POWER ELECTRONICS AS THE ENABLING TECHNOLOGY FOR BUILDINGS DECARBONIZATION

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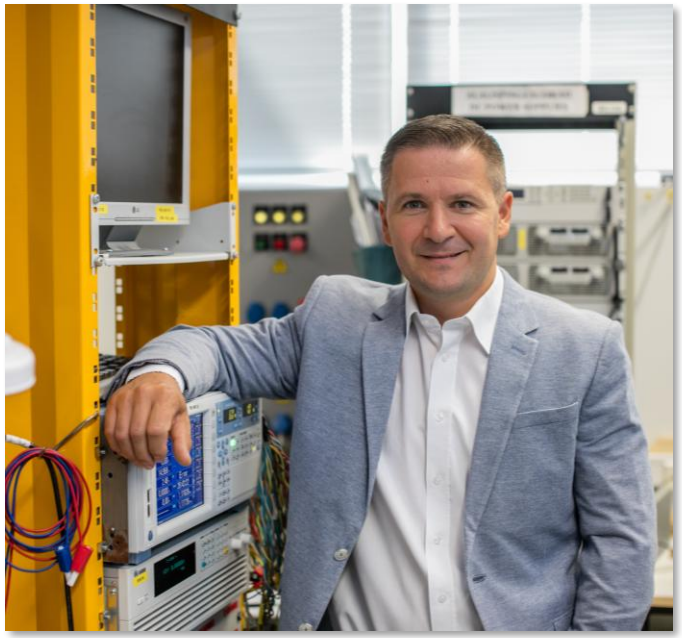
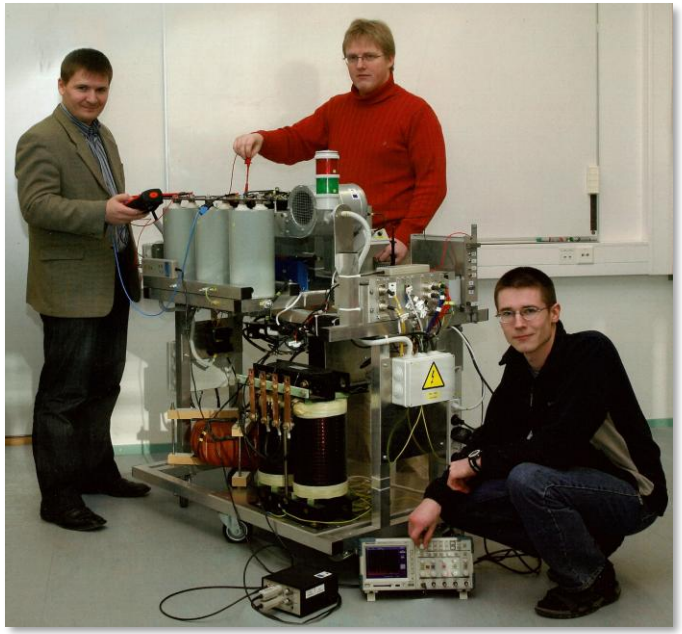


- *Dreamed of becoming a pilot, but life led me to electrical engineering*
- *Staying with TalTech (Tallinn University of Technology) since 1993*
- *Passionate of power electronics and energy efficiency*
- *DC ambassador and founder of I^3DC initiative*
- *Founder of TalTech Power Electronics Group (2006)*
- *Co-Founder of Estonian cleantech start-up UBIK Solutions (2010) and two Estonian Centers of Excellence in Research: ZEBE (2015) and ENER (2024)*
- *Full Member of the Estonian Academy of Sciences (2021)*
- *IEEE Fellow; founder of the Estonian IES/PELS joint chapter; activist, past chair and mentor of the IEEE IES SYP Activity Commitee*
- *Hobbies: Grill/BBQ, fishing, gym and building engineering*



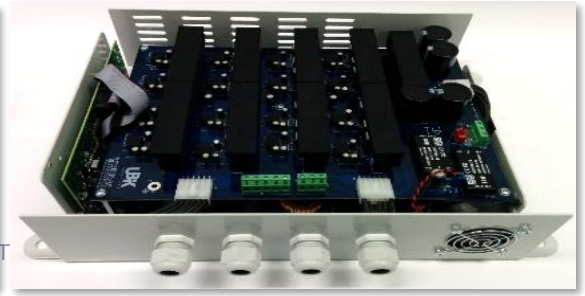
ESTONIA

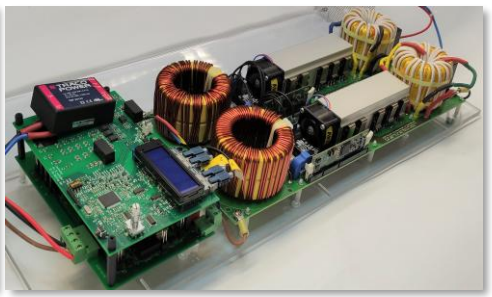
skype™

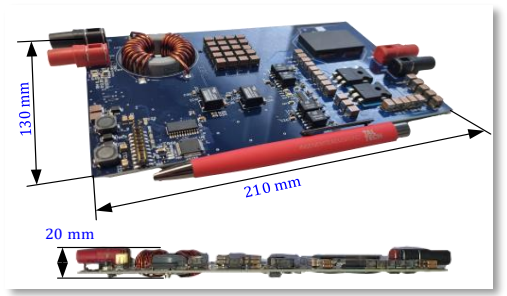
Bolt

skeleton+

POWER ELECTRONICS GROUP OF TALTECH







POWER ELECTRONICS GROUP OF TALTECH

A PROUD MEMBER OF THE GLOBAL FAMILY OF POWER ELECTRONICS RESEARCHERS

Celebrating +20 years of friendship and cooperation with Poland


Tallinn University of Technology, June 2004

IV Summer Seminar on Nordic Network for Multidisciplinary Optimized Electric Drives


Gdynia Maritime University, 2009


WUT, 2013


University of Zielona Gora, 2011

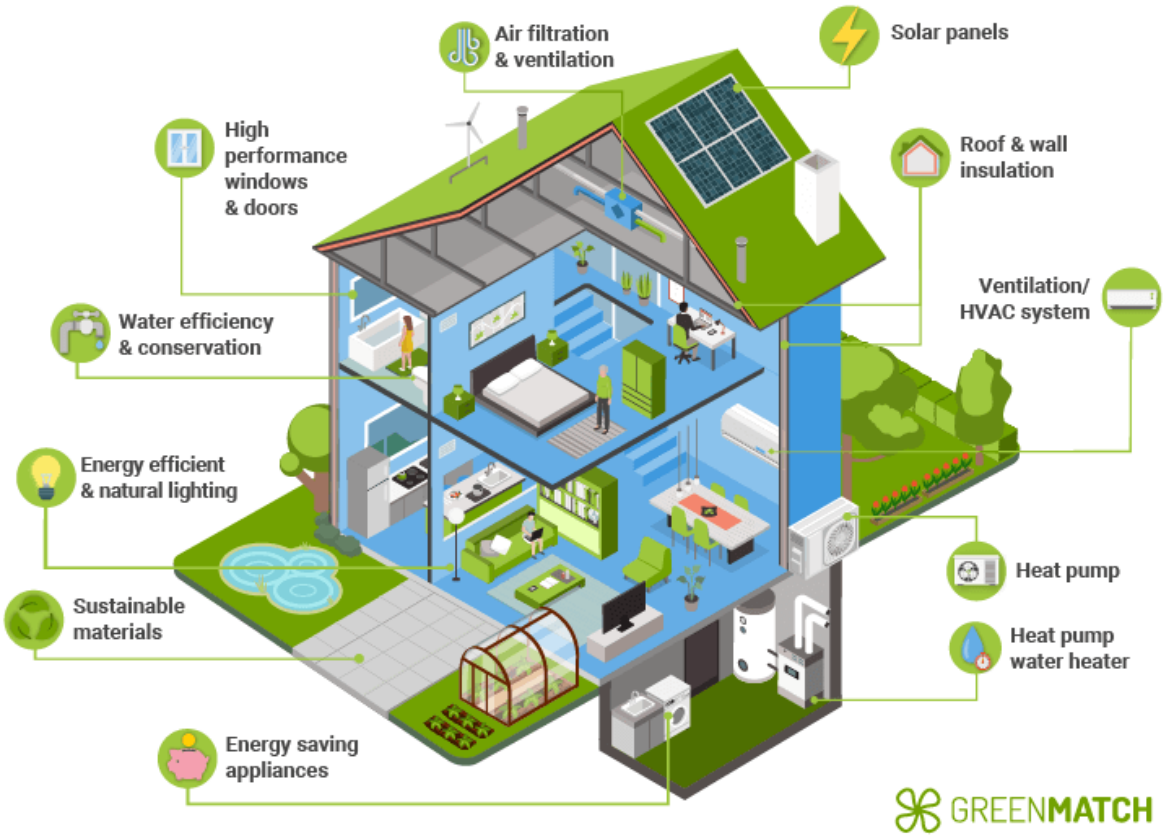

Estonian Academy of Sciences, 2022

PRIORITY R&I FIELD: ENERGY EFFICIENT HOMES

- ***Highly reliable cost-optimal power electronic systems*** *for integration of residential PV, battery energy storages and EVs*
- ***Safe and secure control*** *of residential microgrids, power trading between the building and utility grid*
- *Application of* ***direct current (DC) power distribution*** *concept for energy efficiency enhancement of buildings*
- ***Widening the awareness and acceleration of the industrial uptake*** *of the residential DC microgrid technology (i³DC initiative)*

PEG is one of the key players in the Estonian Energy Efficiency Centre of Excellence (ENER), which brings together the best expertise in engineering, data science, and social sciences in Estonia and contributes to addressing Estonia's societal and economic challenge of transforming 75% of the existing low-energy-efficiency building stock into emission-free buildings by 2050

Centre of Excellence in Energy Efficiency

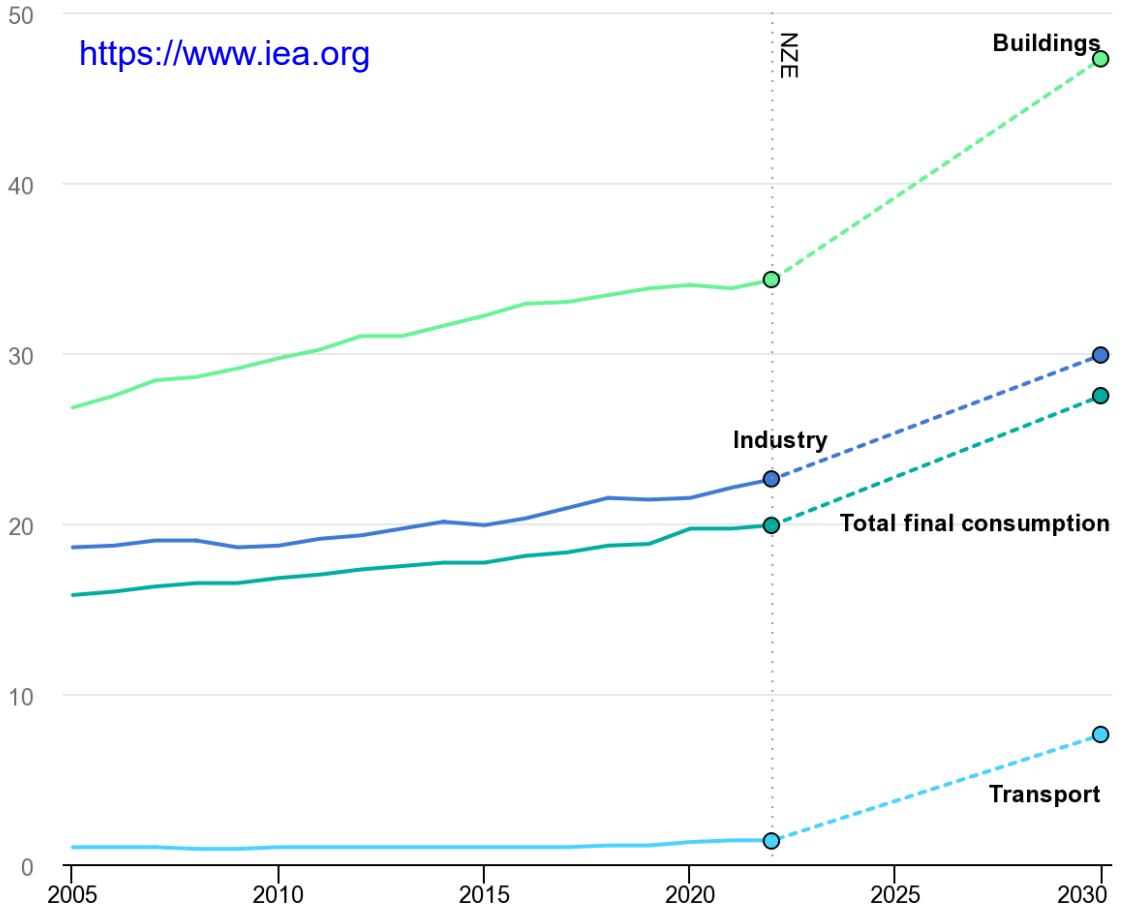


CLIMATE NEUTRAL BY 2035

TAL TECH

TOWARDS 2050 NZE PATHWAY (EU GREEN DEAL)

