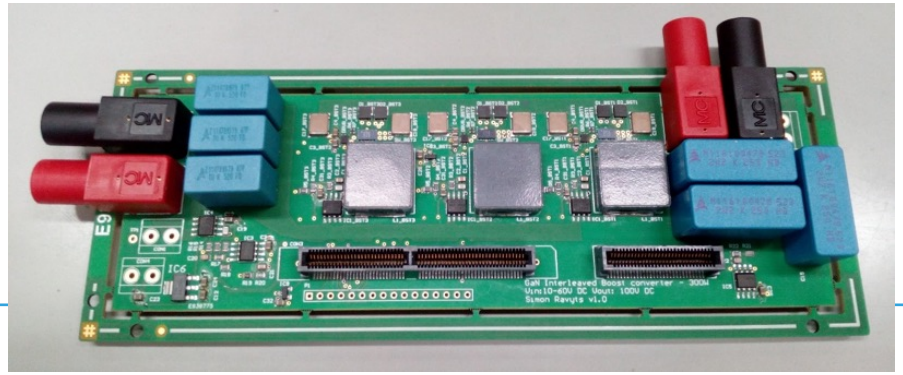
Comparison of Si vs. GaN

- Two PCB prototypes of PV power optimizer
  - (a) employs Si MOSFETs
  - (b) employs GaN HEMTs and is three times more compact

(a)
115x250x30 mm³



(b)
55x175x30 mm³



Board	Si MOSFET	GaN HEMT
Switching frequency	100 kHz	200 kHz
Switch	Infineon IPB320N20N3	EPC 2047
$V_{ds,max}$	200 V	200 V
$I_{d,max}$	34 A	32 A
$R_{ds,on,max}$	32 mΩ	10 mΩ
$Q_{g,tot,max}$	29 nC	10,2 nC
C_{oss}	180 pF	585 pF
Footprint	10,7x16,05 mm²	4,6x1,6 mm²
Diode	VS-10CSH02HM3	VS-10CSH02HM3
$V_{R,max}$	200 V	200 V
V_F	0,75 V	0,75 V
Q_{rr}	53 nC	53 nC
Footprint	6,8x4,8 mm²	6,8x4,8 mm²
Inductor	BOURNS SRP1770TA	BOURNS SRP1770TA
Inductance	100 μH	68 μH
$R_{L,DC,max}$	118 mΩ	80 mΩ
Footprint	18,5x12,5 mm²	18,5x12,5 mm²
Driver	Silicon Labs Si8272	Texas Instruments UCC27611

Integrated (GaN) components

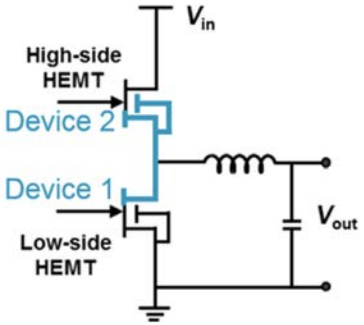
GaN IC (imec)

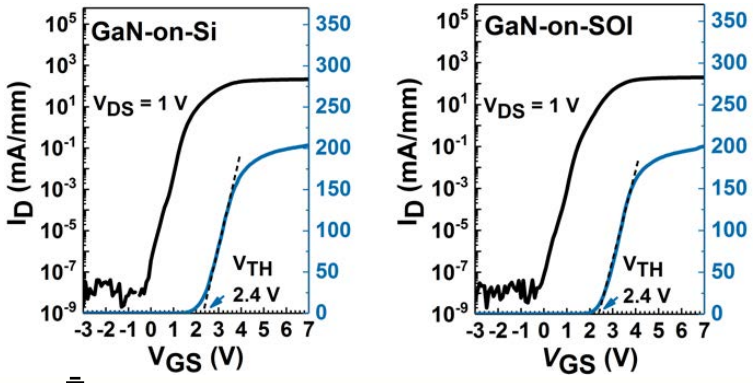
GaN IC : GaN-on-SOI for monolithic integration

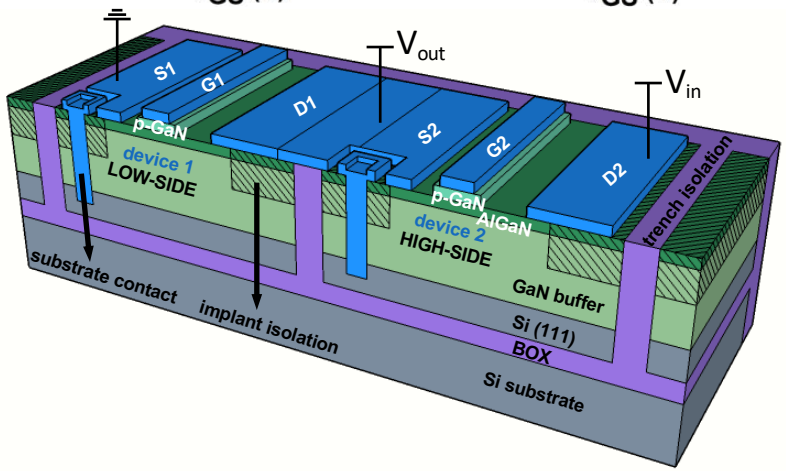
- Half-bridge
- GaN driver
- Schottky diodes

Isolation of common Si substrate by :

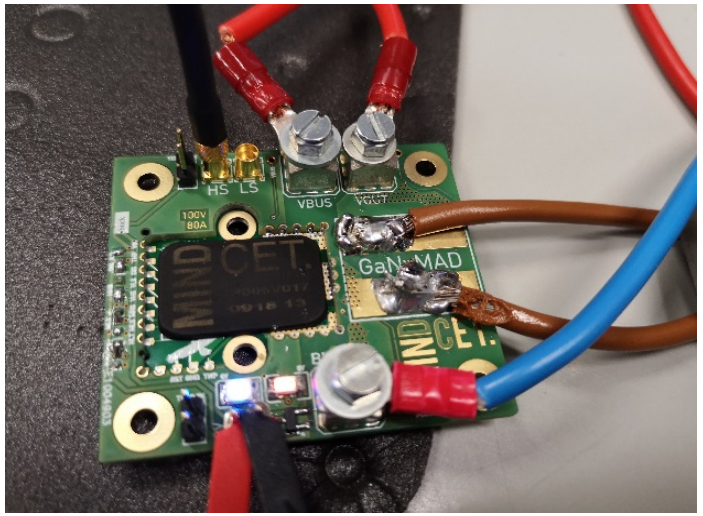
- Buried oxide
- Deep trench isolation
- Deep substrate contact







