ENERGY-EFFICIENT ELECTRIFICATION TECHNOLOGIES FOR BUILDINGS AND NEIGHBOURHOODS

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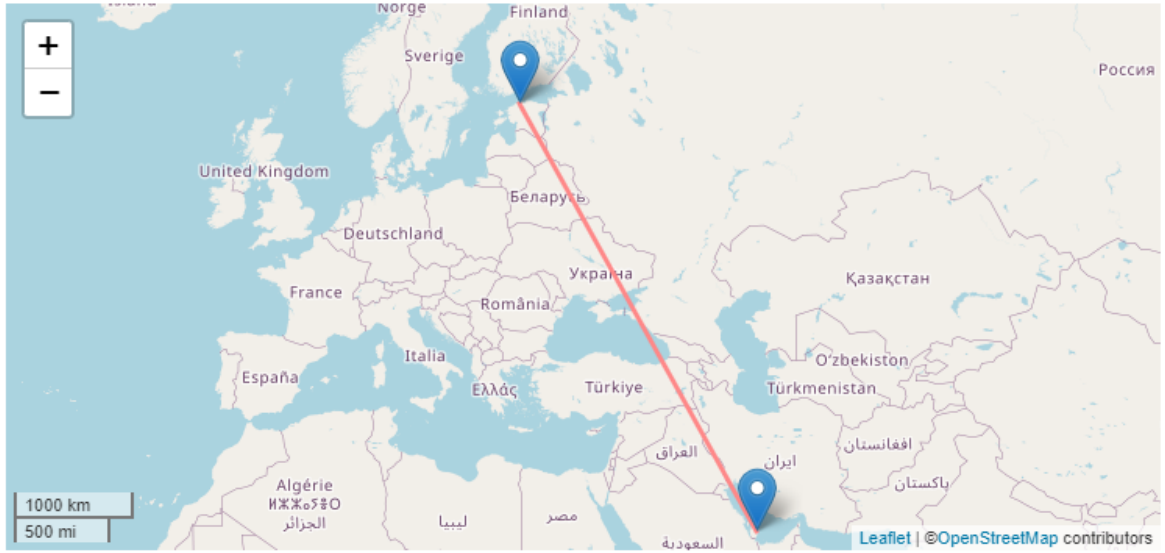
WHERE I AM FROM

TALLINN - THE BEST-PRESERVED MEDIEVAL CITY IN NORTHERN EUROPE

The geographical distance (airline route) between Tallinn and Doha is **4325** km (**2687** miles).



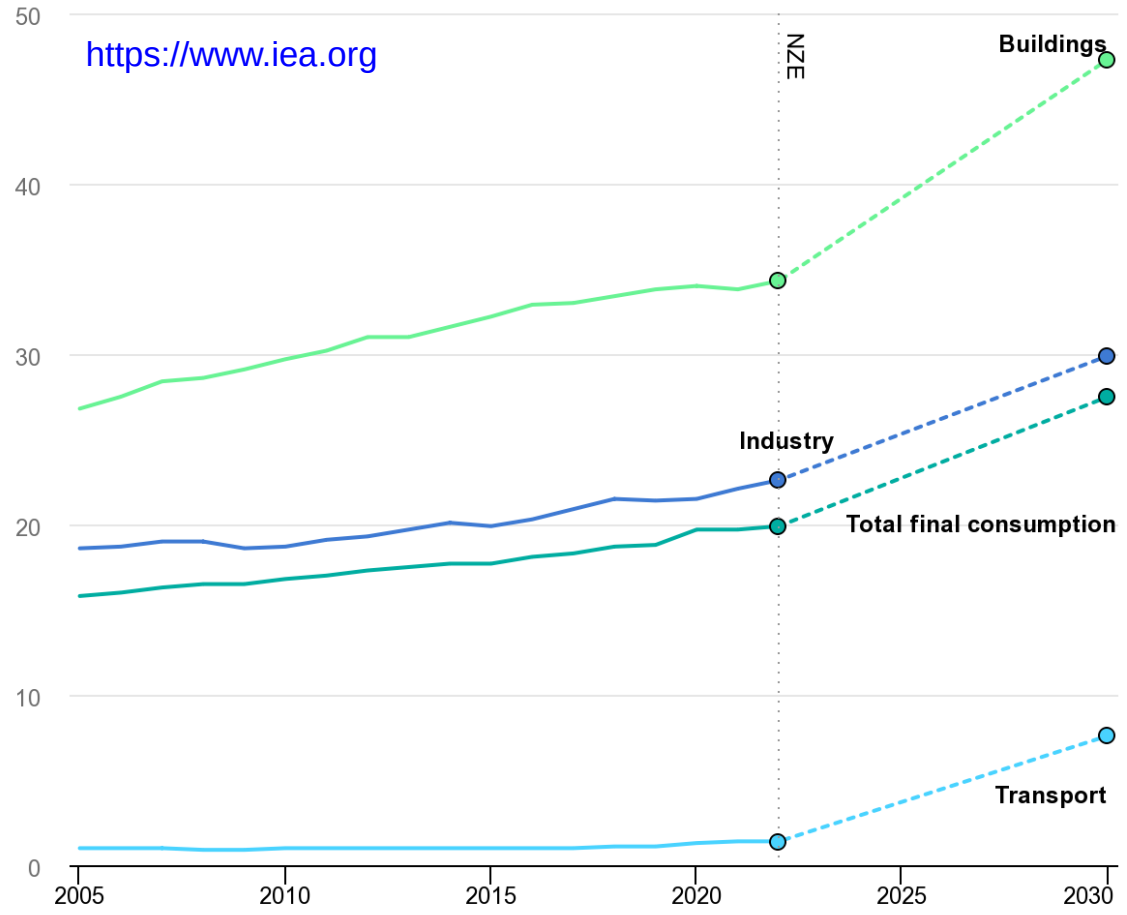
Sunrise, Sunset, and Local Times in Tallinn, Estonia and Doha, Qatar

When traveling from Tallinn, Estonia to Doha, Qatar, note their sunrise and sunset times. Also note their current local times. Please note that Tallinn is 1 hours behind Doha.

	Tallinn, Estonia	Doha, Qatar
Sunrise	09:18 a.m.	06:20 a.m.
Sunset	3:32 p.m.	4:56 p.m.
Day Length	6h 14m	10h 36m

TOWARDS 2050 NZE PATHWAY (EU GREEN DEAL)

- *By 2050 the EU aims to become the **world's first "climate-neutral bloc"** having an economy with net-zero greenhouse gas emissions (NZE)*
- ***Electrification** is considered one of the key strategies to reach NZE goals*
- *The **share of electricity** in the final energy consumption in 2050 is targeted to be **more than 50%***
- *By 2050, almost **90%** of electricity generation in EU is expected to come **from renewable sources**, with wind and solar PV together accounting for nearly 70%*
- *Much of the NZE need will be met by shifting towards **electric transport** and **electrification of heating/cooling demand of buildings** using heat pumps*
- *In 2050, **electricity will become the dominant energy carrier for the buildings in EU**: the prognosed growth in demand by 2030 is 12% and 35% by 2050*



Share of electricity in total final energy consumption in the NZE scenario (2005-2030)

DECARBONIZATION OF BUILDING STOCK IN EU

- *Currently, **roughly 75% of buildings** in the EU are not energy efficient, yet 85–95% of today's buildings will still be in use in 2050*
- *To **boost decarbonization** the EU requires all new buildings from 2021 to be nearly zero-energy buildings (nZEB)*
- ***nZEB (or class A building)** means a building with a very high energy performance where the very low amount of energy should be covered to a **very significant extent by energy from the renewable sources***
- *In practice, **nZEB consumes up to 4 times less energy** than the traditional „old school" building*
- *Recently, the EU proposed to move from the current nZEB to zero-emission buildings (**ZEB, A+ or A_0**) from January 1, 2030. In ZEB the very low amount of energy still required must be **fully covered by energy from the renewable sources and without on-site carbon emissions from fossil fuels***

Table 2. Estonian energy labels for the three categories of detached houses D1, D2, and D3; EPC (kWh/(m²a)).