- *By 2050 the EU aims to become the **world's first "climate-neutral bloc"** with net-zero greenhouse gas emissions (NZE)*
- ***Electrification** is considered one of the key strategies to reach NZE goals*
- *In 2050 the **share of electricity** in the final energy consumption is targeted to be **more than 50%***
- *By 2050, almost **90%** of electricity generation in EU is expected to come **from renewable sources***
- *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*
- ***Power electronics is one of the key enablers** of the EU Green Deal*



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

DECARBONIZATION OF BUILDING STOCK IN EU

- ***Buildings*** *are responsible for approximately* ***40% of EU energy consumption***, ***50% of EU gas consumption,*** *and* ***36% of the energy-related CO2 emissions. About 80%*** *of energy used in EU homes is for heating, cooling and hot water*
- ***85% of buildings in the EU were built before 2000*** *and* ***75% have poor energy performance****. 85–95% of today's buildings will still be in use in 2050*
- *In 2002, the EU began implementing the* ***Energy Performance of Buildings Directive (EPBD)****, which is a framework to reduce energy consumption and boost decarbonization of buildings*
- *The EPBD requires all new buildings from 2021 to be* ***nearly zero-energy buildings (nZEB)***
- ***nZEB (or class A building)*** *must have a* ***high energy performance and very low energy needs****, covered largely by* ***onsite and nearby renewable energy sources***
- *From January 2030 the EPBD requires all new buildings (all new public buildings from January 2030) to be* ***zero-emission buildings (ZEB, A+ or A_0), i.e. without on-site carbon emissions from fossil fuels***
- *EPBD demands the installation of* ***EV charging points*** *in new and significantly renovated non-residential buildings with more than 5 parking spaces, and in residential buildings with more than ten parking spaces*
- *EPBD introduces „Smart Readiness Indicator" to assess the technological readiness of the building to* ***interact with their occupants and adapt to signals from the grid (for ex., energy flexibility)***

https://energy.ec.europa.eu

EU RENOVATION WAVE STRATEGY

- ***Key initiative of the EU*** *launched in 2020 to improve building energy efficiency and overall living standards*
- *Aims at* ***doubling annual renovation rates*** *by 2030 and renovating 35 million buildings*
- *In practice,* ***A class building consumes up to 4 times less energy*** *than the traditional „old school“ building (G-class)*

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

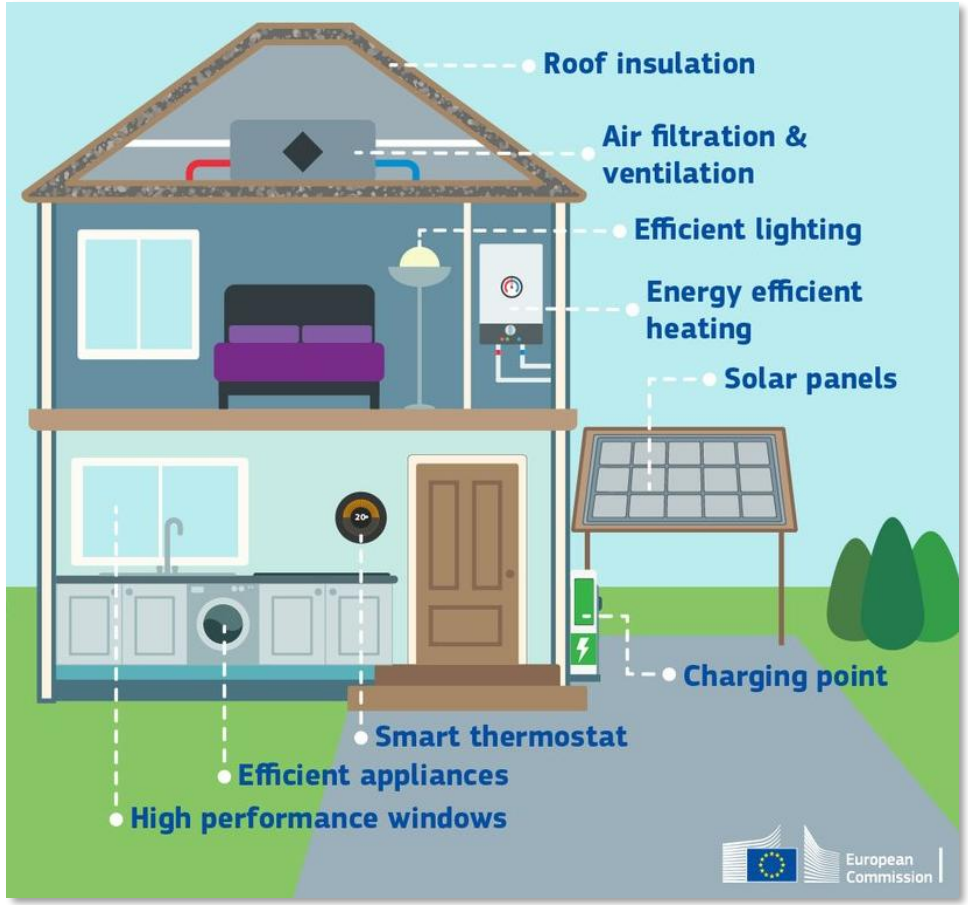
En. Label	D1 (EPC)	D2 (EPC)	D3 (EPC)
A	≤145	≤120	≤100
B	146–165	121–140	101–120
C	166–185	141–160	121–140
D	186–235	161–210	141–200
E	236–285	211–260	201–250
F	286–350	261–330	251–320
G	351–420	331–400	321–390
H	≥421	≥401	≥391

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

ZEB AND POWER ELECTRONICS

IT IS ALL ABOUT EFFICIENCY AND ENERGY SAVING

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



GOOD EXAMPLES OF BUILDING DECARBONIZATION

BAD EXAMPLES OF BUILDING DECARBONIZATION

https://greensunnj.com/solar-hall-of-shame/

BAPV vs BIPV- RENEWABLE ENERGY SHOULDN'T COME AT THE COST OF AESTHETICS !

Building-Attached Photovoltaics (BAPV) *lacks full integration into the building, adds additional load, with limited contributions to aesthetics and structural integrity*

Building-Integrated Photovoltaics (BIPV) *is revolutionizing the solar industry by bridging the gap between electricity generation and building design*


Image: Roofit Solar

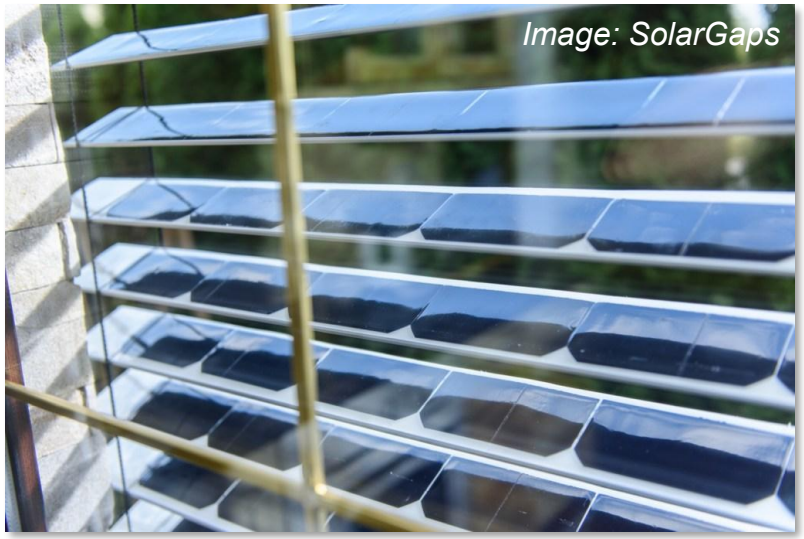

Image: Solarstone

THERE'S MORE OPTIONS THAN THE ROOFTOP PV!