- GaNyMaD PoL Module
  - 300 kHz
  - Peak eff = 95,2%
  - 48V to 12V

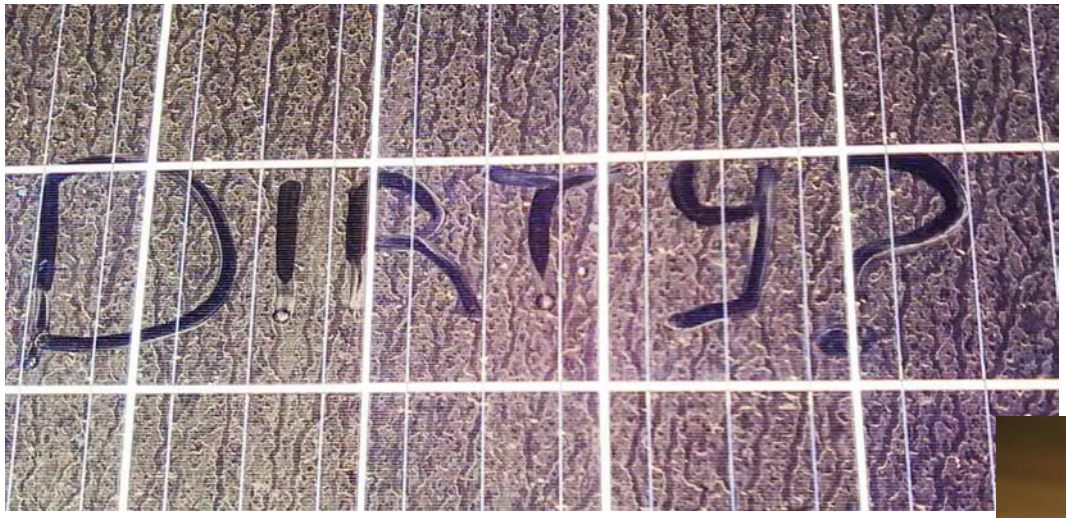


Power electronics for renewables

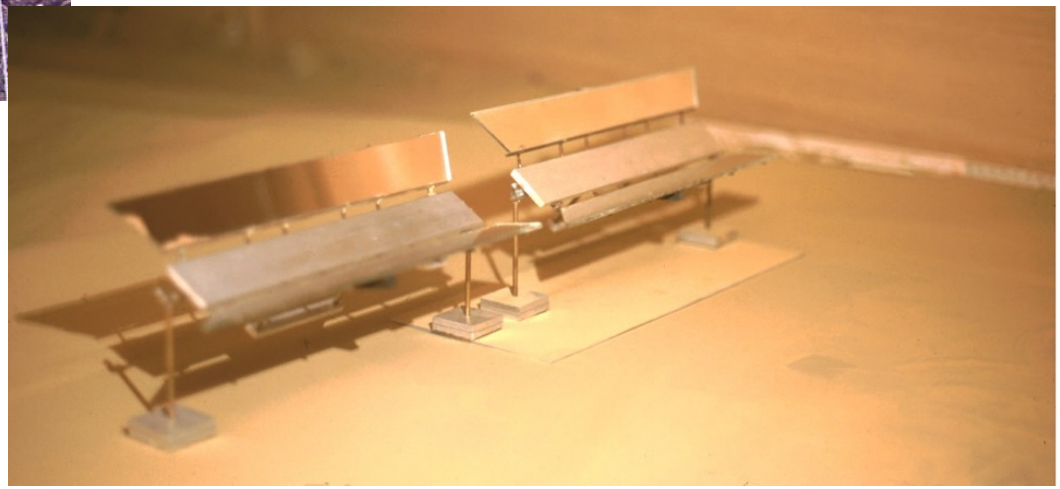
New trends in photovoltaics

Solar farms

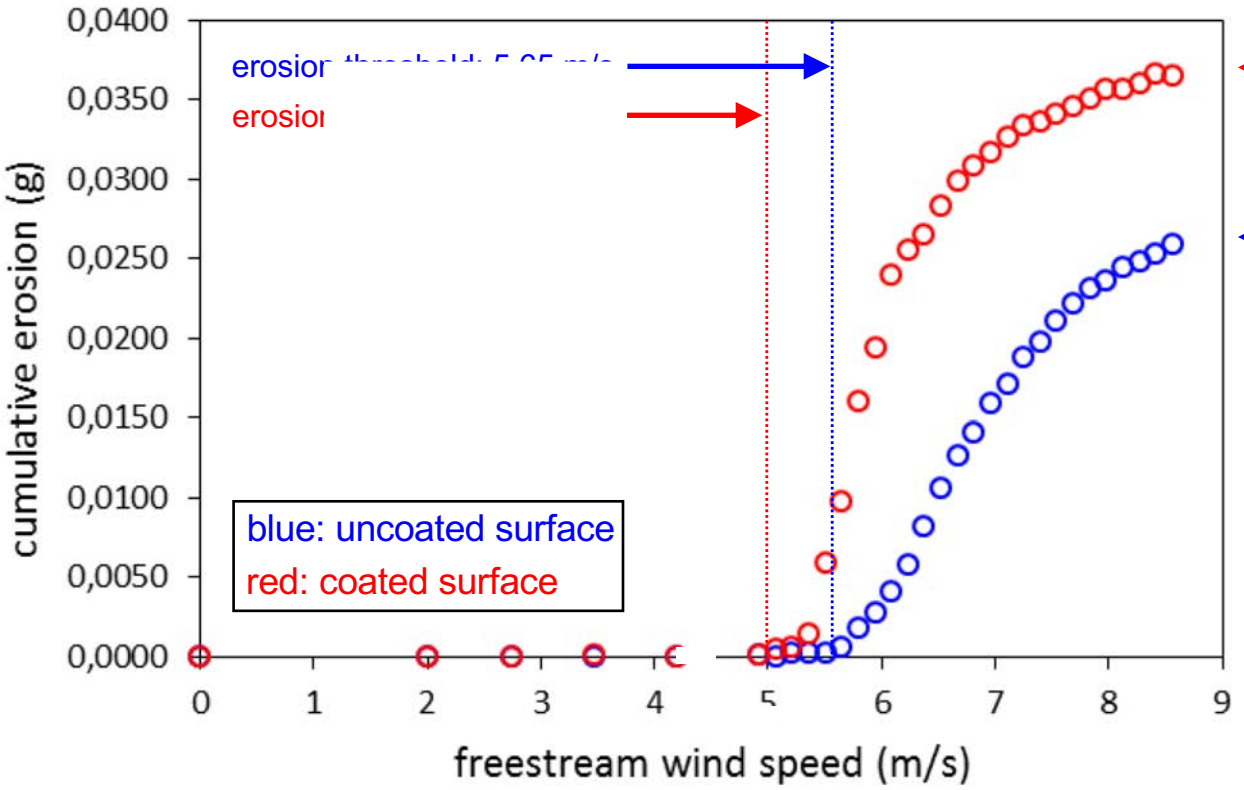
Dust in PV systems?