En. Label	D1 (EPC)	D2 (EPC)	D3 (EPC)
A	≤145	≤120	≤100
B	146–165	121–140	101–120
C	166–185	141–160	121–140
D	186–235	161–210	141–200
E	236–285	211–260	201–250
F	286–350	261–330	251–320
G	351–420	331–400	321–390
H	≥421	≥401	≥391

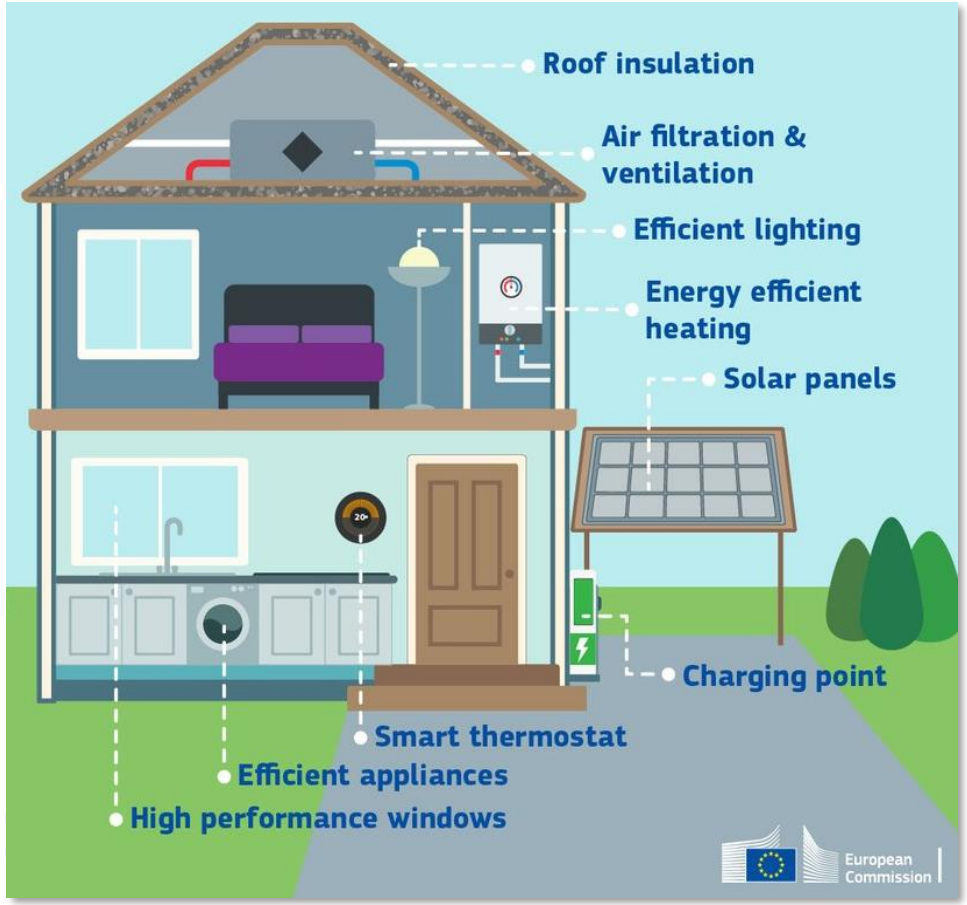
D1, <120 m²
D2, 120–220 m²
D3, >220 m²

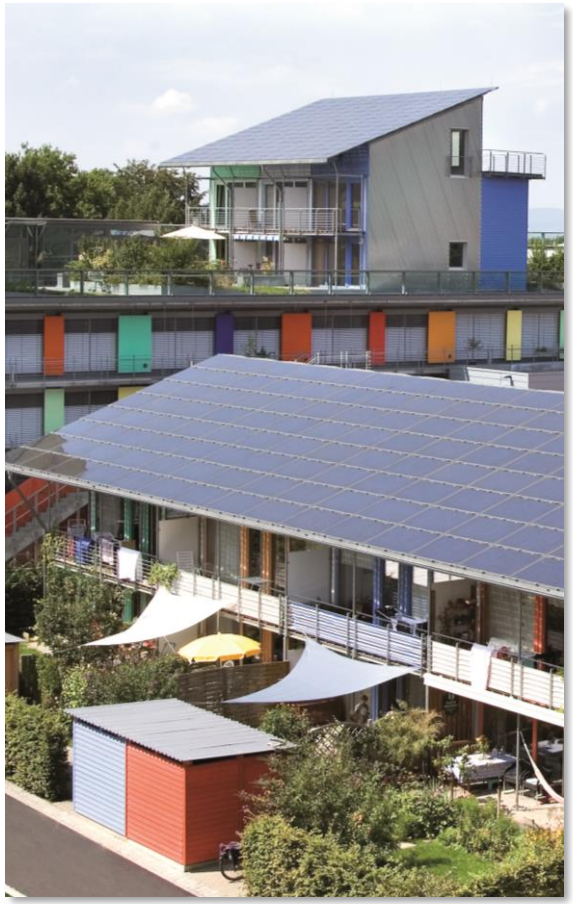
https://energy.ec.europa.eu

ZEB AND POWER ELECTRONICS

IT IS ALL ABOUT EFFICIENCY AND ENERGY SAVING

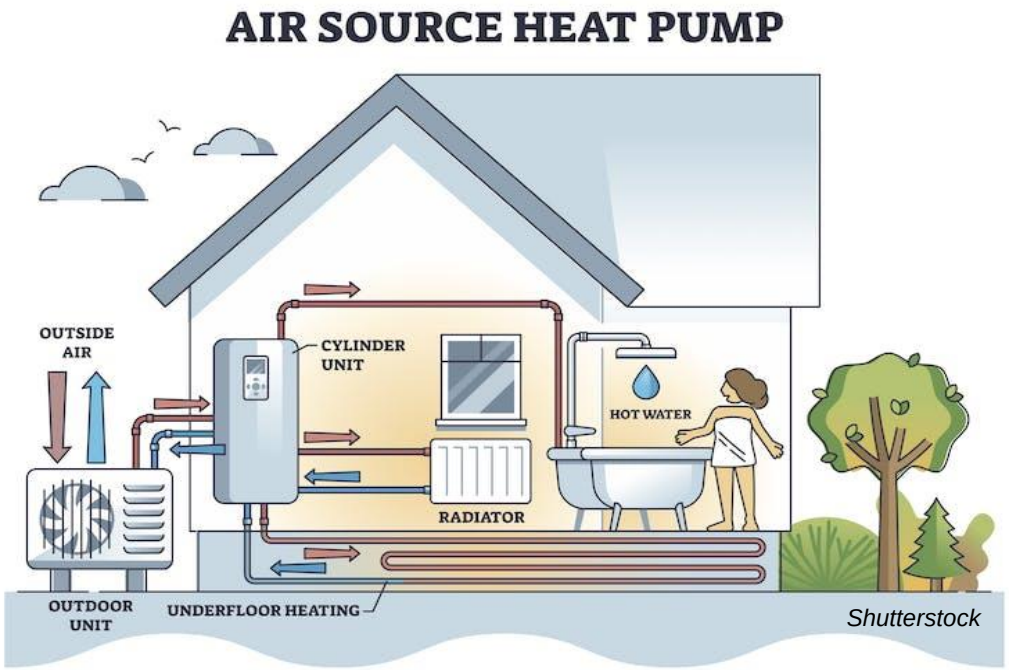
- *ZEB = high energy performance + local renewable energy generation*
- ***Energy efficiency is the main feature of ZEB** - heat pump, heat recovery ventilation, PV installation backed up with energy storage, energy-efficient appliances and lighting, smart control of loads, energy arbitrage*
- *Most of the energy saving technologies used in ZEBs are **power electronics based***

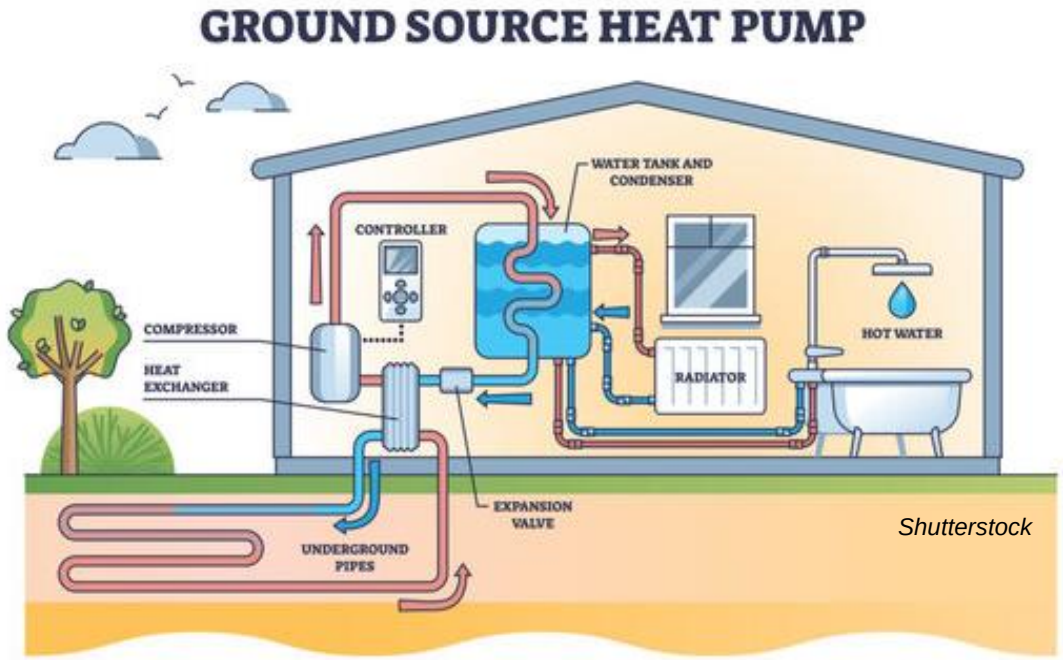




ADVANTAGES OF HEAT PUMPS

- *There are **two main types of heat pumps** – air source and ground source (geothermal)*
- ***Excellent energy efficiency**: can deliver up to 5 times more heat energy to a home than the electrical energy it consumes (see COP – Coefficient of Performance or SCOP – Seasonal Coefficient of Performance)*
- *Used for **space heating/cooling** and providing **domestic hot water** for showers and sinks*
- *Can be **easily paired with PV** installation*
- ***Power electronics enabled smart control** – heat pump can be operated as a **flexible and grid-responsive resource***