SOLAR PV FENCES

SOLAR WINDOWS

SOLAR PANEL WINDOW BLINDS

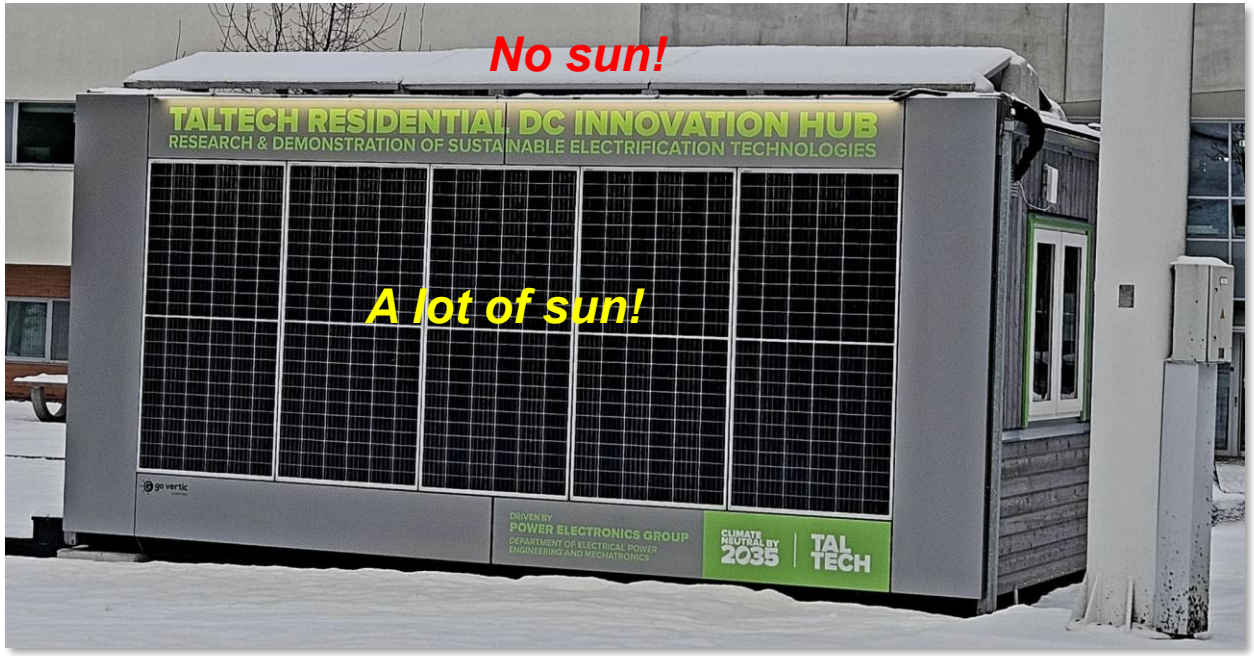


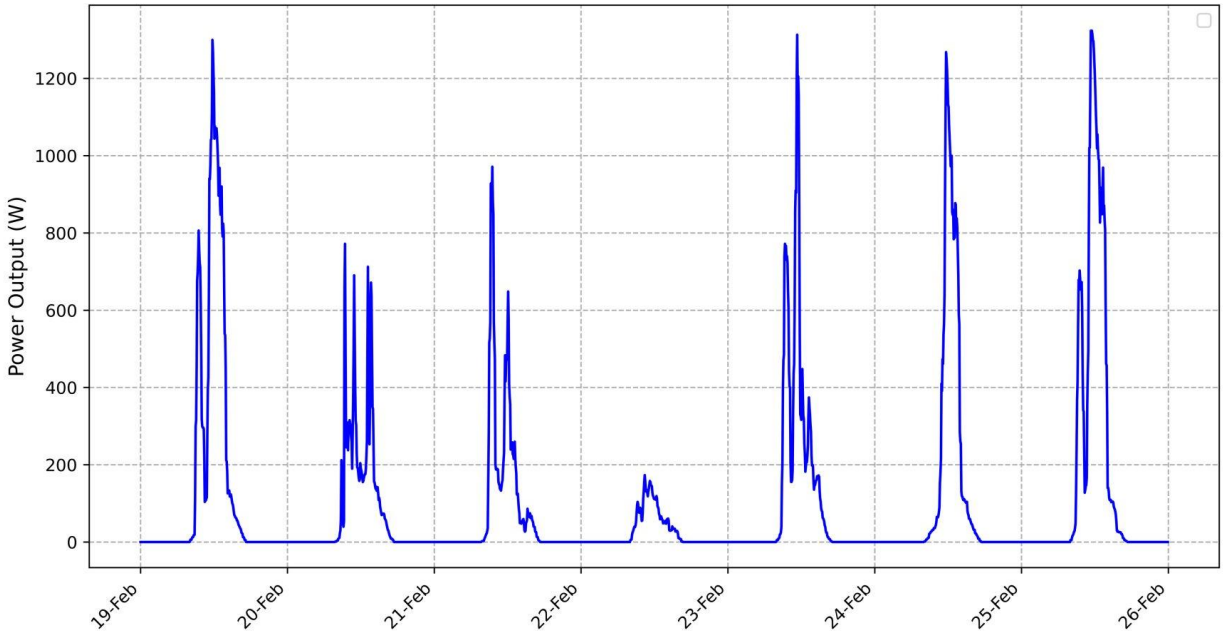
SOLAR BALCONIES

SOLAR FAÇADES

SOLAR FAÇADE – GENERATE WHEN OTHER DO NOT

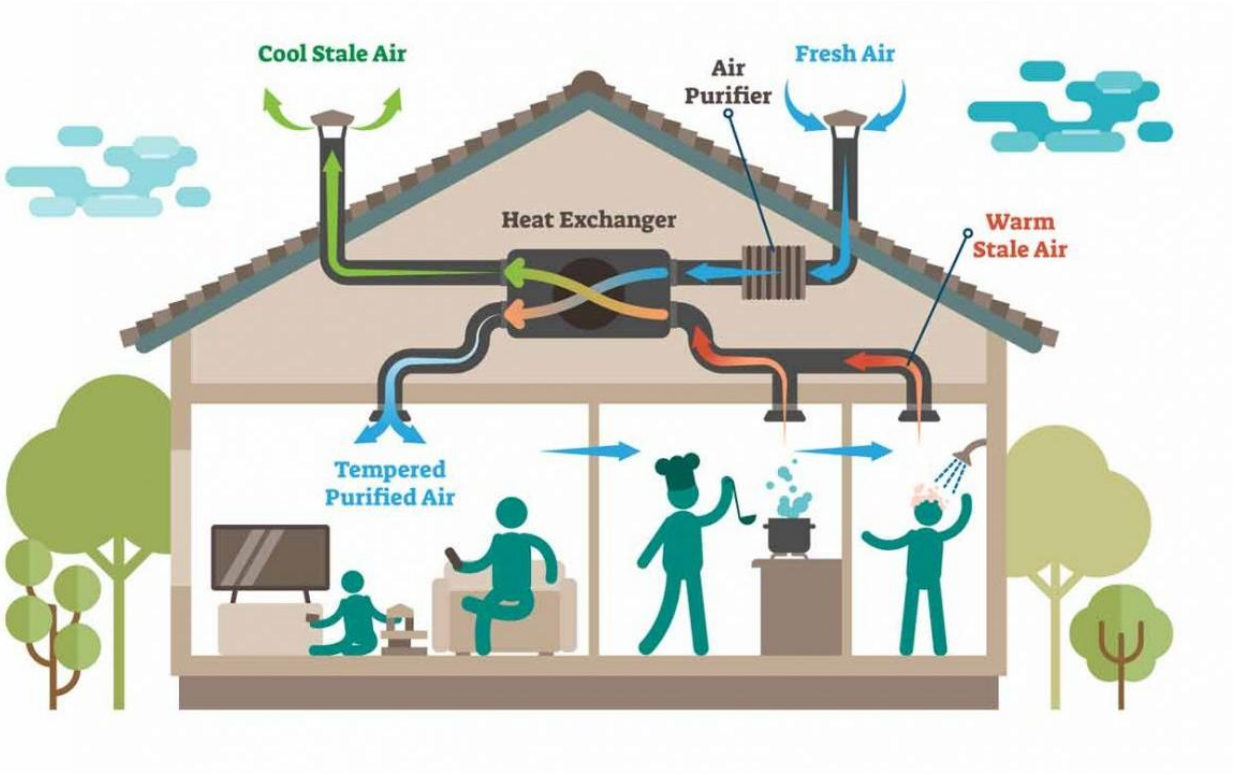
- ***In Northern EU,*** *snow covers the PV panels on the roof for long time, but they cannot generate much even without snow as sun ray's incident angle is highly unfavorable (sun rays nearly horizontal)*
- ***Solar façades*** *are never covered by snow, while sun incident angle is nearly ideal in winter*
- ***TalTech Residential DC Innovation Hub*** *has 5 PV modules of 144 half-cut cells rated for 360 W*
- *Test data from February 2026 show that the solar façade produced* ***17.9 kWh vs. 0 kWh*** *from the roof*





HEAT RECOVERY VENTILATION SYSTEMS

- ***Improved energy efficiency**: reduces heating demand of the buidling by recovering up to 60–90% of the heat from exhaust air; lowers energy bills*
- ***Better indoor air quality**: reduces buildup of carbon dioxide and radon levels, removes pollutants such as VOCs (from paints, furniture), allergens, and odors; maintains balanced indoor humidity levels.*
- ***Power electronics enabled smart control** and **easily pairing with PV** installation*



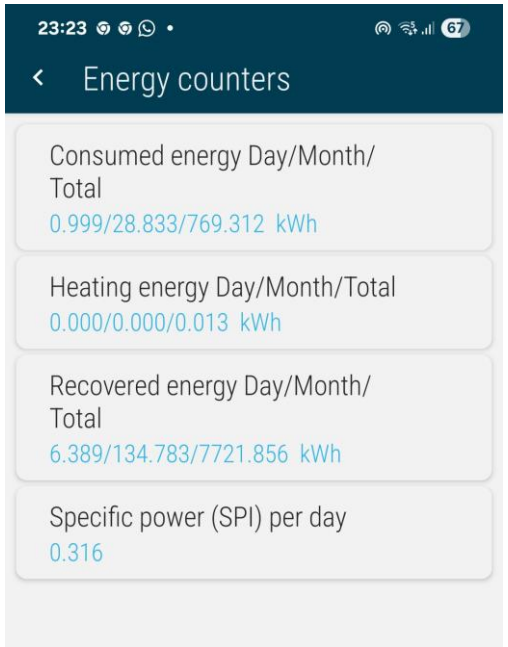
Domekt R 400 V C6M

Maximal air flow, m^3/h	373
Maximal air flow, l/s	104
Reference flow rate, m^3/s	0,073
Reference pressure difference, Pa	50
SPI, $W/(m^3/h)$	0,3
Thermal efficiency of heat recovery, %	86
Electric air heater capacity, kW / Δt, °C	1/11,2
Supply voltage, V	1~230

Temperature efficiency

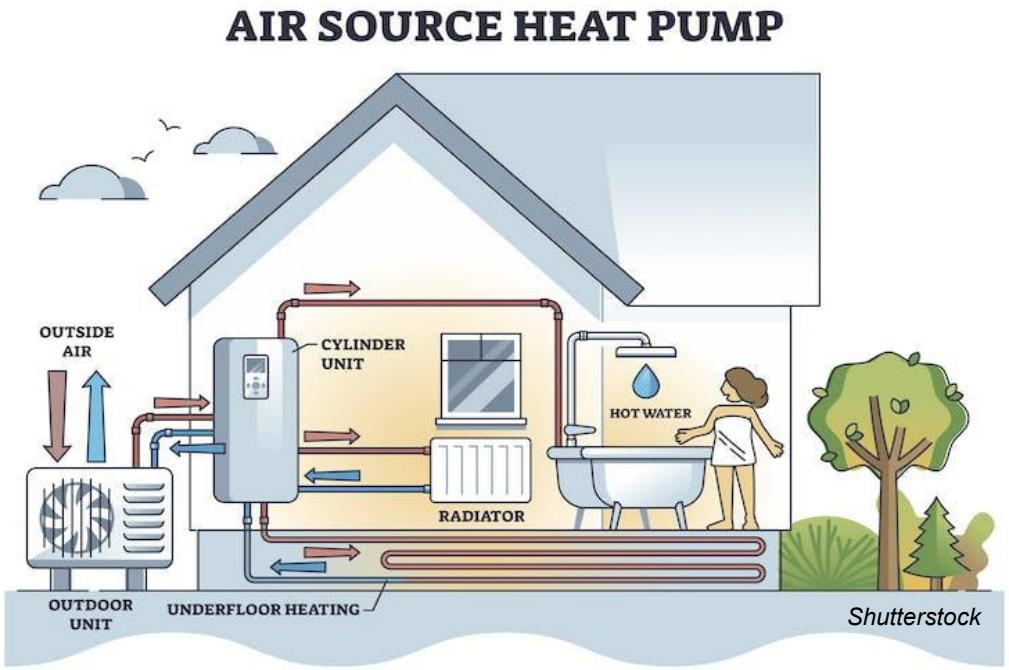
	Winter				
Outdoor temperature, °C	-23	-15	-10	-5	0
After heat exchanger, °C	15,6	16,7	17,4	18,1	18,9