Wind tunnel testing at KU Leuven



Effect of an anti-soiling coating on dust erosion ?

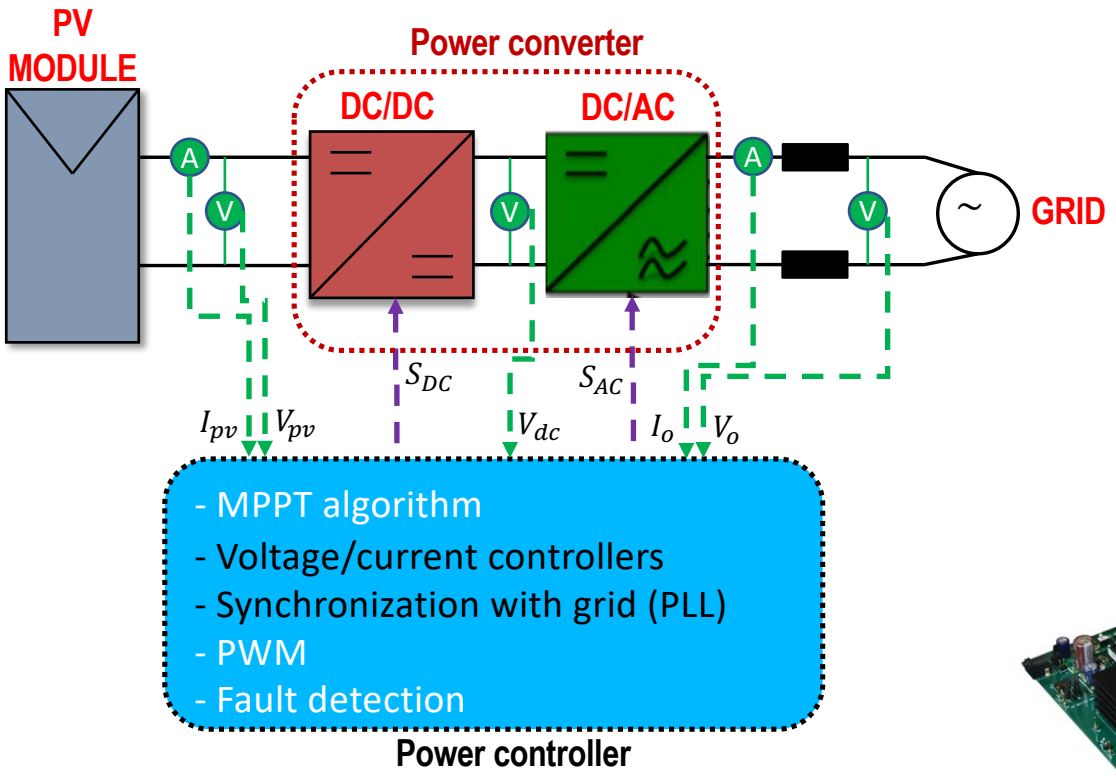


73% of original amount of dust eroded

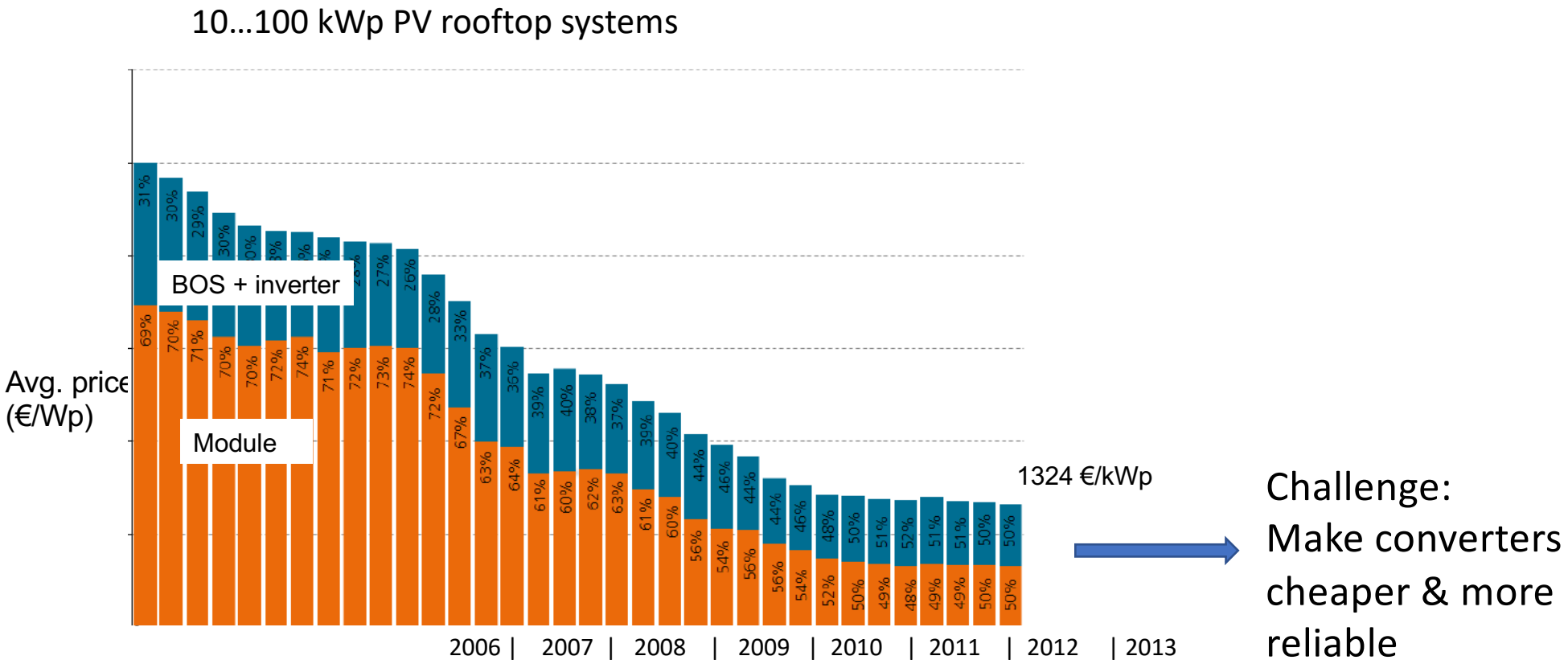
52% of original amount of dust eroded

(Sometimes) coatings may help to erode off the dust

From DC module to AC grid



Prices of inverter and balance-of-system (BOS)