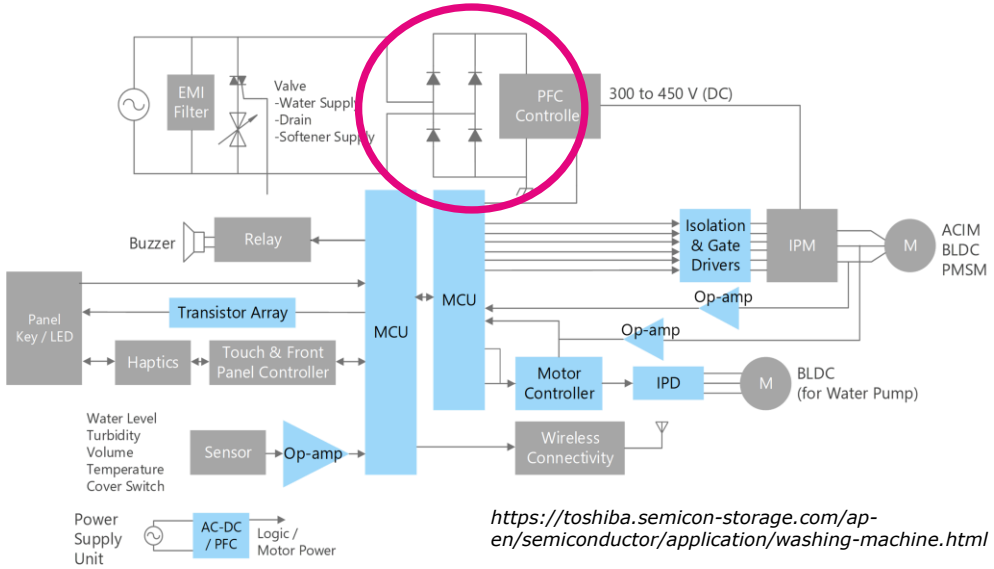




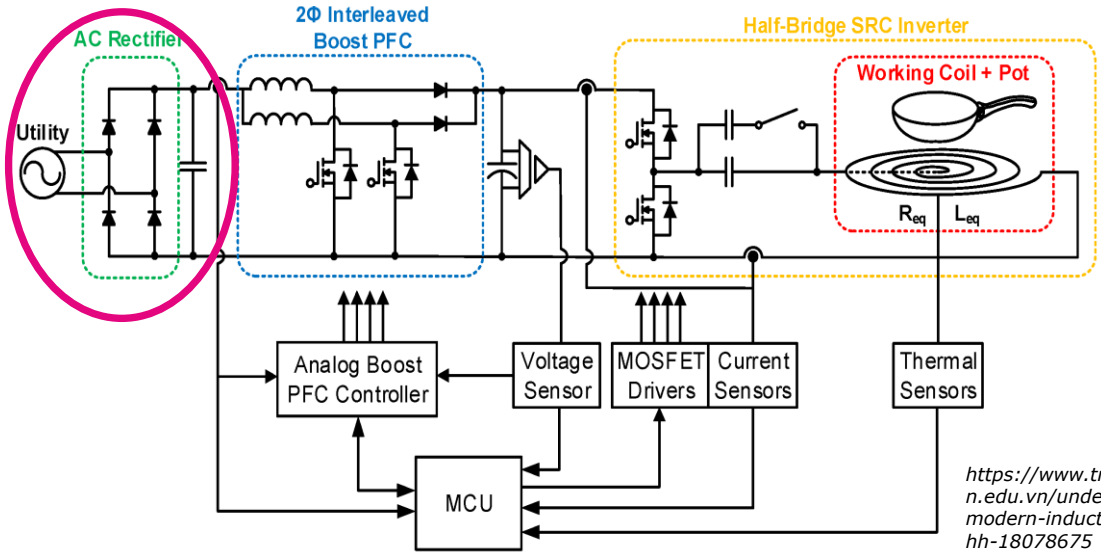
CLASS-A ENERGY-EFFICIENT APPLIANCES

WASHING MACHINES, REFRIGERATORS, INDUCTION COOKTOPS, HEAT PUMPS, ETC.

THEY ALL USE DIRECT CURRENT (DC) FOR OPERATION !!!



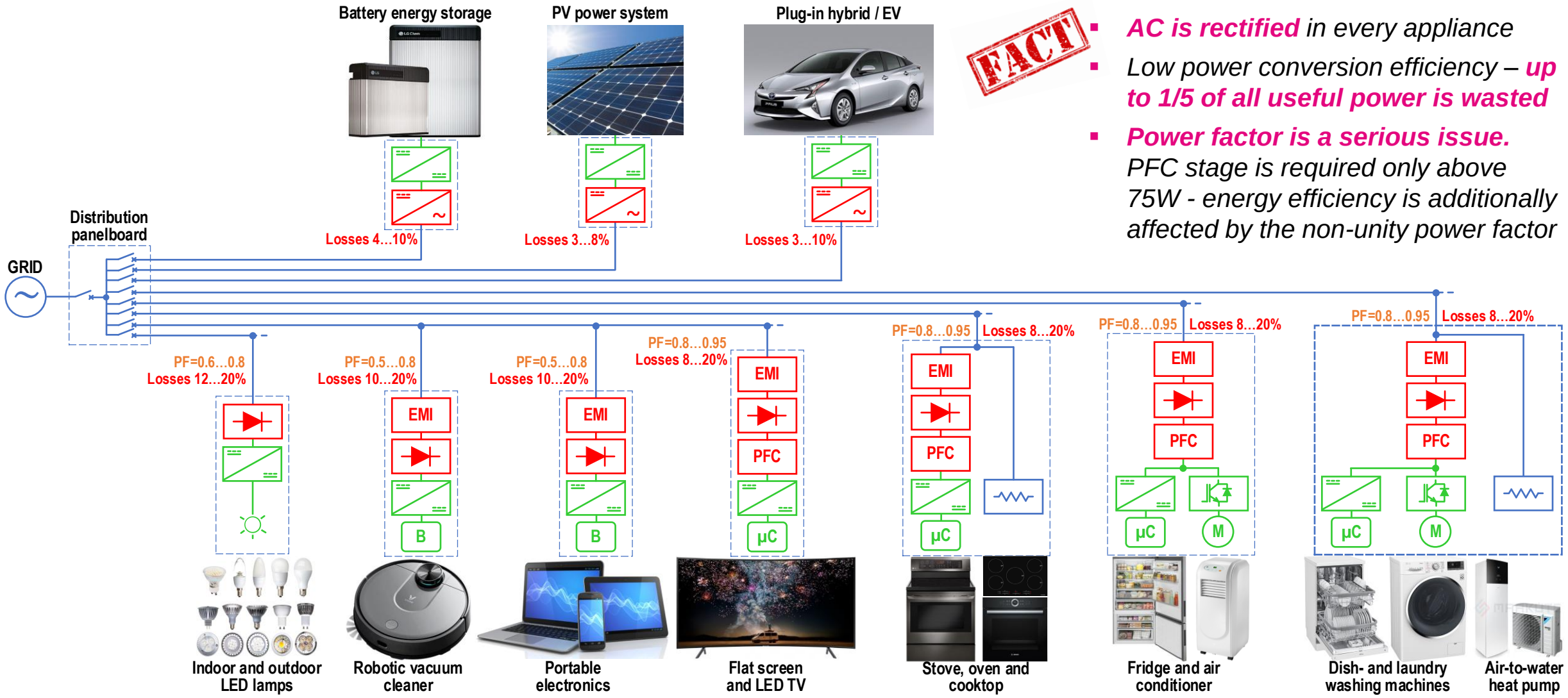
https://toshiba.semicon-storage.com/ap-en/semiconductor/application/washing-machine.html



https://www.truongquoctesaigon.edu.vn/understanding-how-modern-induction-cooker-work-hh-18078675

AC-BASED ELECTRICAL SYSTEM OF ZEB TODAY

WE ARE LIVING IN A DC WORLD WITHOUT FULLY REALIZING ITS TRUE POTENTIAL !