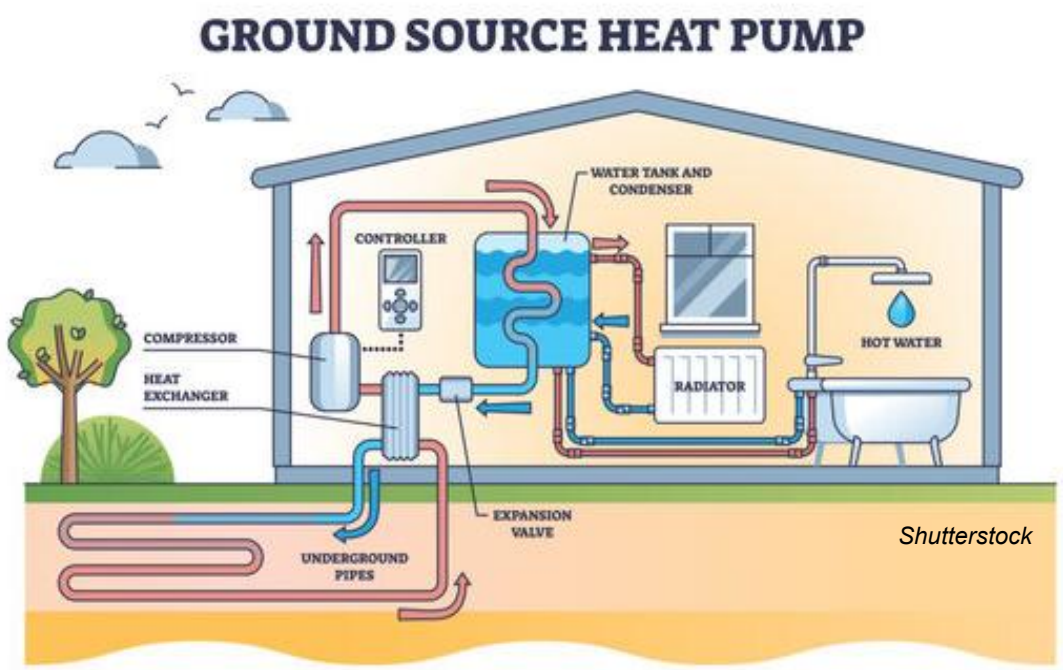
indoor +22 °C, 20 % RH



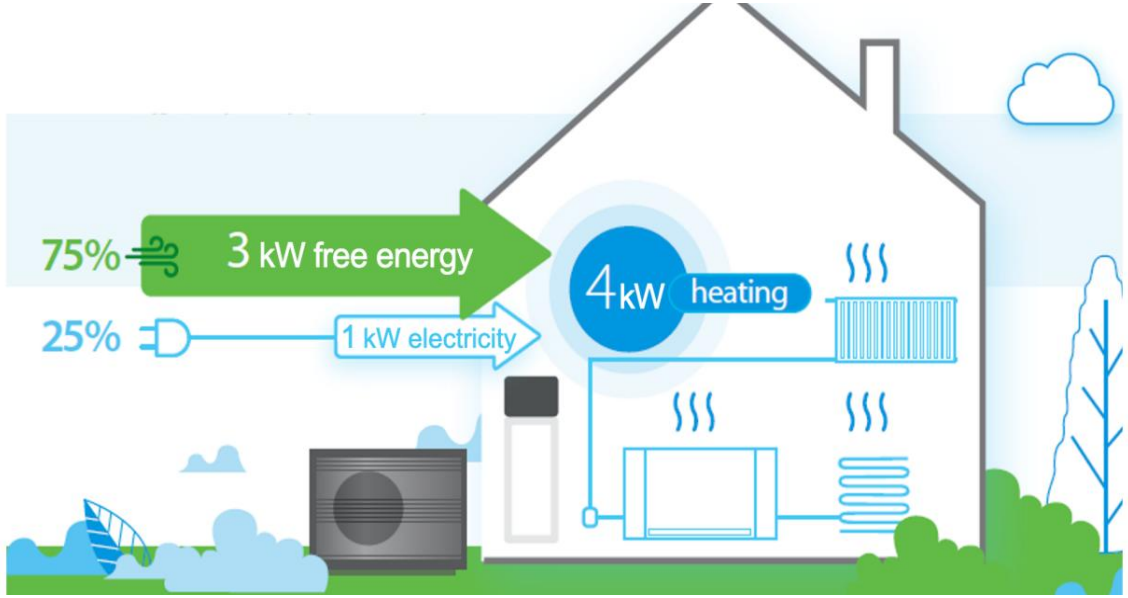
ELECTRIFICATION OF HEATING WITH HEAT PUMPS

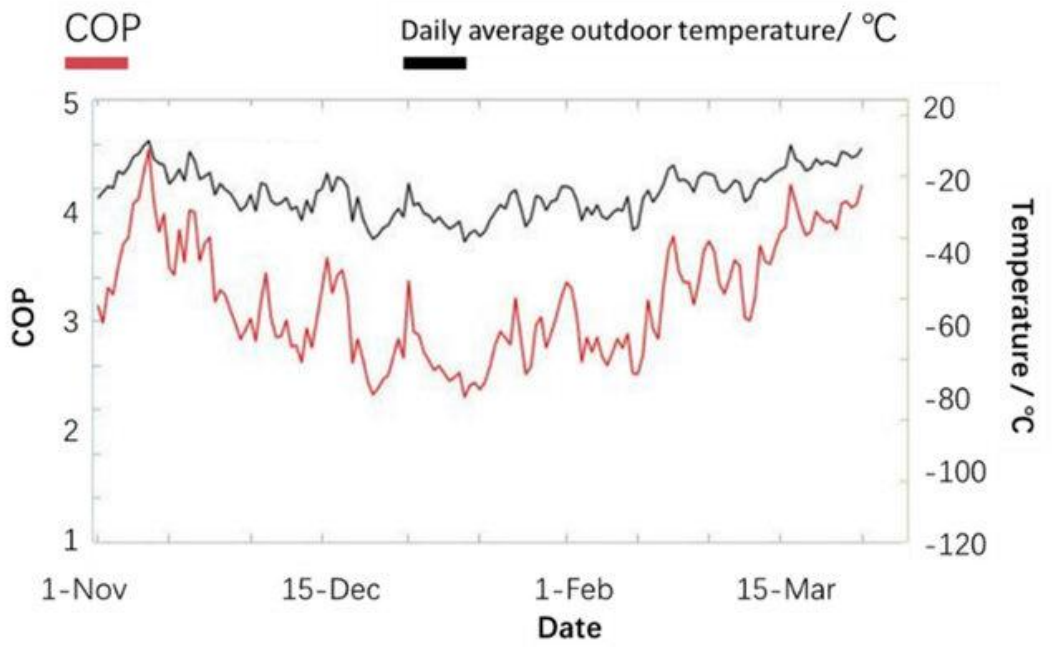
- *There are **two main types of heat pumps** – air source and ground source (geothermal)*
- ***Excellent energy efficiency**: can deliver up to 5 times more heat energy to a home than the electrical energy it consumes (see COP – Coefficient of Performance or SCOP – Seasonal Coefficient of Performance)*
- *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***

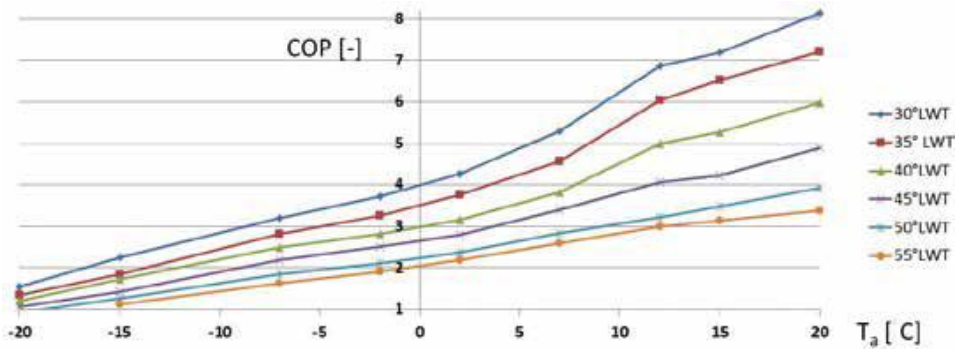




COP - COEFFICIENT OF PERFORMANCE

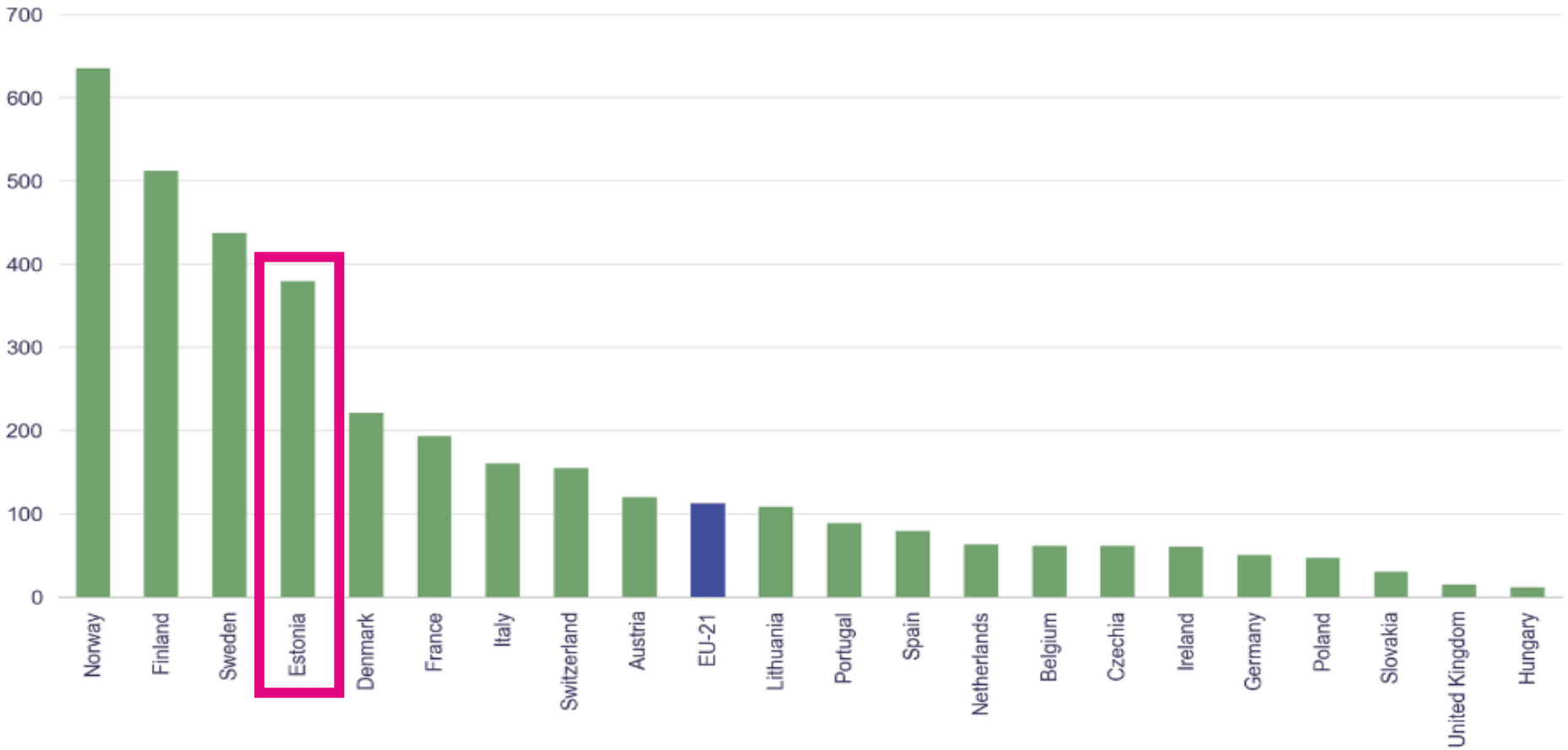






- Source: daikin.ie

HEAT PUMPS IN EU (PER 1000 HOUSEHOLDS, 2023)