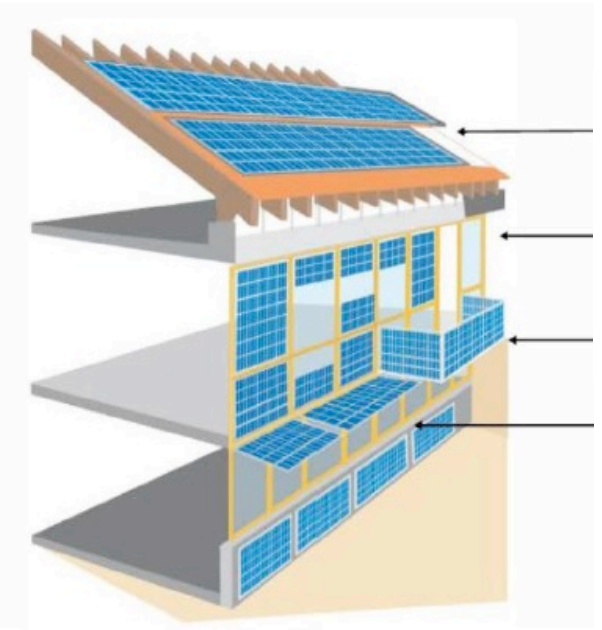
Challenge:
Make converters cheaper & more reliable

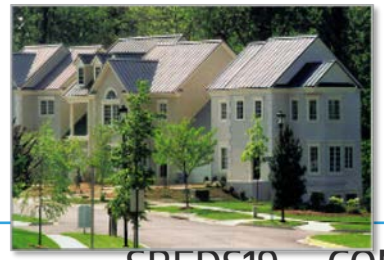
Source: Fraunhofer ISE

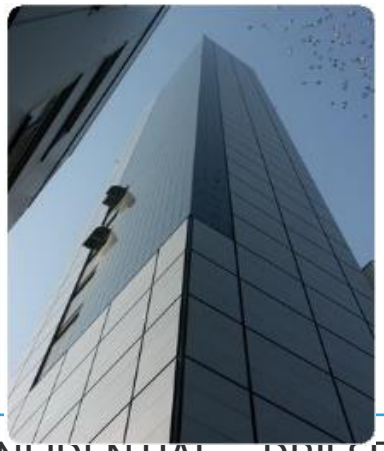
Building-Integrated-PV potential

- Today: PV modules “added” to the building
- BIPV = multi-functional use
  - As building component
  - To generate electricity
- Long lifetime required
  - 30-40 years or >100k hours (more than aerospace!)
  - Problem for converters?
- What will drive BIPV ?
  - Façade-integration of PV for tall NZEB-compli buildings

    potential market > 100 GW/yr
  - PV-roofs with improved esthetics
  - Lower overall cost (building + PV)

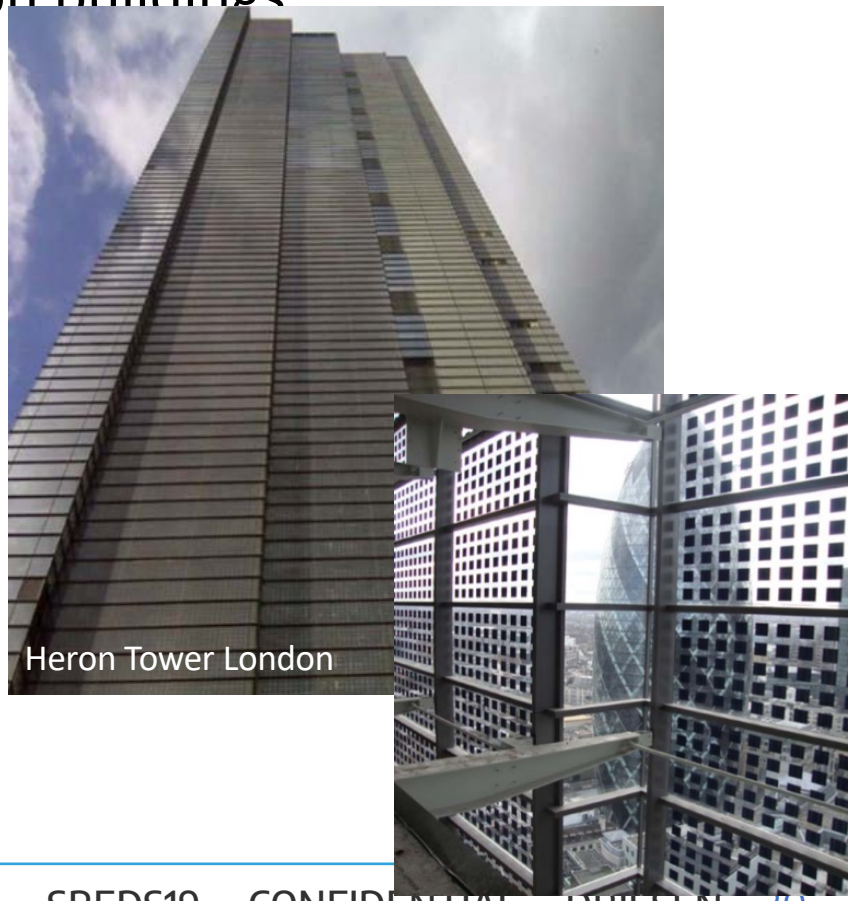






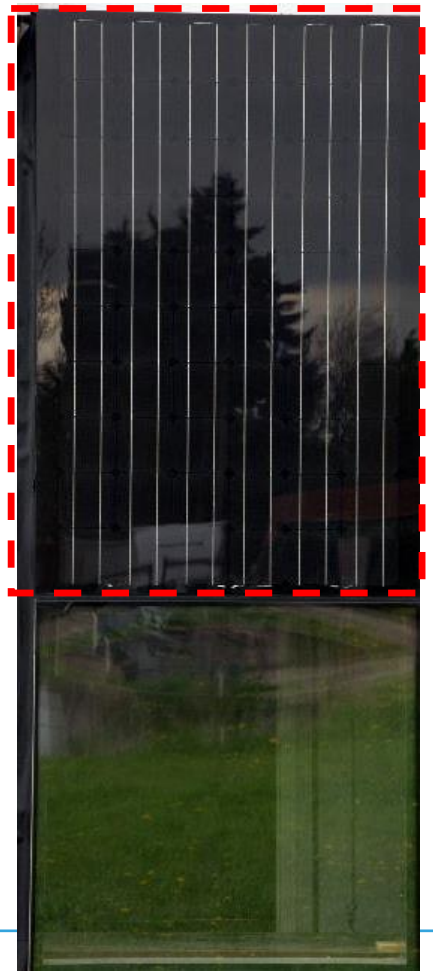
PV in facades of high-rise buildings

- 2020 NZEB directives => enhanced use of PV on buildings
  - rooftop area for PV often scarce
  - aesthetics suited for office-buildings
  - high facade engineering capacity
  - benign to the local grid (congestion !)
    - generation close to consumption
    - in sync with airco load
    - East – South – West facades => flatter day profile
    - seasonal profile
  - façade cost Euro/m^2 marginally increased and compensated by enhanced “greening”