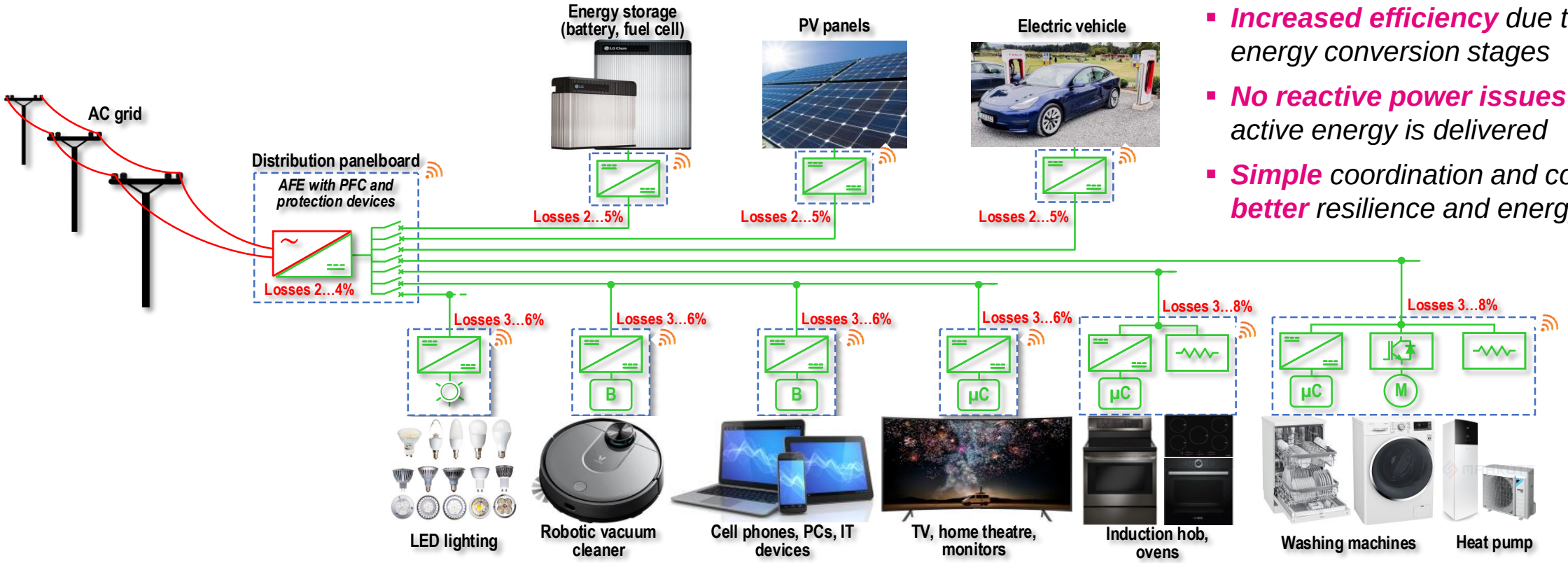


FACT

- ***AC is rectified*** *in every appliance*
- *Low power conversion efficiency –* ***up to 1/5 of all useful power is wasted***
- ***Power factor is a serious issue.***
  PFC stage is required only above 75W - energy efficiency is additionally affected by the non-unity power factor

NEXT-GEN ELECTRICAL SYSTEM OF ZEB

DC POWER DISTRIBUTION AND DC-FED APPLIANCES



- ***Increased efficiency*** *due to less energy conversion stages*
- ***No reactive power issues*** *– only active energy is delivered*
- ***Simple*** *coordination and control,* ***better*** *resilience and energy security*

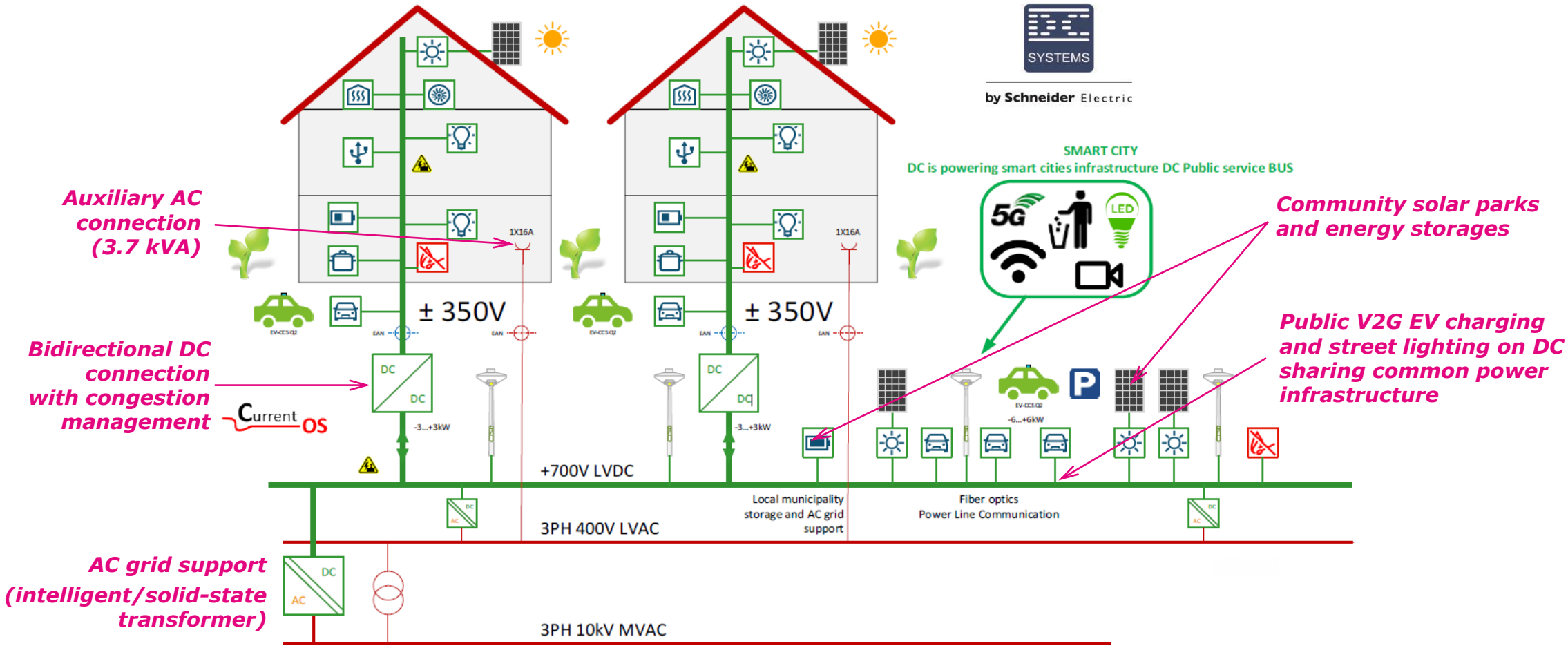
DC OPENS A NEW DIMENSION IN ENERGY PERFORMANCE OF BUILDINGS

- ***DC distribution*** *can reduce electricity consumption* ***by up to 30%****
- ***DC distribution*** *can enhance the energy performance class of a building* ***from A to A+***

** V. Vossos, S. Pantano, R. Heard, and R. E. Brown, "DC appliances and DC power distribution: A bridge to the future net zero energy homes," Lawrence Berkeley National Laboratory, Berkeley CA, USA, Technical Report LBNL-2001084, Sep. 2017.*