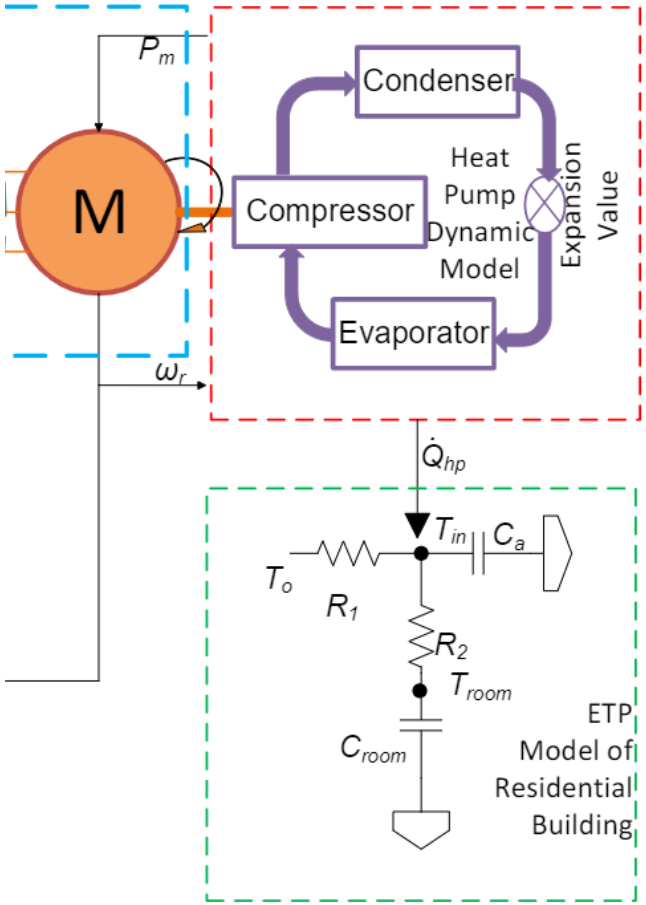


3.6 million heat pumps *installed by 2023, annual sales ca 3 million units*

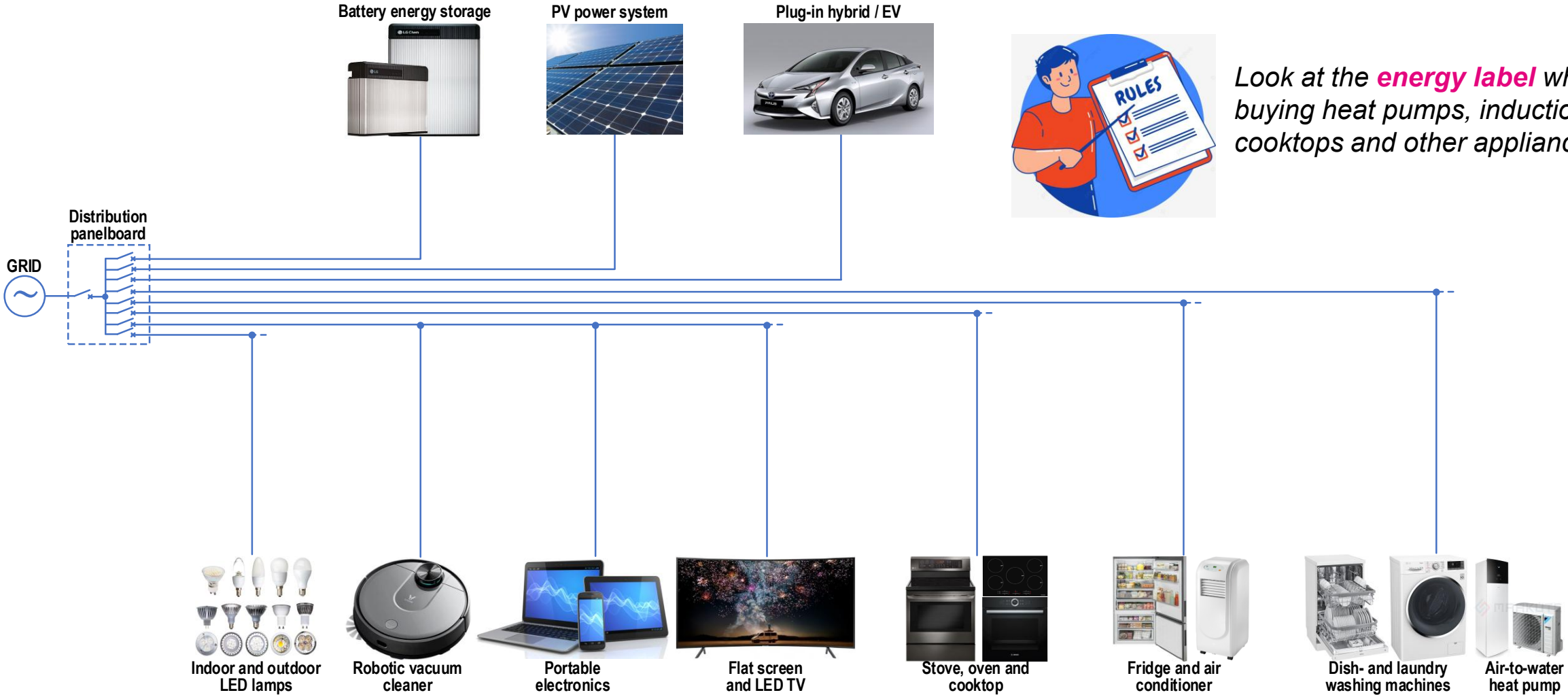
- Source: EHPA

EFFICIENT HEAT PUMPS USE POWER ELECTRONICS

- Source: daikin.ie



DECARBONIZATION OF BUILDINGS: „ALL-ELECTRIC“ LIFESTYLE WITH ZEB

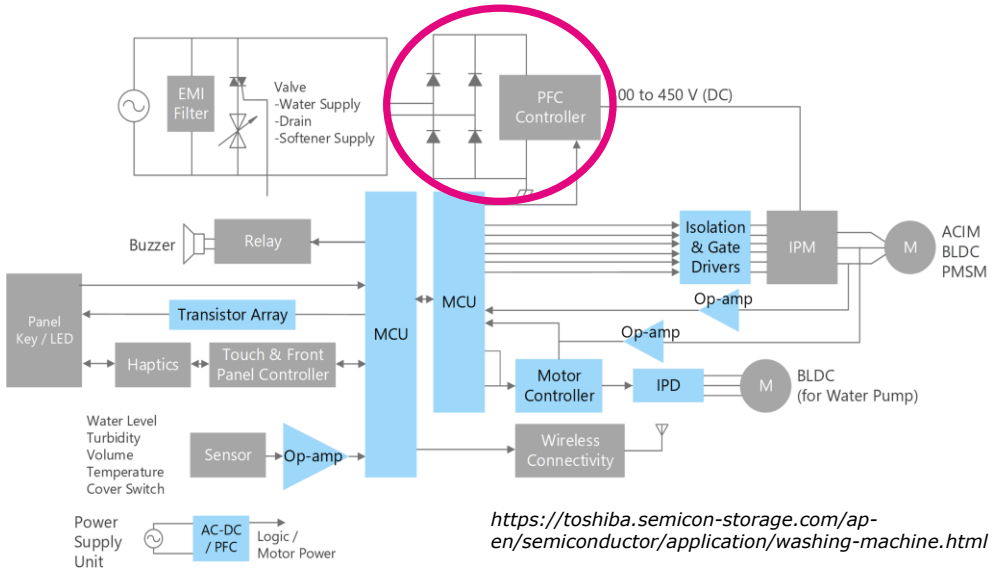


*Look at the **energy label** when buying heat pumps, induction cooktops and other appliances!*

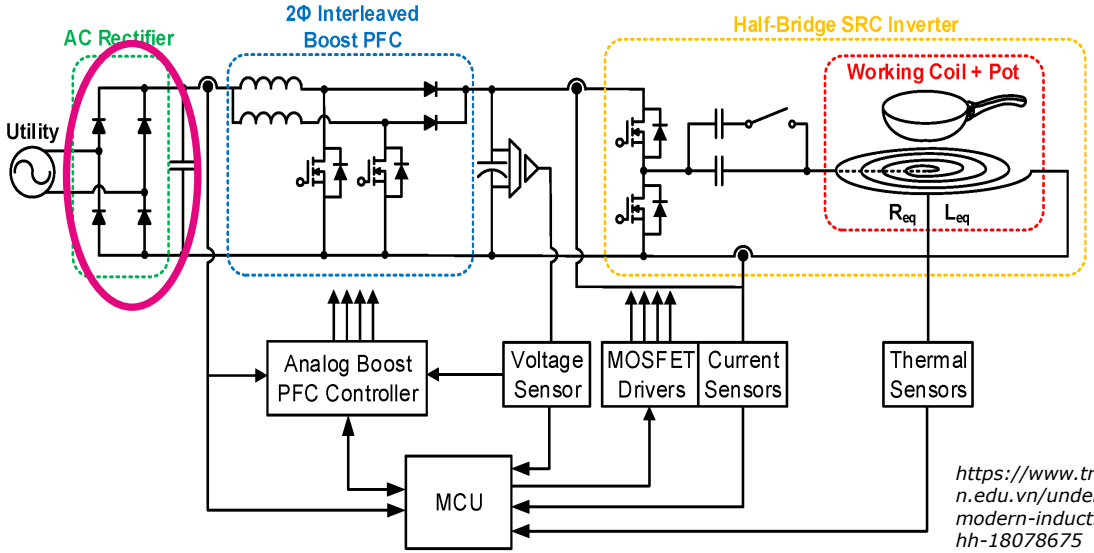
CLASS-A ENERGY-EFFICIENT APPLIANCES

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

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



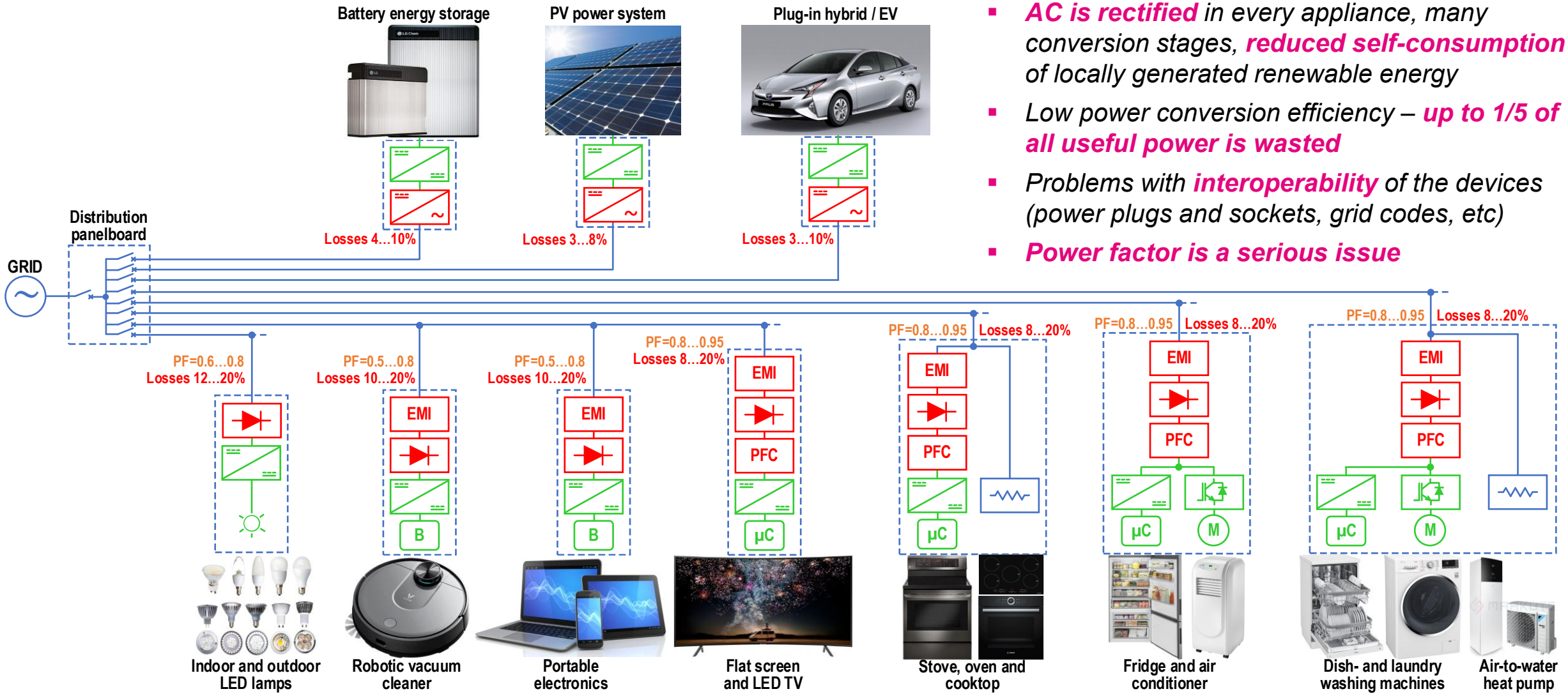
https://toshiba.semicon-storage.com/ap-en/semiconductor/application/washing-machine.html



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

AC-BASED ELECTRICAL SYSTEM OF A ZEB TODAY

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



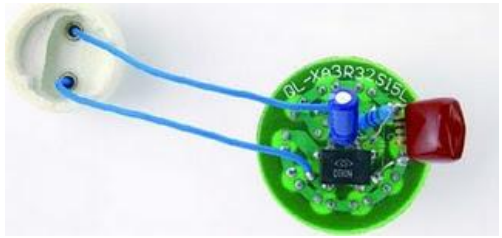
- *AC is rectified in every appliance, many conversion stages, **reduced self-consumption** of locally generated renewable energy*
- *Low power conversion efficiency – **up to 1/5 of all useful power is wasted***
- *Problems with **interoperability** of the devices (power plugs and sockets, grid codes, etc)*
- ***Power factor is a serious issue***