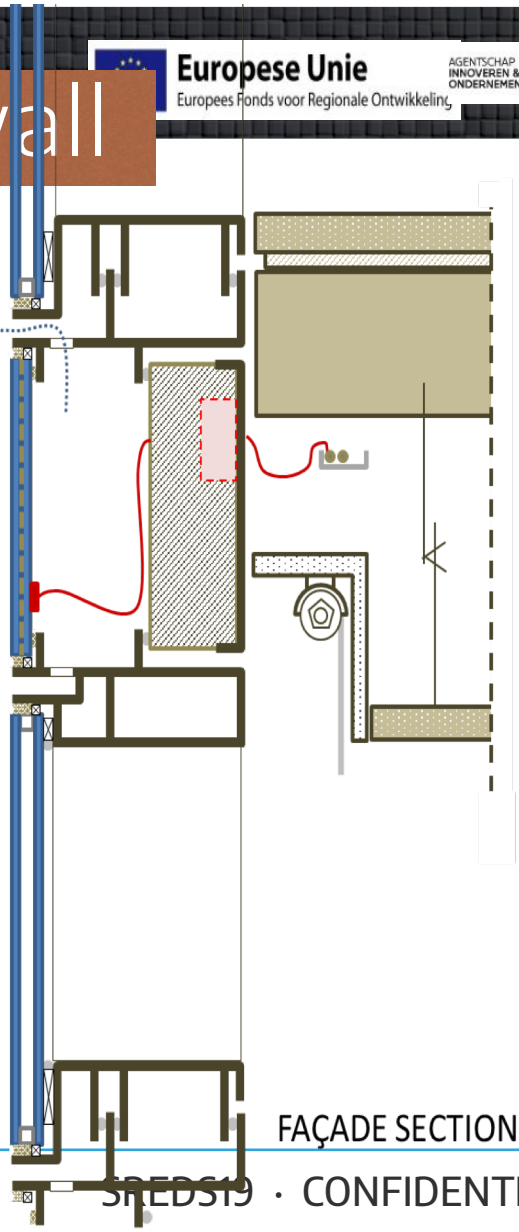
Prototype: PV in curtain wall

Ventilation holes



PV module

Glass

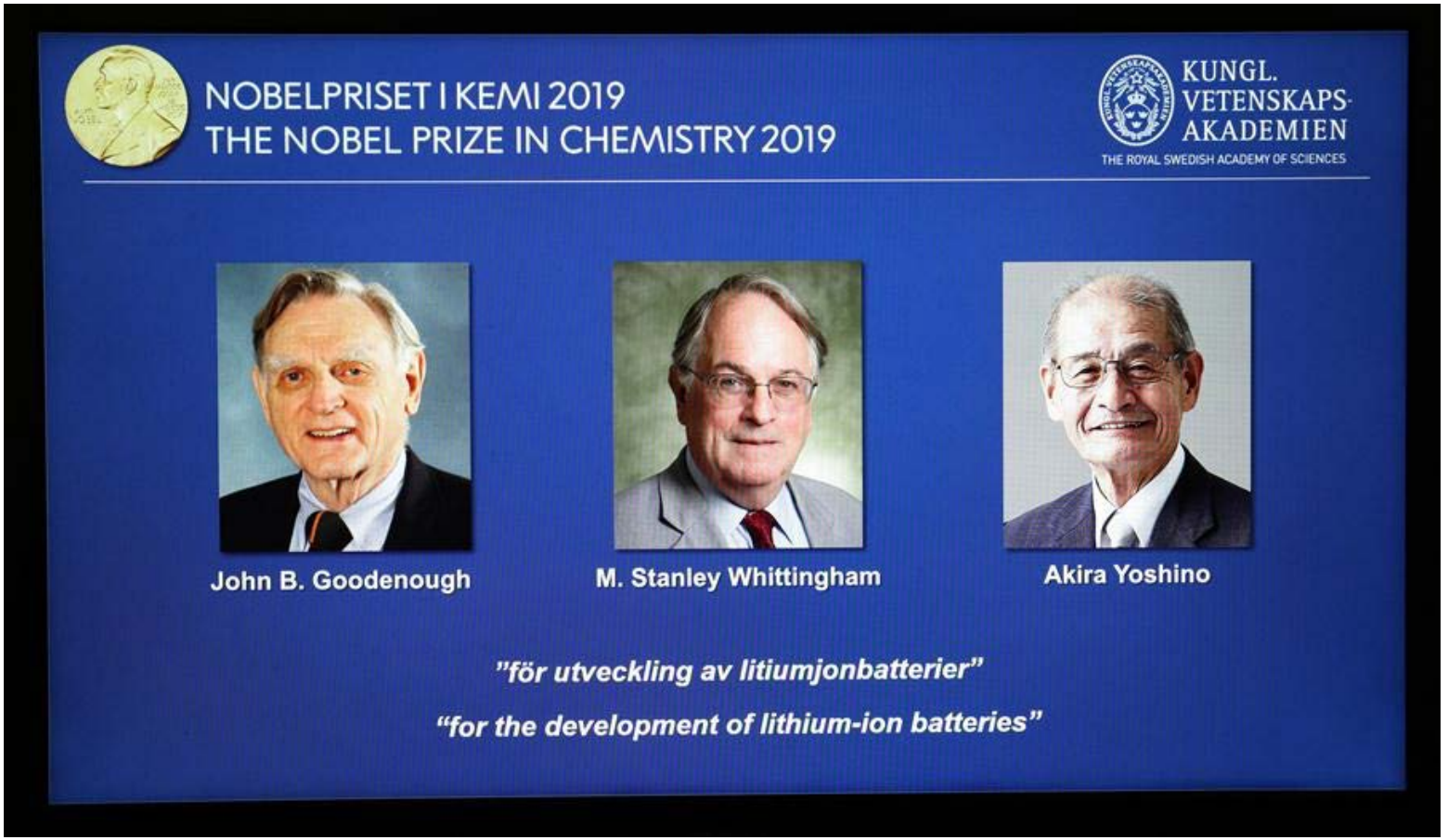


FAÇADE SECTION

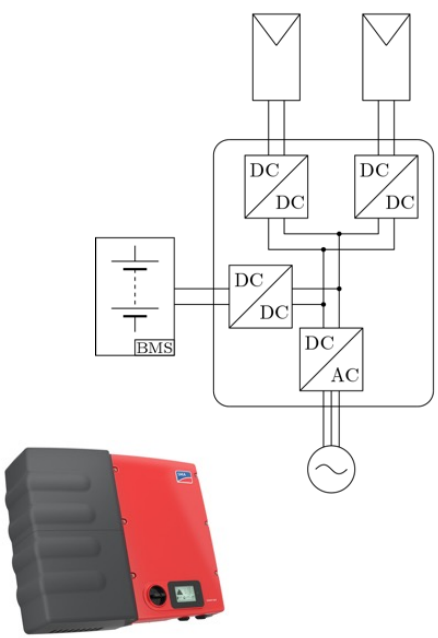
The role of batteries

The missing link for sustainable electrical energy?