DC ELECTRIFICATION OF NEIGHBOURHOODS

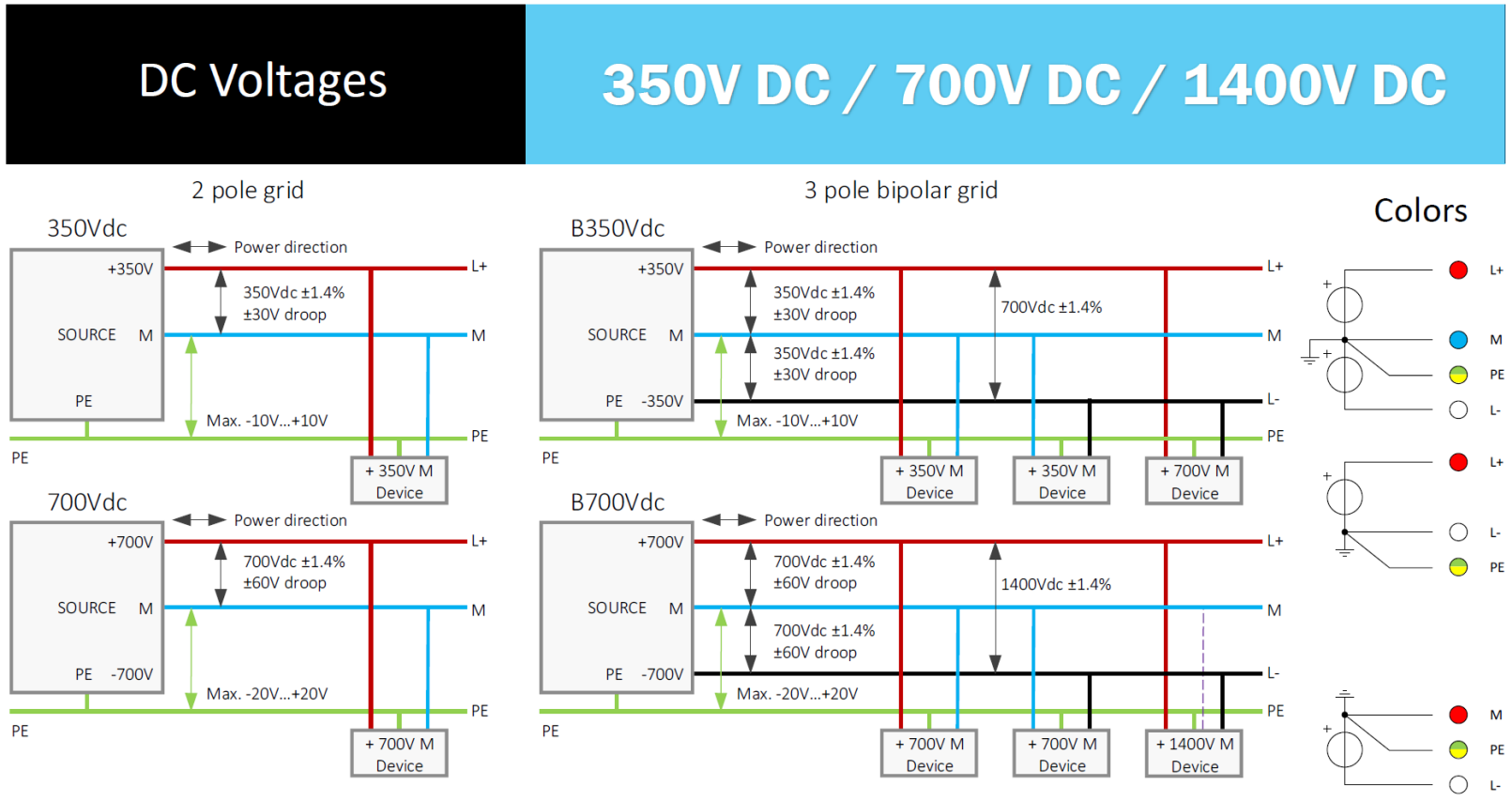
- ***Facilitates*** *energy communities and other collective initiatives and business models (energy hubs, EaaS, VPPaaS, etc.)*
- ***Supports*** *the main grid and provides grid ancillary services (power consumption curtailment, phase balancing, etc.)*
- ***Fosters*** *V2X adoption via DC charging thus unlocking the untapped potential of EVs as „mobile energy storages“*



HISTORICAL CHOICE: FROM 230 VAC TO 350 VDC

NPR9090: THE FIRST PRACTICAL GUIDELINE FOR DC INSTALLATIONS

- ***The Netherlands*** *has a leading position in the global consultation on international standards for DC installations*
- *In 2018 the* ***350 V DC*** *has been implemented formally in the Dutch standardization in the NPR9090 (Dutch Practical Guideline for the installations up to 1500 V DC)*
- *The new* ***core colors for DC*** *installations are red, blue and white*



SYSTEMS by Schneider Electric

CurrentOS

https://currentos.foundation

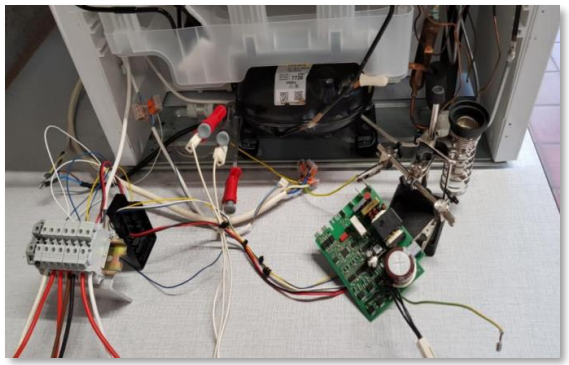
350 VDC TECHNOLOGY IS VERY FAST DEVELOPING

RECENTLY IS A TECHNOLOGY VALIDATION AND DEMONSTRATION PHASE (2020-2025)

- *Big players (Schneider Electric, EATON, ABB, etc.) strongly support the technology development and innovation*
- *Solid state circuit breakers (DC Systems B.V., Blixt, DC Opportunities B.V.)*
- *USB-C PD (power delivery) 100W wall socket outlet (DC Systems B.V.)*
- *30/60/90 W public light LED drivers (DC Systems B.V.)*
- *Induction cooktop (ATAG Benelux)*
- *Hood fan (ATAG Benelux)*
- *Refrigerator (ATAG Benelux)*
- *Heat pumps (NRGtec)*
- *Under development: coffee machine, oven, microwave, washing machines, etc.*

SYSTEMS ATAG BENELUX DCpportunities BLIXT

https://gelijkspanning.org/
https://www.dc.systems/
https://blixt.tech//



MAIN CHALLENGES OF DC TODAY

- *Lack of public awareness*
- *Lack of international standardization and mature technology*
- *Lack of market-ready power electronic systems (photovoltaic converters, energy storage interfaces, EV chargers, energy routers, etc.)*

*i*³ DC INITIATIVE: *i*nform *i*nspire & *i*nnovate (est. 2020)

Non-profit joint venture of TalTech and Ubik Solutions LLC. aimed at increasing the awareness, pushing forward the innovation and acceleration of the industrial uptake of the residential DC nanogrid technology in Estonia, Baltic states and Northern Europe

- ✓ *organization of national and international seminars and workshops on residentilal DC nanogrids, DC buildings and districts*
- ✓ *research, development and showcasing of innovative technologies*
- ✓ *development of public policies and standards for DC buildings*
- ✓ *creation of new cleantech ventures and joint seeking for funds*

i³ DC
Accelerates Energy Transition

TALTECH RESIDENTIAL DC INNOVATION HUB

DEMONSTRATION OF SUSTAINABLE ELECTRIFICATION TECHNOLOGIES

- ***First academic member of Current OS Foundation***
- ***International open platform*** *for research and demonstration of residential DC power distribution technology*
- *Validation of the* ***net-zero-energy solutions*** *(workplace, space heating and cooling, ventilation, etc.)*
- ***Living lab*** *allows for blending the everyday real-life experience of pilot users with academic research to develop future-proof energy saving technologies*
- ***Data collection*** *for the future design of the energy-neutral TalTech campus*