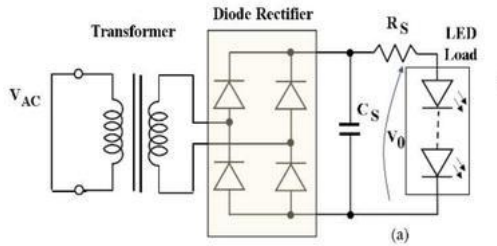
FULL-ELECTRIC LIFESTYLE WITH AC

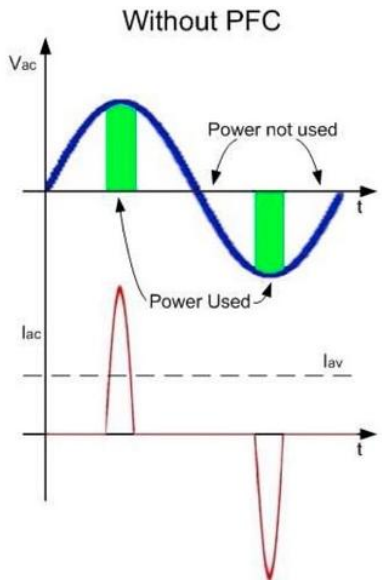
A CLOSER LOOK AT THE POWER FACTOR ISSUE

PFC stage is required only above 75W - energy efficiency is additionally affected by the non-unity power factor

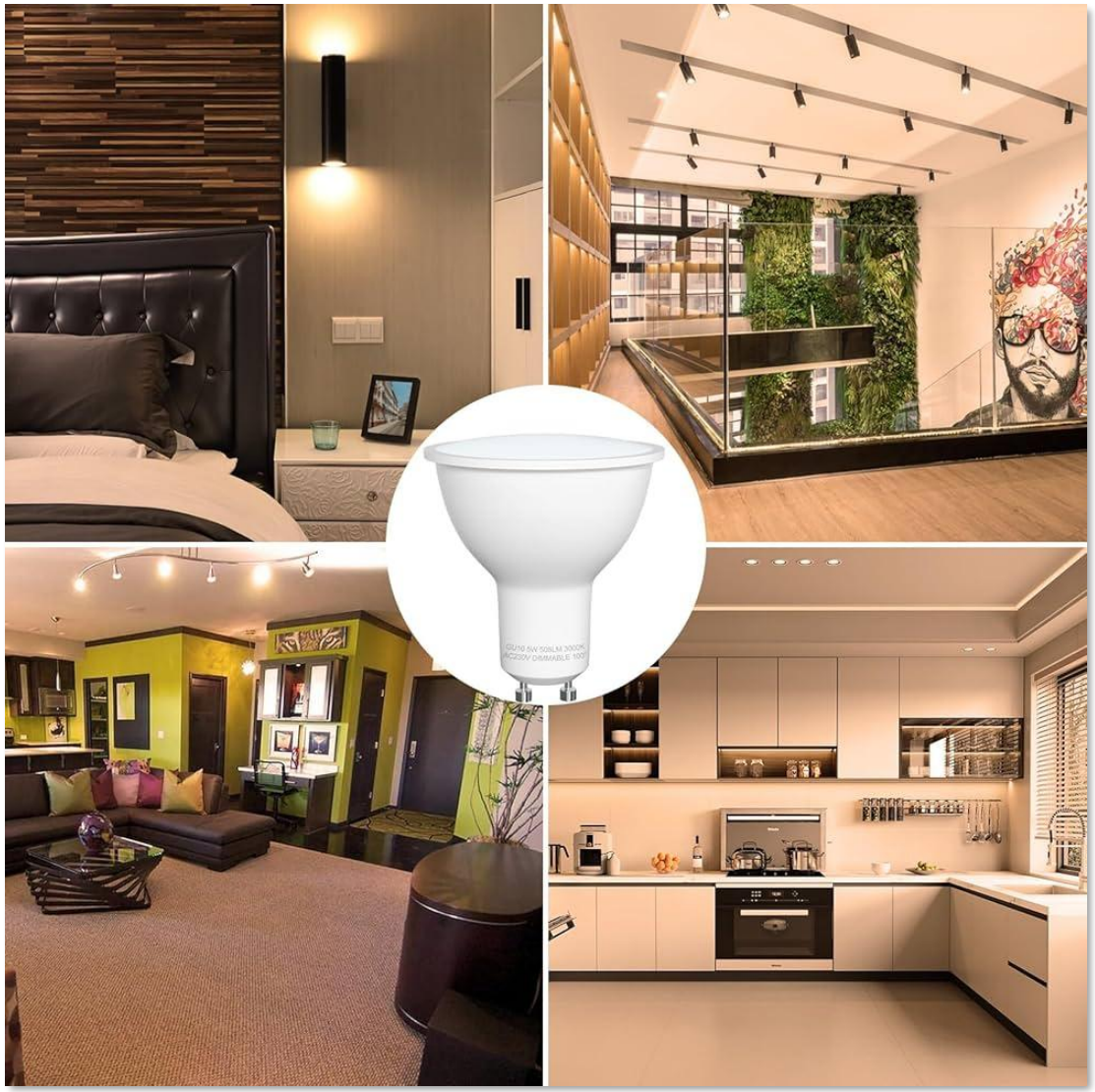
GU10 LED bulb (4.3 W)







1	Urms	1	—	232.40	V
2	Irms	1	—	0.0337	A
3	P	1	—	4.33	W
4	S	1	—	7.83	VA
5	Q	1	—	6.52	var
6	Uthd	1	—	0.964	%
7	Ithd	1	—	74.420	%
8	PF	1	—	0.5534	

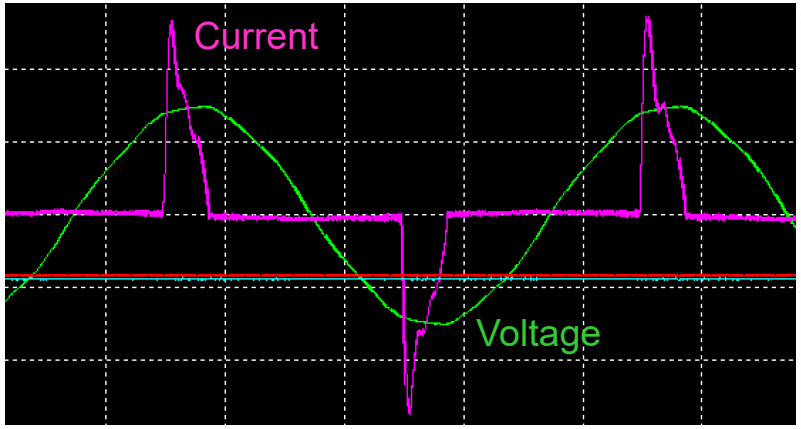


FULL-ELECTRIC LIFESTYLE WITH AC

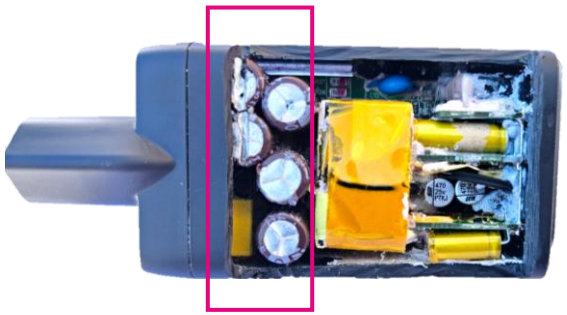
A CLOSER LOOK AT THE POWER FACTOR ISSUE

PFC stage is required only above 75W - energy efficiency is additionally affected by the non-unity power factor

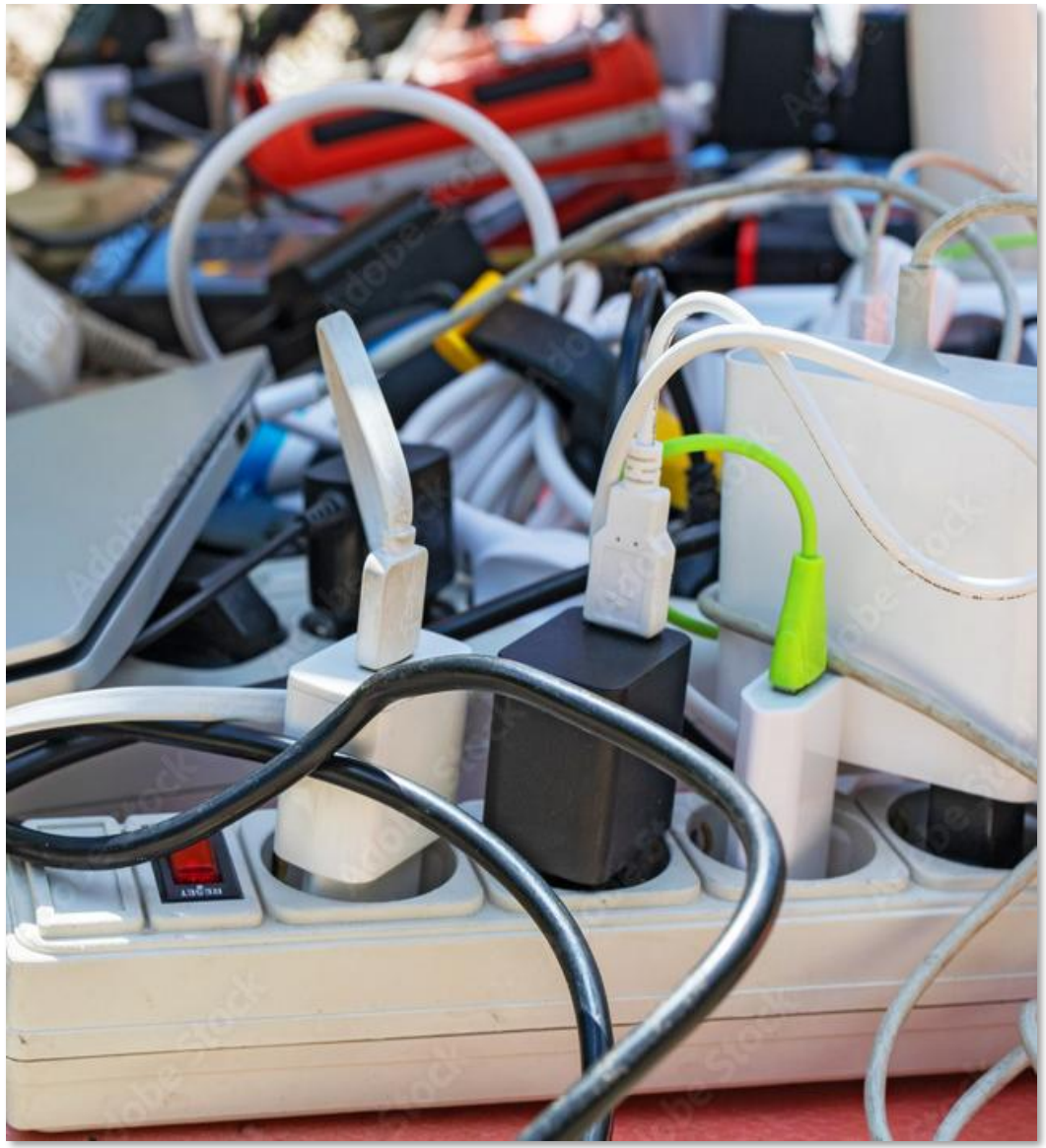
Laptop charger (65 W)



DC capacitors



No.	Function	Data	Units
1	Urms	232.37	V
2	Irms	0.5766	A
3	P	65.09	W
4	S	133.99	VA
5	Q	117.12	var
6	Uthd	1.122	%
7	Ithd	86.841	%
8	PF	0.4858	
9	Udc	19.243	V
10	Idc	-3.022	A
11	P	-58.16	W