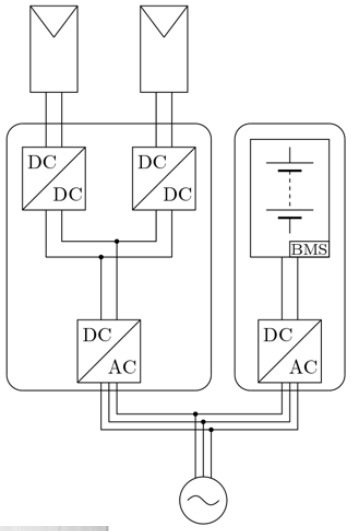
Nobel Prize Chemistry 2019



PV + battery systems



Industry trend



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Large-scale BESS

18 MW battery units by Tesla (Dilsem-Stokkem)

Second-life battery units (coming from Renault-Nissan) – pilot at Umicore

Ever cheaper batteries thanks to Gigafactories

Batteries push transition in mobility towards EV

Audi e-tron

350 kW charger

EnergyVille Smart Charging

- **EnergyVille 1 – Some relevant numbers…**

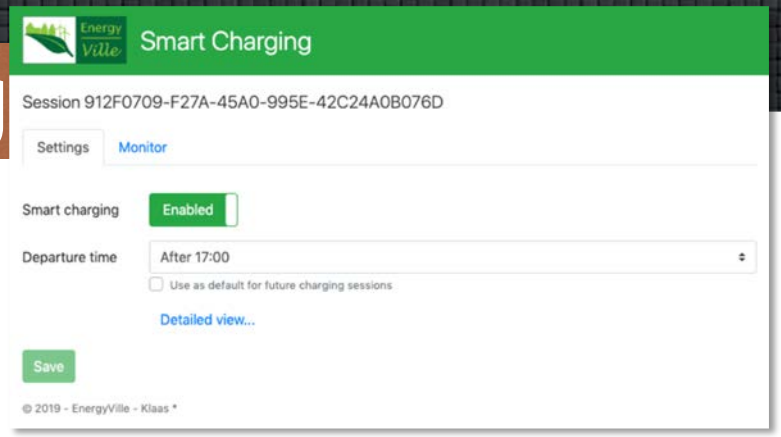
EnergyVille 1 - Infrastructure	
Installed EV charging power	530kVA
Charging connections:	
OCPP compliant	12(+6)
Non-controllable	7
Fast charger	2 (DC) + 1 (AC)
Vehicle-2-grid	1
Electric cabinet of parking	436kVA
Electric vehicles per day	Avg. 6,4 (max. so far 14)
Photo-voltaic rooftop installation	369kWp

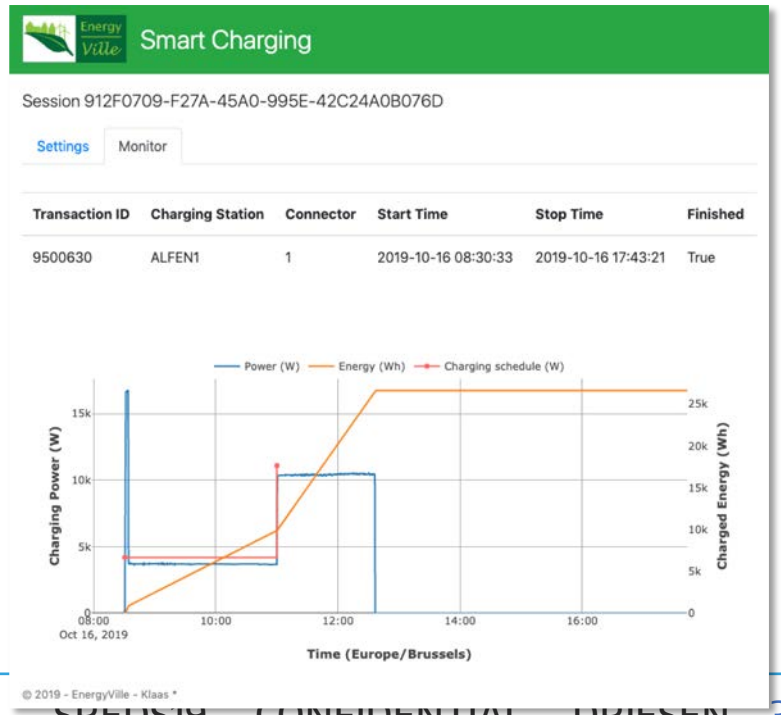
- Capacity of electric cabinet < installed EV charging power
- Regular grid injection due to large PV rooftop installation
- Morning peak in electrical consumption due to coinciding EV charging sessions