CLIMATE NEUTRAL BY 2035

TAL TECH | TALLINN UNIVERSITY OF TECHNOLOGY

i³ DC Accelerates Energy Transition

Estonian Research Council

CurrentOS

ENERGIA PARTNER

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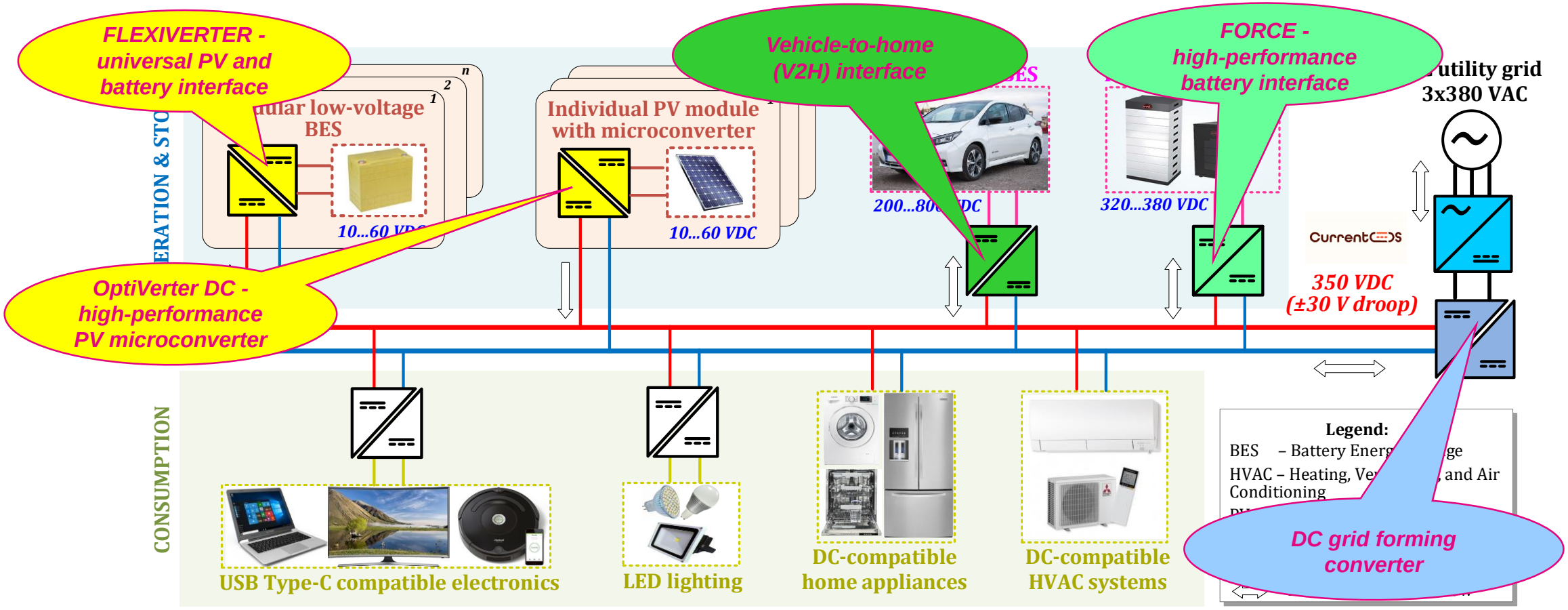
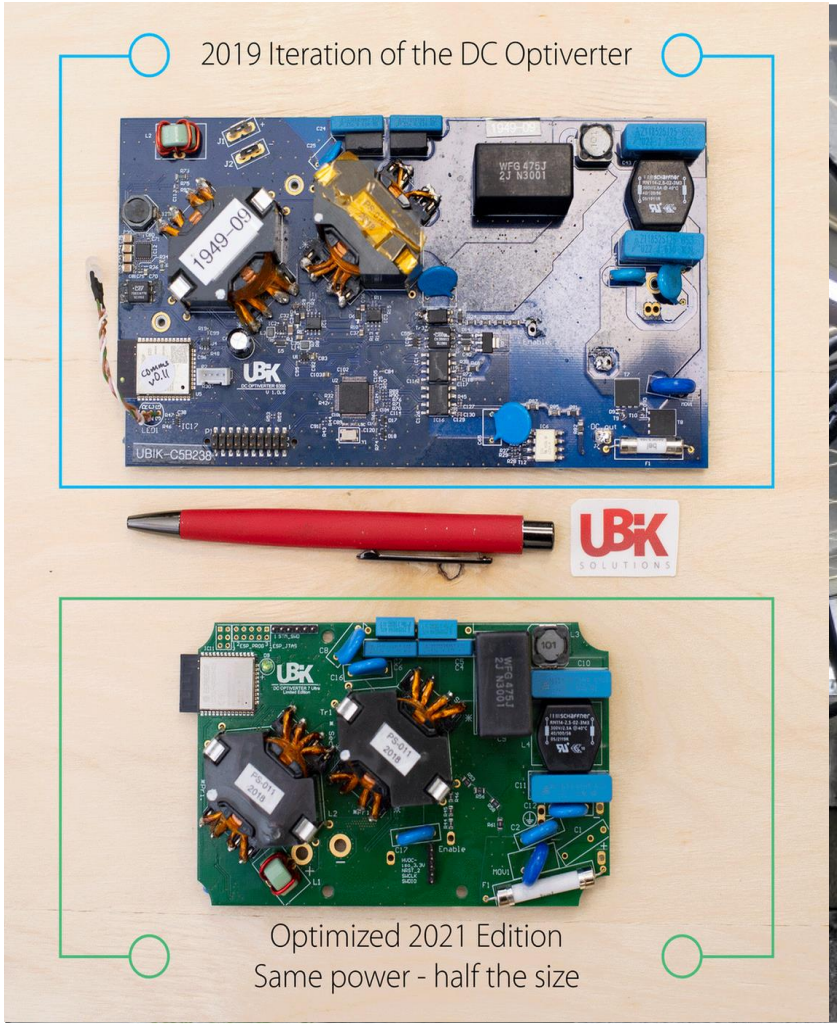
TALTECH RESIDENTIAL DC INNOVATION HUB

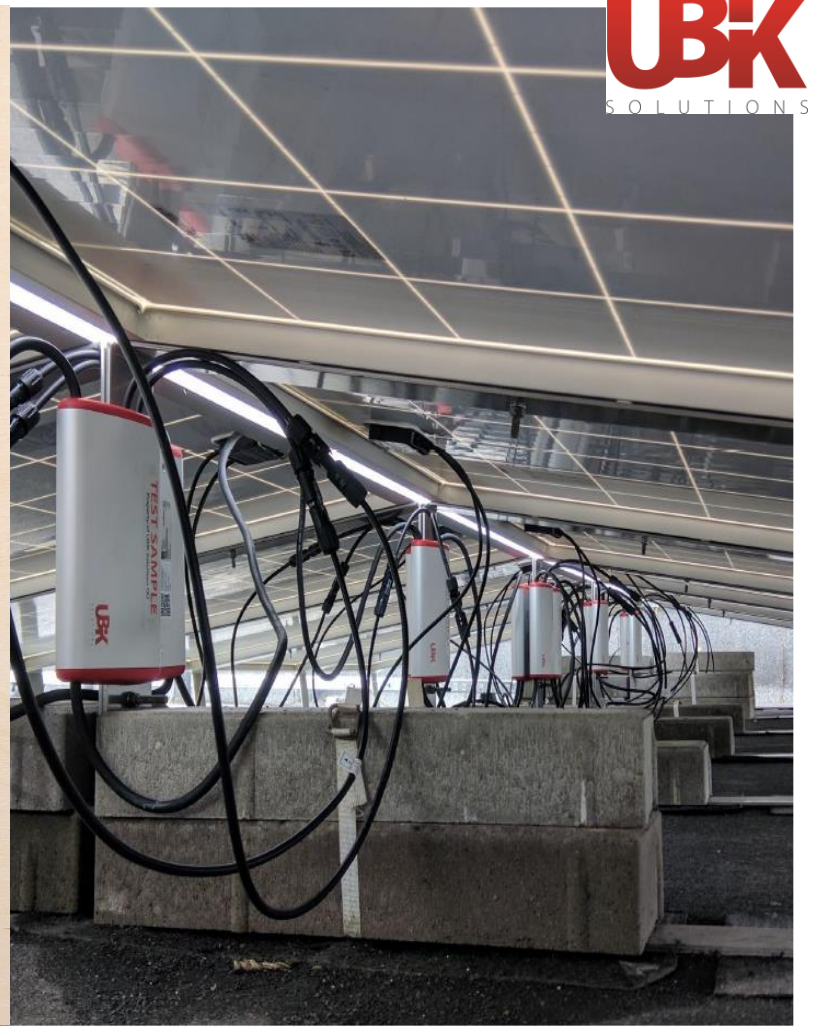
R&D OF ADVANCED POWER ELECTRONIC SYSTEMS FOR DC-FED ZEB