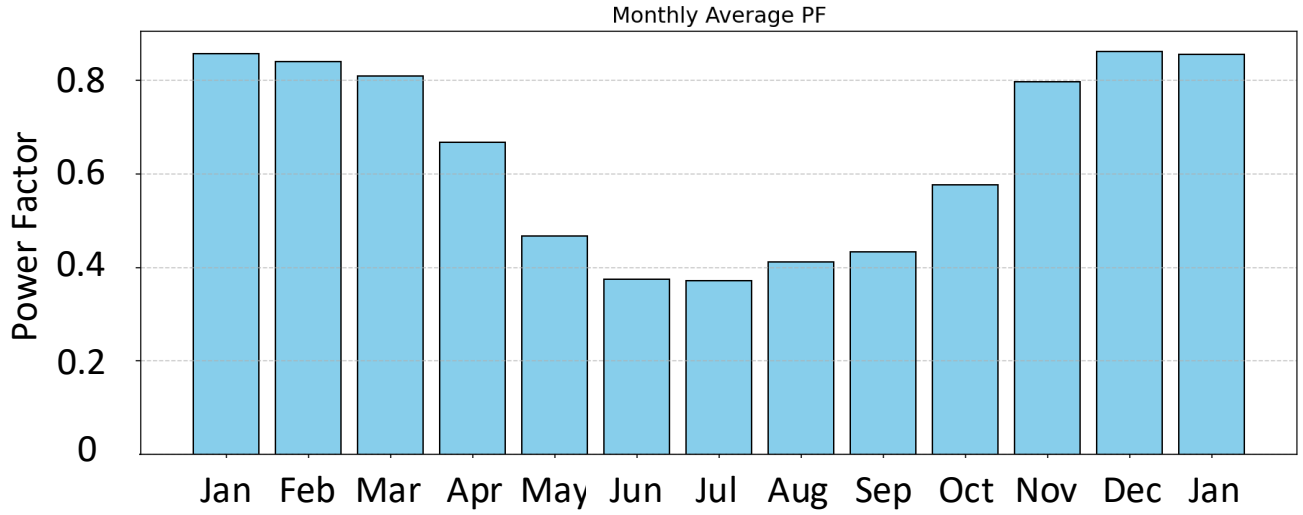


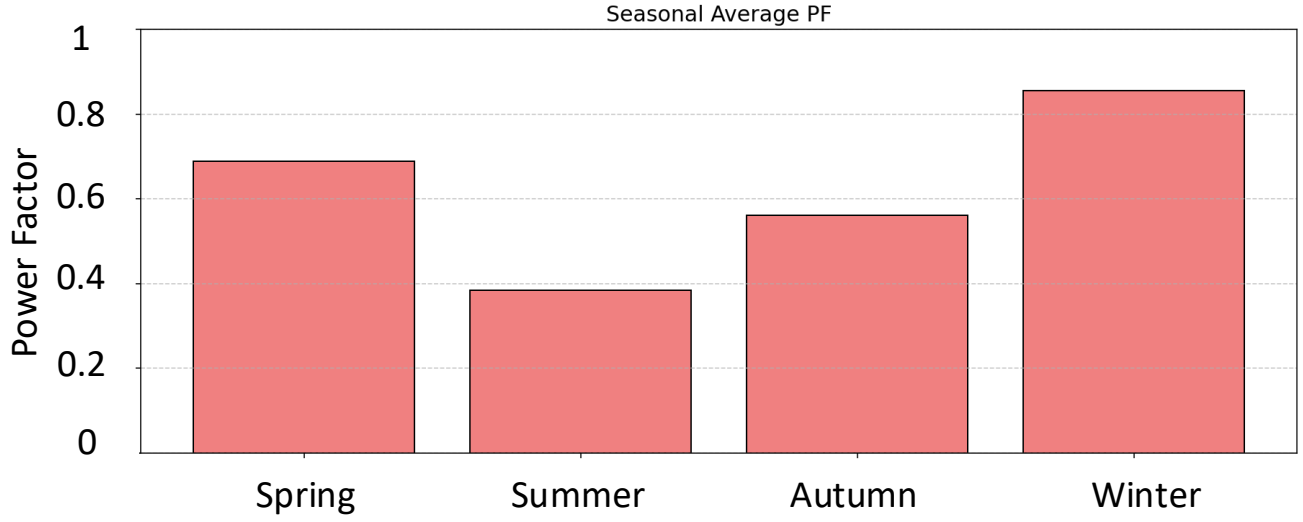
FULL-ELECTRIC LIFESTYLE WITH AC

A CLOSER LOOK AT THE POWER FACTOR ISSUE

176.7 m^2 single-family detached home

Location	*Estonia, Tallinn*
Total power of PV	*5 kWp*
Model of HP	*Thermia Atec HP 11*
Electric car	*BMW i3*
COP of HP	*COP 3.8 (+7/+45 °C)*
Habitants	*4*

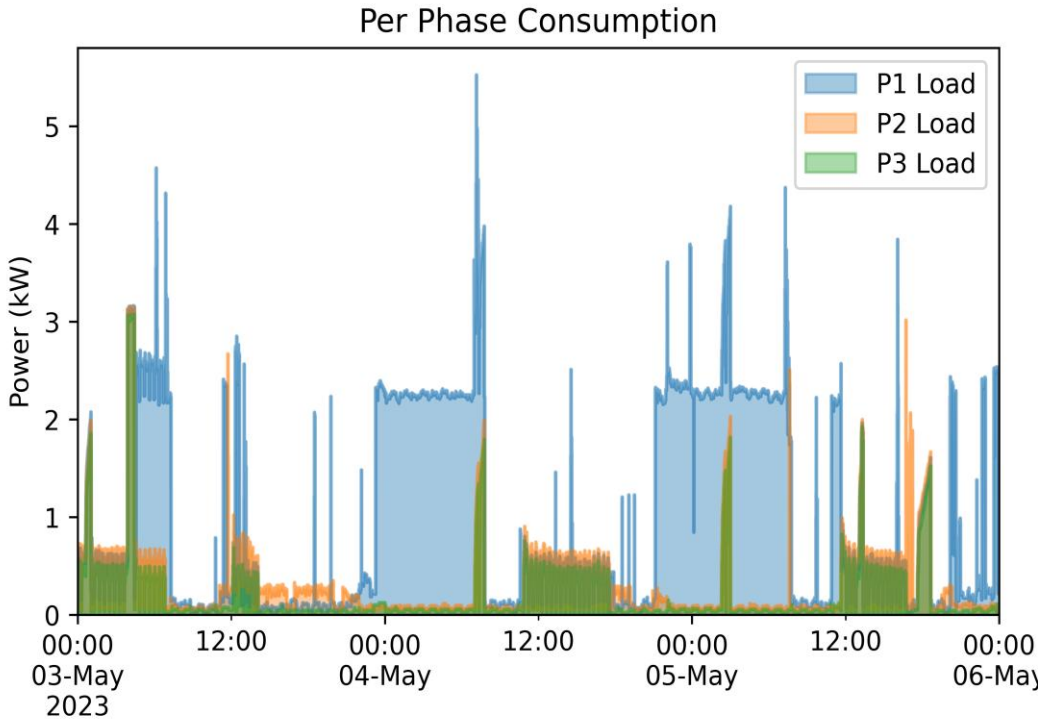


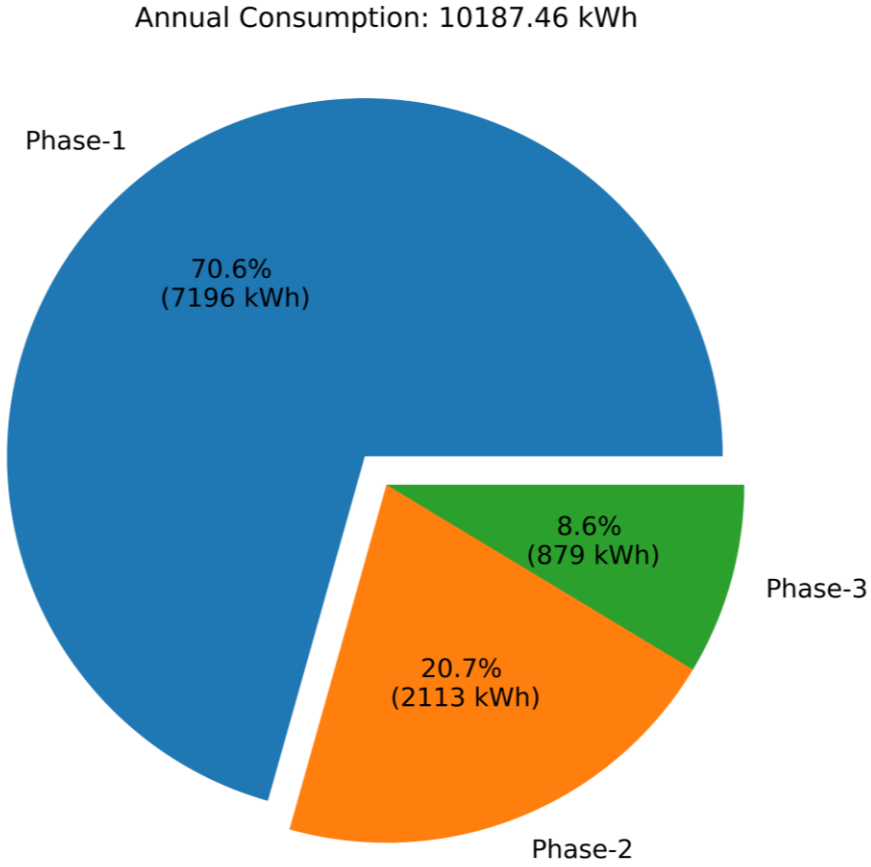


FULL-ELECTRIC LIFESTYLE WITH AC

A CLOSER LOOK AT THE PHASE LOAD IMBALANCE

Many residential (home) EV chargers have a single-phase grid connection with resulting negative impact on distribution transformers