→ *Smart Charging at EnergyVille*

EnergyVille Smart Charging

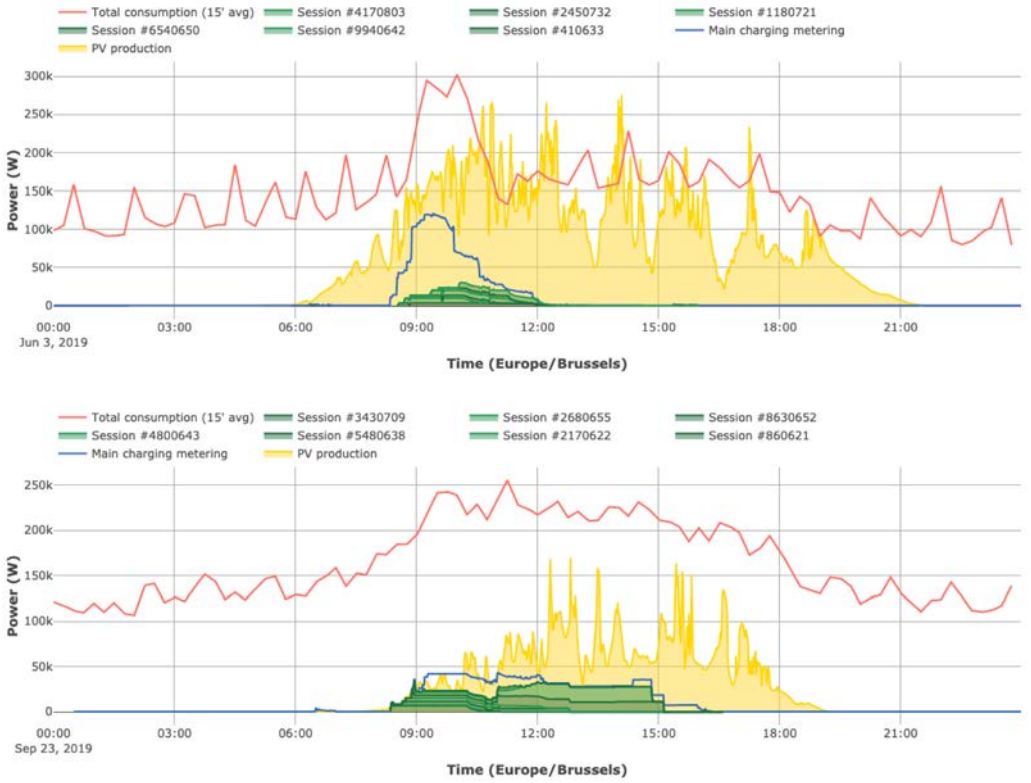
- **User interaction - web page**
  - Settings:
    - En- or disable smart charging
    - Select departure time
  - Monitor: overview of current charging session
    - Current power
    - Energy charged
    - Charging schedule



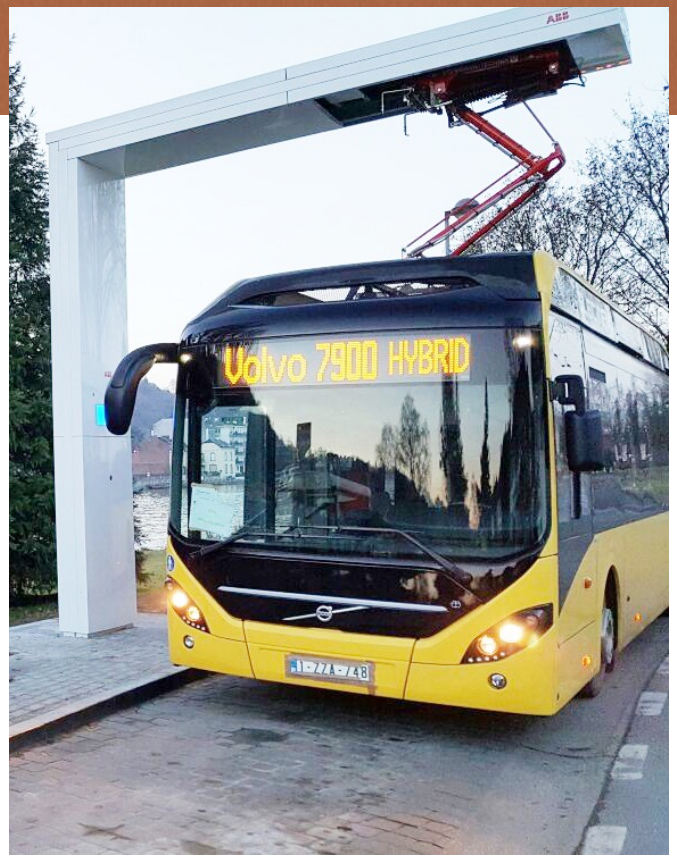


EnergyVille Smart Charging

- **A first ‘smart’ algorithm**
  - *Without ‘smart’ algorithm:*
    - *Clear morning peak in overall electricity consumption at EnergyVille 1*
    - *Affects capacity costs in energy bill*
  - *With ‘smart’ algorithm:*
    - *Charging sessions of select users are delayed and reduced in power*
    - *More spread of charging times*
    - *Mostly flattened peak*



Electric buses: silent & clean cities



Volvo + ABB flash charger

Leuven electric buses

Schiphol airport

Electric vans & trucks: the next step

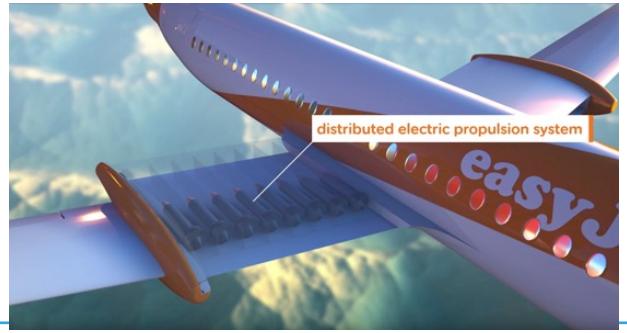
Deutsche Post

Tesla

Mercedes

Electric airplanes: the last challenge

- Short distance (<1000 km): full electric
- Personalised transport using electric drone transport

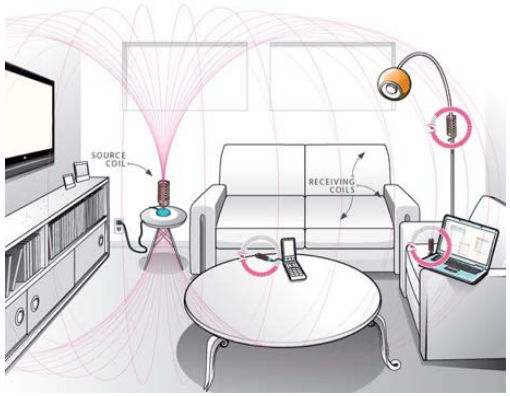


Back to DC?

Rethinking the power system

Wires, sockets & plugs still needed ?

- Many appliances are “cordless”, contain batteries
- Charging through a wireless link: e.g. IT-equipment (QI), kitchen & garden (KI), electric car (enough power?)
- Can be expanded to full room wireless charging: “witricity”

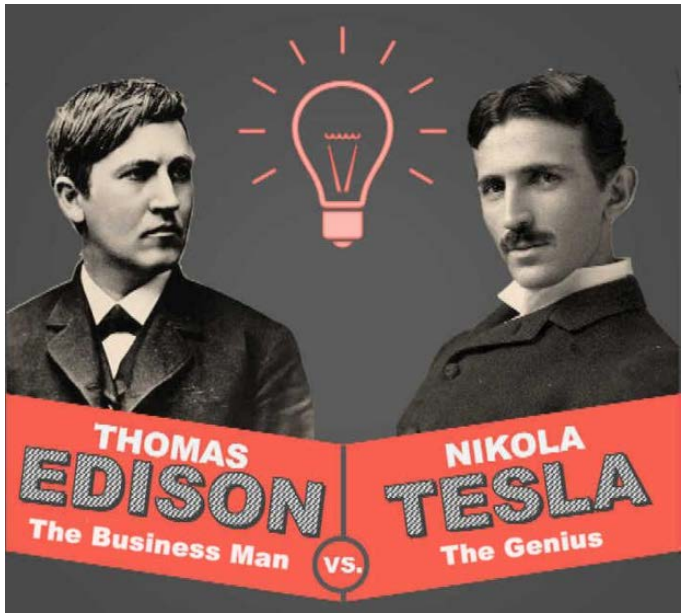


Do we still need AC power ?