TALLINN UNIVERSITY OF TECHNOLOGY

OPTIVERTER – A Hybrid of Photovoltaic OPTImizer and MicroconVERTER





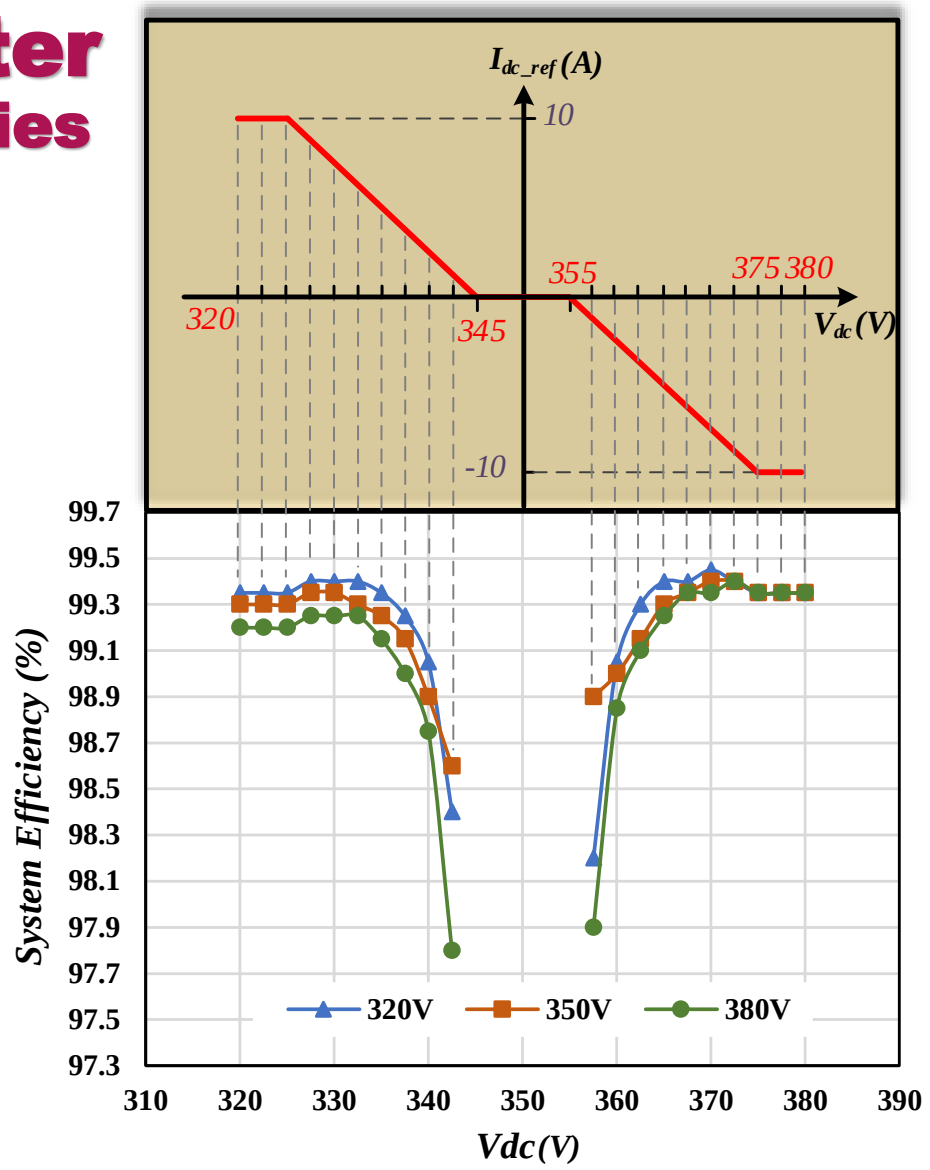
- *An entirely **novel PV MLPE technology***
- *Can be paired with all commercial **60- and 72-cell** PV modules*
- ***Fast GMPPT** and ultimate shade tolerance resulting in up to 30% better energy harvest*
- *Can be plugged either in **the 350 VDC or in 700 VDC** microgrids*
- ***Fully compatible** with emerging NPR9090 standard and Current OS DC microgrid protocol*
- *Supports the **droop control** functionality and features the integrated **solid state protection** circuitry for ensuring the highest level of fire and electric shock safety*
- ***All-in-One approach** with integrated gateway*
- *Integrates **2.4 GHz WiFi** and **BLE** for effortless cloud monitoring and on-site commissioning*

D. Vinnikov, A. Chub, E. Liivik, R. Kosenko and O. Korkh, "Solar Optiverter—A Novel Hybrid Approach to the Photovoltaic Module Level Power Electronics," in IEEE Transactions on Industrial Electronics, vol. 66, no. 5, pp. 3869-3880, May 2019, doi: 10.1109/TIE.2018.2850036.

FORCE – FractiOnal pOweR ConvErter

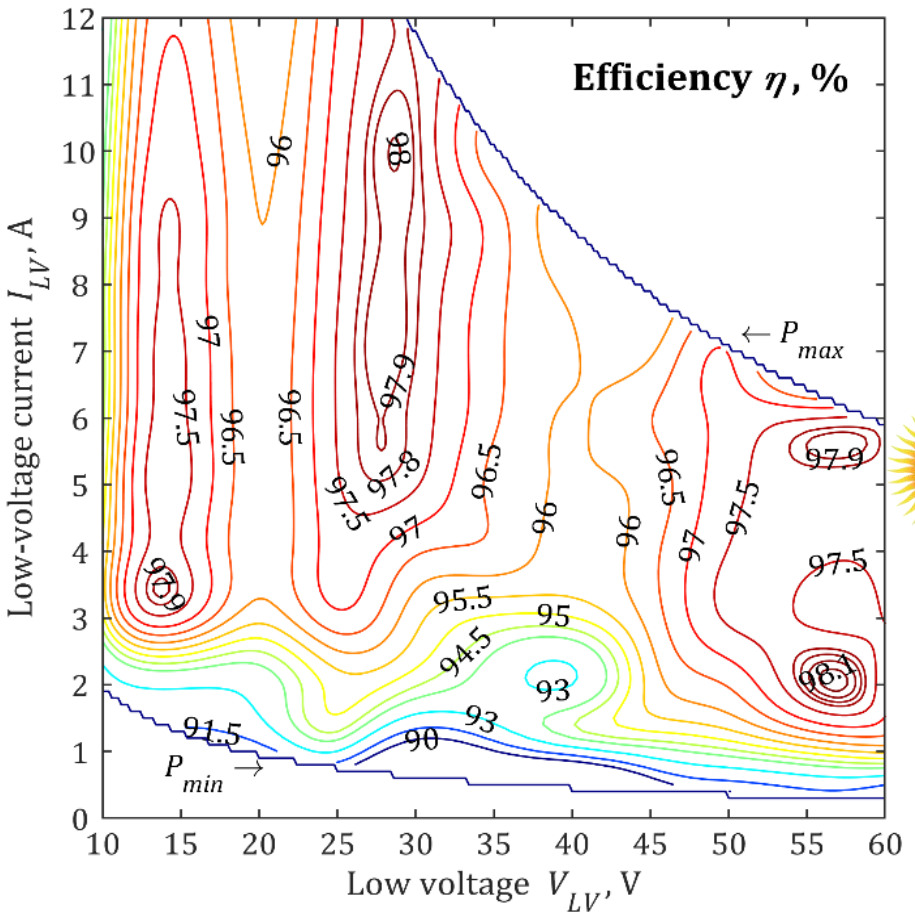
For efficient integration of high-voltage batteries

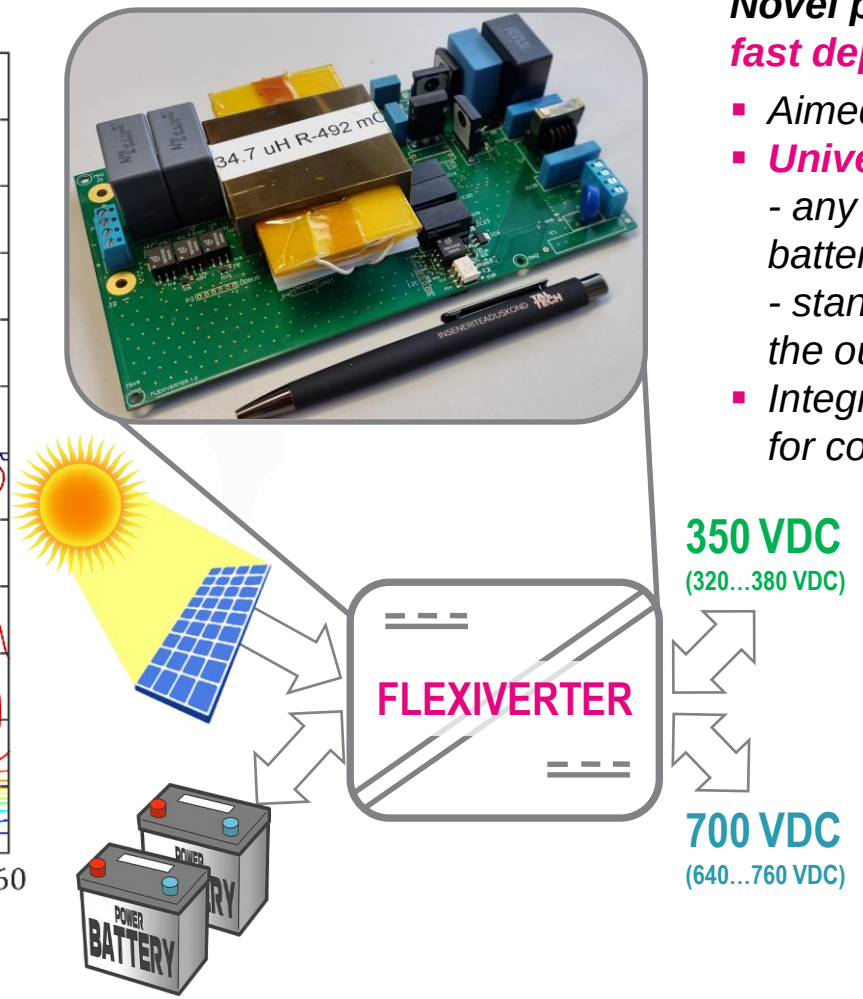
- *Ultra-efficient – **over 99%** for 25%+ load*
- *Optimized for **350±30V** residential DC microgrids*
- *Designed for **second-life** LFP battery stack of 109 cells, approx. capacity ~8 kWh (depends on degradation)*
- ***Patented control** with soft-switching in the entire range*
- ***Soft-start** and embedded solid-state **protection** for compatibility with **CurrentOS** DC microgrid protocol*
- ***Low stress** on components*
- *Ready for emerging bidirectional **monolithic GaN switches** (by Infineon)*



N. Hassanpour, A. Chub, A. Blinov and D. Vinnikov, "Soft-Switching Bidirectional Step-Up/Down Partial Power Converter with Reduced Components Stress," in IEEE Transactions on Power Electronics, vol. 38, no. 11, pp. 14166-14177, Nov. 2023.

FLEXIVERTER – FLEXIble conVERTER
power electronics “LEGO” for ZEB





Novel power electronic building block for fast deployment of residential DC systems:

- *Aimed at nano-producers (<800W)*
- ***Universal compatibility:***
  - any residential PV module and 24V or 48V batteries at the input
  - standard 350±30V or 700±60V microgrid at the output
- *Integrated soft-start and solid-state protection for compatibility with **CurrentOS** protocol*

Features:

- *Peak efficiency **>98%***
- *Input source type **identification***
- *DC microgrid ready – **droop control** for battery and **power clipping** for PV*
- ***Global** maximum power point tracking verified*
- ***Integrated** design*
- *Generic **off-the-shelf components** used*

V. Sidorov, A. Chub, D. Vinnikov and A. Lindvest, "Novel Universal Power Electronic Interface for Integration of PV Modules and Battery Energy Storages in Residential DC Microgrids," in IEEE Access, vol. 11, pp. 30845-30858, 2023.

DEVELOPMENTS IN PROGRESS

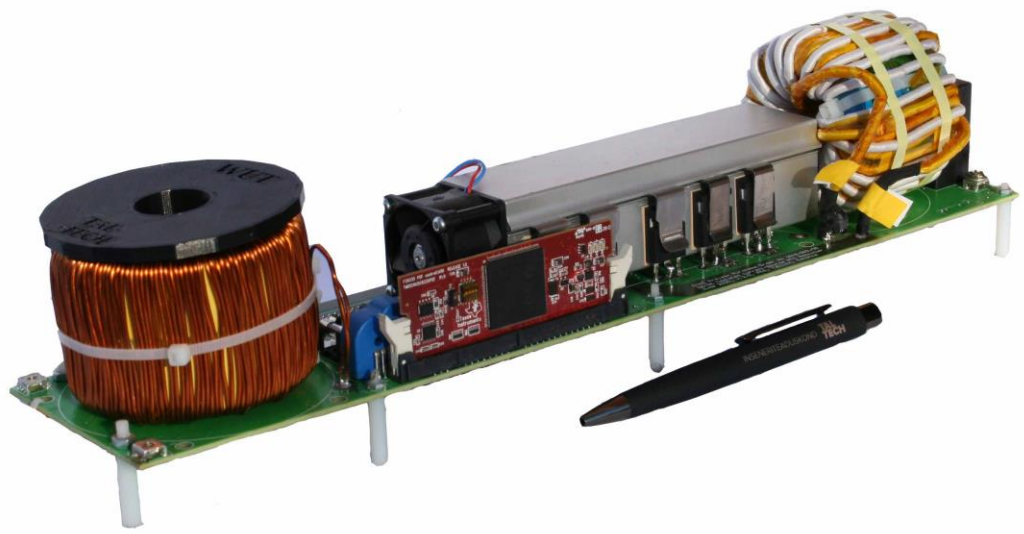
DC GRID FORMING CONVERTER

- *Bidirectional power router for prosumer DC buildings*
- *High-frequency galvanic isolation*
- *Power 5…20 kW, input 700 VDC, output 350 VDC*
- *Droop control according to CurrentOS protocol*
- *Efficiency curve optimized for part-load operation based on statistical data*
- *Possible multi-port configuration with USB-PD output*

E. L. Carvalho et al. "Design Considerations of Dual-Active Bridge DC Grid-Forming Converter for DC Buildings," in IEEE Transactions on Industrial Electronics, doi: 10.1109/TIE.2023.3331125.

VEHICLE-TO-HOME (V2H) INTERFACE

- *Charges EV and employs energy stored in it for the emergency backup power supply of ZEB*
- *High-frequency galvanic isolation*
- *Power 3…7.4 kVA, universal EV-side range of 200…800 VDC*
- *Droop controlled according to CurrentOS (in emergency bands)*
- *High weighted efficiency of >97%*
- *Low-cost single-stage design*



D. Zinchenko et al. "High-Efficiency Single-Stage On-Board Charger for Electrical Vehicles," in IEEE Transactions on Vehicular Technology, vol. 70, no. 12, pp. 12581-12592, Dec. 2021, doi: 10.1109/TVT.2021.3118392.

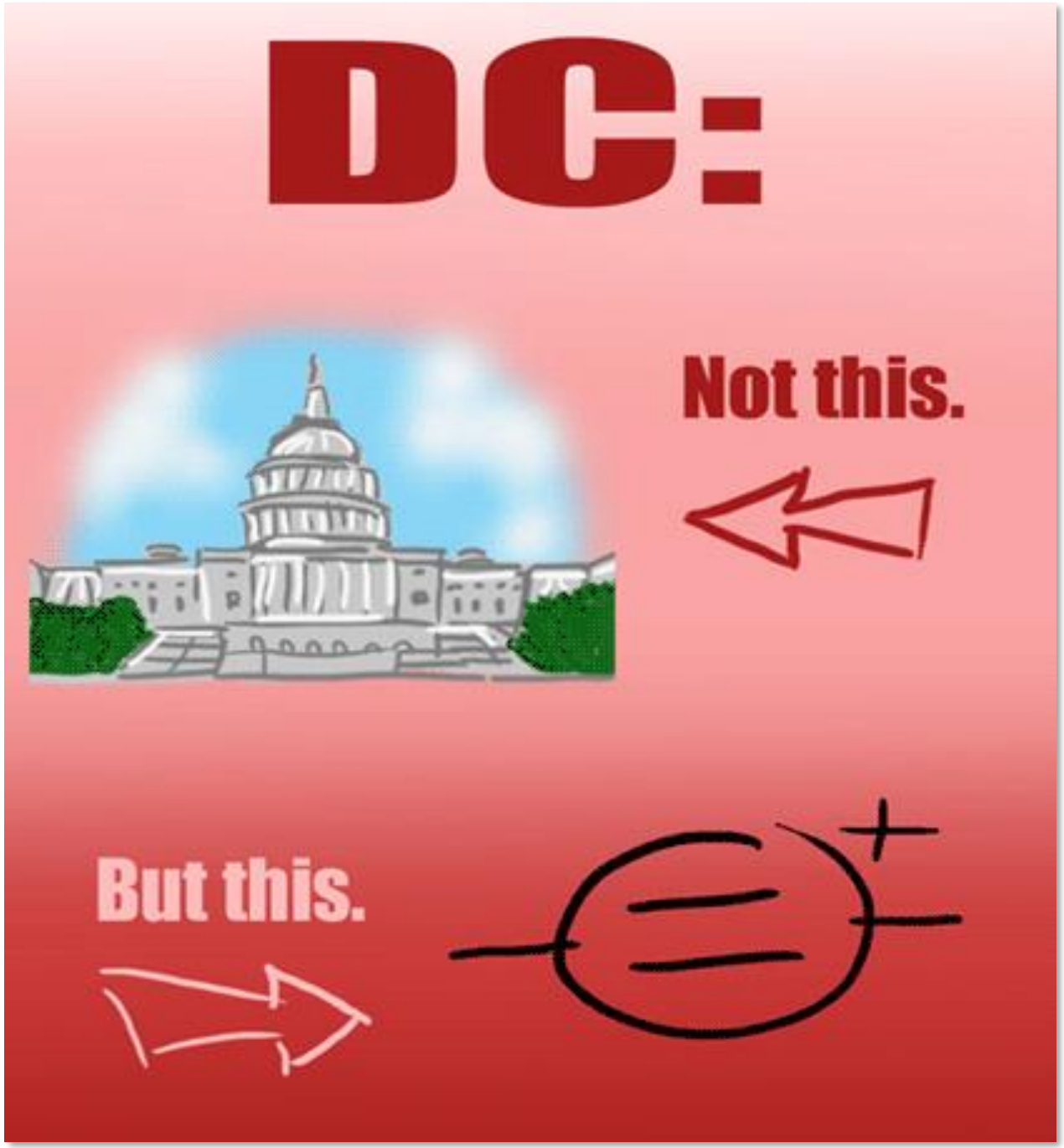
ICDCM 2025 IN TALLINN – MARK THE DATE!

THE 7TH IEEE INTERNATIONAL CONFERENCE ON DC MICROGRIDS (ICDCM 2025)

FULLY SPONSORED BY THE IEEE PELS (TC1)

You can expect:

- *Highly relevant program on DC microgrids and applications*
- *~100 papers to be presented*
- *7 tutorials from world-renown experts*
- *Conference venue next to the Tallinn's Old Town – a UNESCO World Heritage Site*
- *Entertaining social events for attendees, special events for PELS student and WiE members*
- *Lunches and coffee breaks*
- *White nights and mild summer weather*



QUESTIONS

Centre of Excellence in Energy Efficiency

Estonian Research Council

i³ DC Accelerates Energy Transition