- PV = DC
- Batteries = DC
- LED-lighting = DC
- IT-equipment = DC
- Electric cars (batteries) = DC
- Etc.

- Hence: lots of AC-DC conversion
  - Extra losses
  - Extra (too much?) electronic converters
  - Different types of cabling

- Should we go back to DC in buildings?



Applications of DC nanogrids

Datacenters

Source: https://www.quadranet.com

Running on $380V_{DC}$

- 10% less energy losses (ABB, Green.ch datacenter, 1 MW)
- 15% less upfront capital cost
- 33% less floor space occupied
- Increased availability

Public street lighting

Source: Direct Current BV

Running on $+/-350V_{DC}$

- Copper conductor savings
- Feeder length up to 4 km reduces the number of AC connection points
- LED driver becomes more reliable

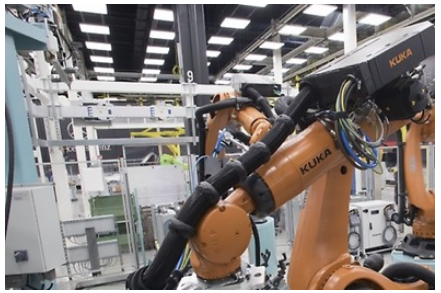
Commercial buildings/districts

Source: Arda Power

Running on $+/-380V_{DC}$

- Reduce the number of converters
- Less conversion losses
- Able to operate in islanding mode
- Able to provide ancillary services to the AC grid

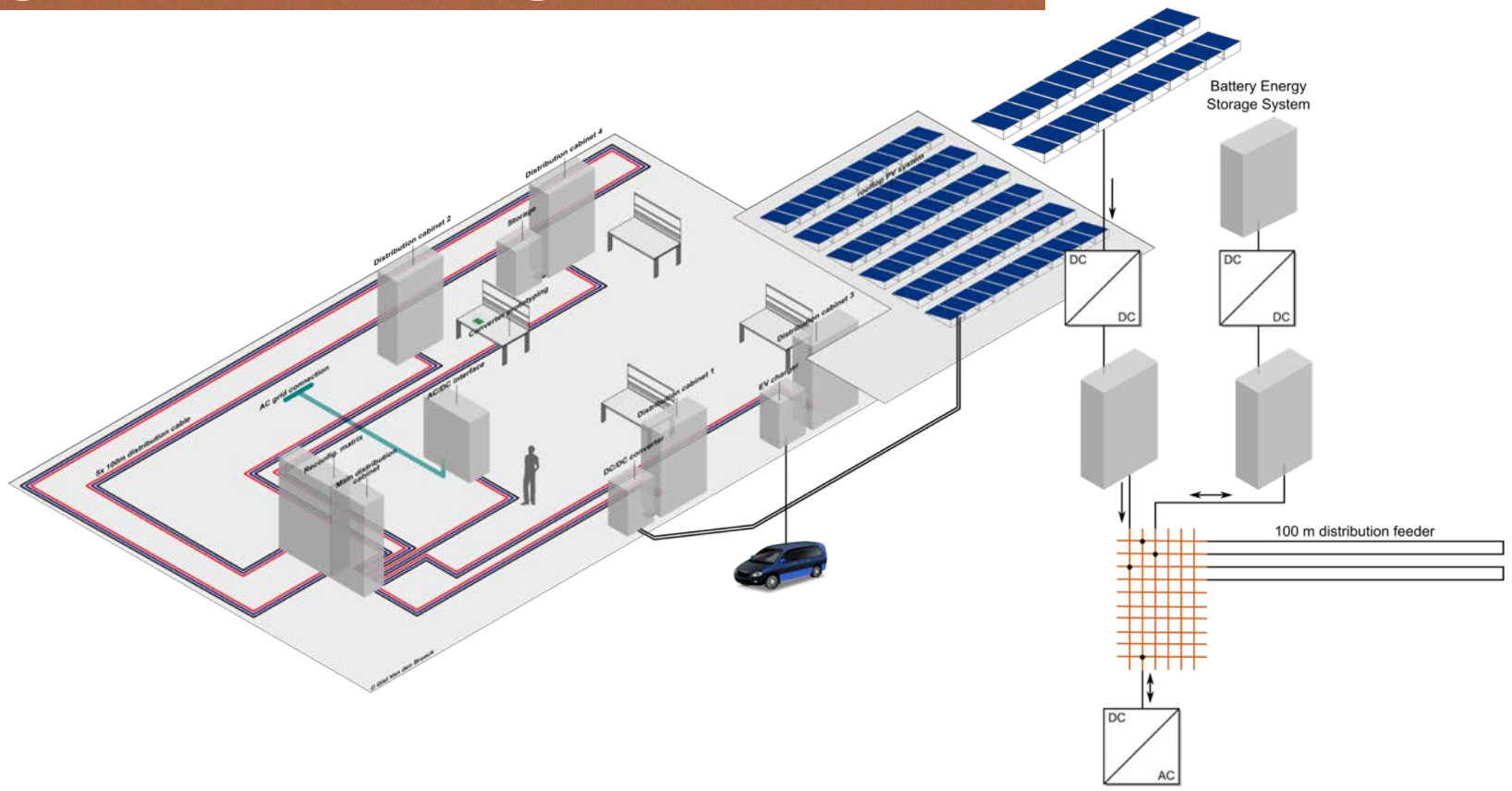
Industry



Running on $600V_{DC}$

- DC improves immunity and grid stability
- 40% less copper consumption
- Able to operate in islanding mode

Living Lab: LVDC living lab in EnergyVille building



Final thoughts

breakthrough technology

The role of power electronics

- Power electronics have become the core conversion technology of modern electricity systems
- Power electronics enable energy controllability & efficiency, renewable resources, energy storage, sustainable mobility
- New components & circuits allow higher performance, lower losses, smaller converters, and eventually high reliability

Thank You ◿

Feedback and Interest Survey ◿

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