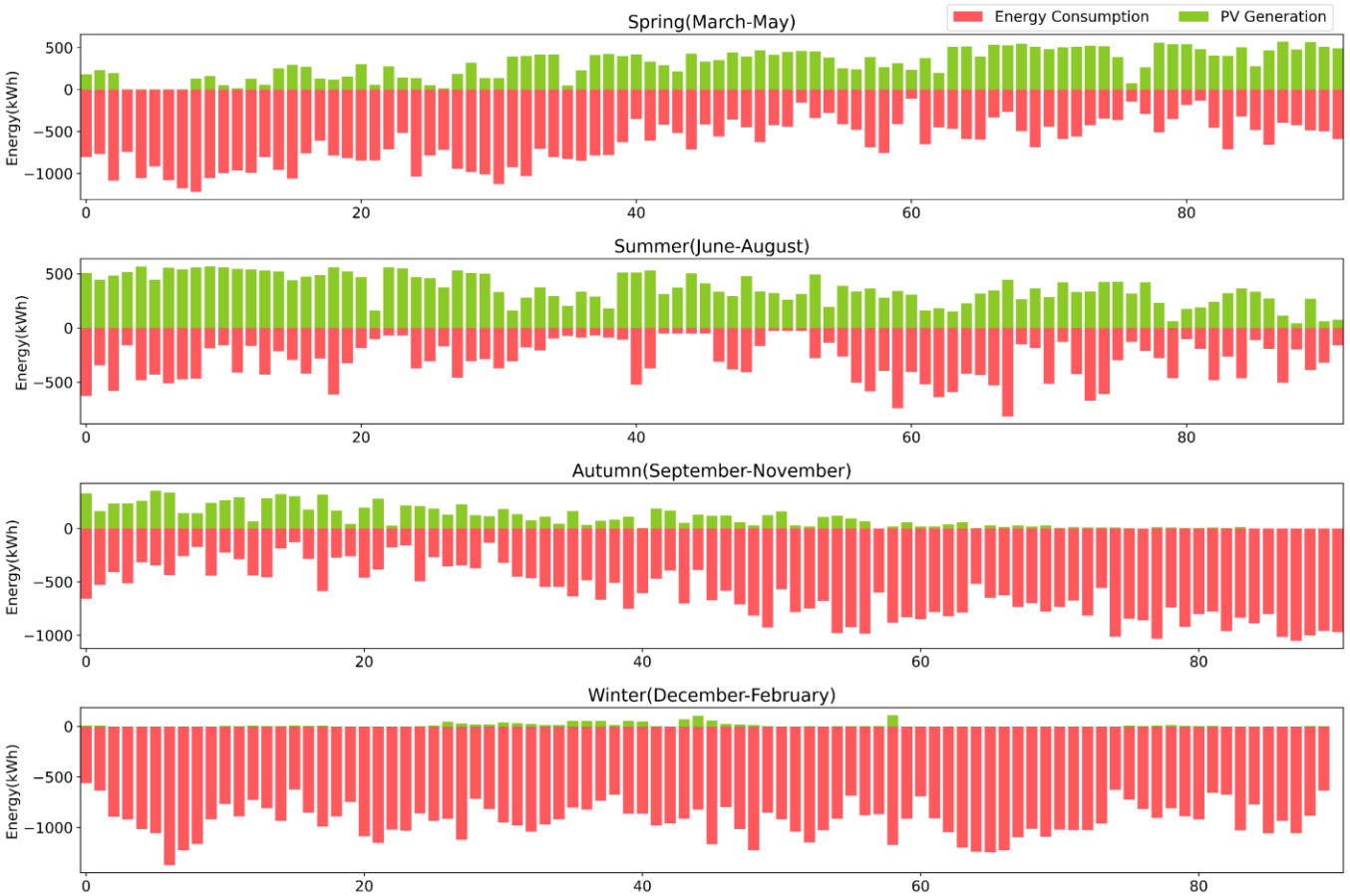


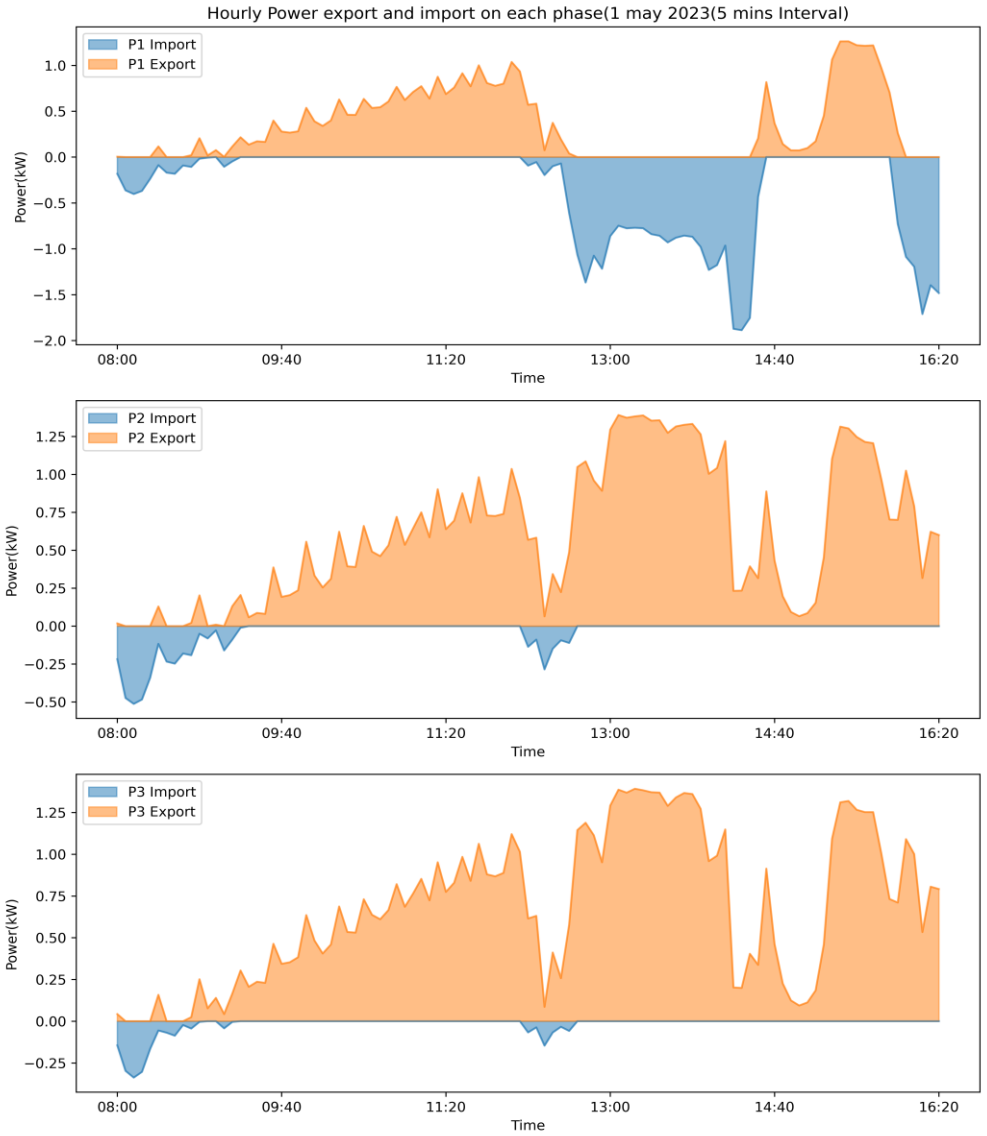
Hasan, S.; Blinov, A.; Chub, A.; Vinnikov, D. "PV Generation and Consumption Dataset of an Estonian Residential Dwelling", Dataset; DOI:10.48726/6hayh-x0h25 [Online]:https://data.taltech.ee/records/6hayh-x0h25

FULL-ELECTRIC LIFESTYLE WITH AC

ENERGY EXPORT/IMPORT BALANCE ISSUES

Poor self-consumption of the locally generated renewable energy due to mismatch of the per phase generation and consumption

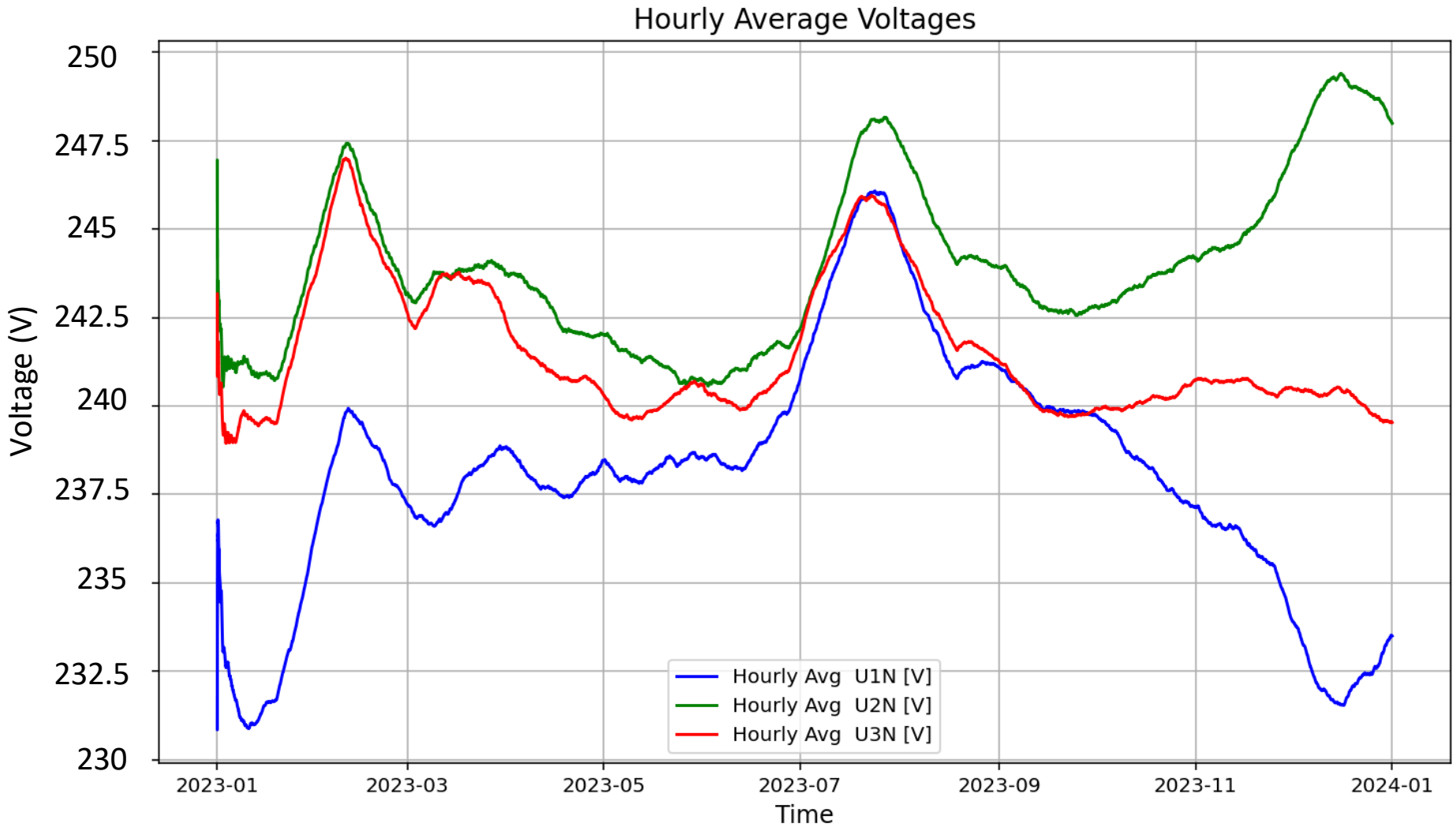




Hasan, S.; Blinov, A.; Chub, A.; Vinnikov, D. "PV Generation and Consumption Dataset of an Estonian Residential Dwelling", Dataset; DOI:10.48726/6hayh-x0h25 [Online]:https://data.taltech.ee/records/6hayh-x0h25

FULL-ELECTRIC LIFESTYLE WITH AC

VOLTAGE IMBALANCE ISSUE

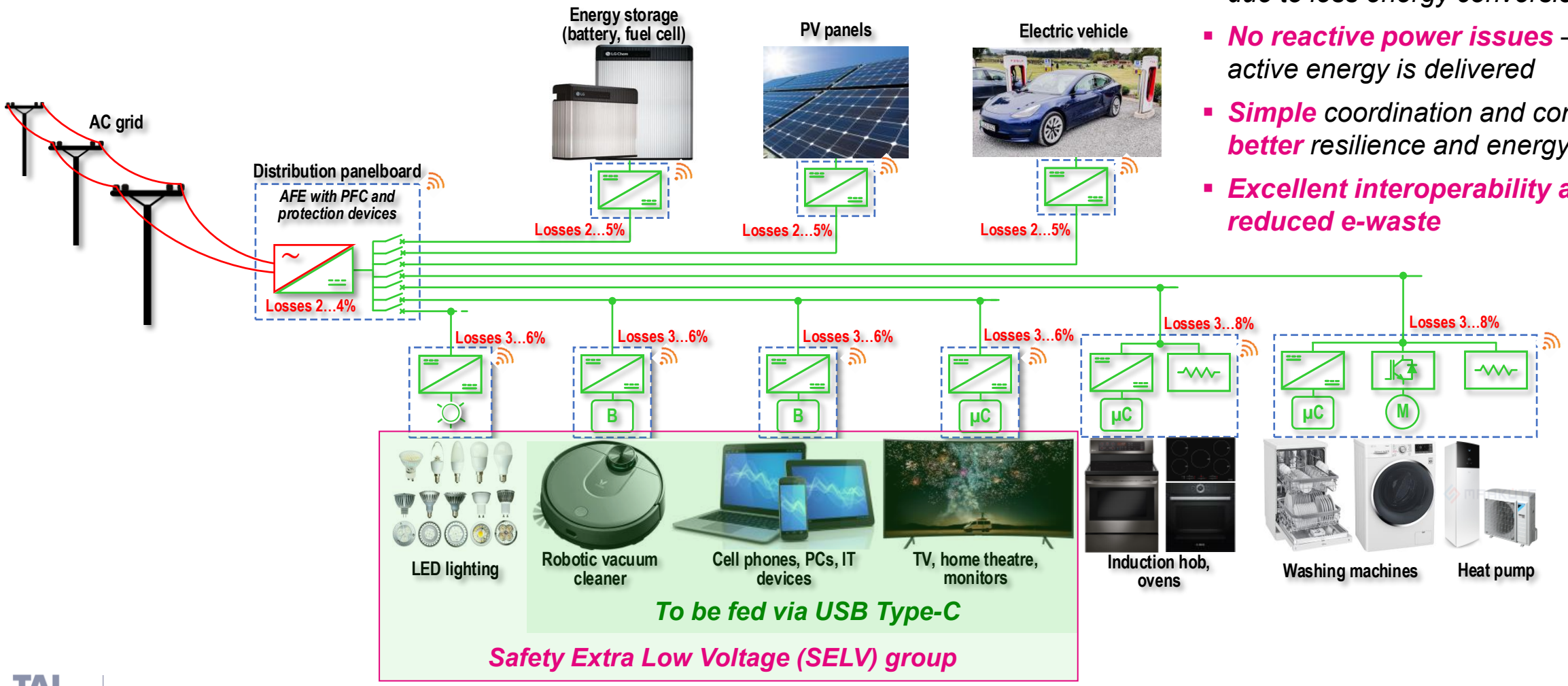


FULL-ELECTRIC LIFESTYLE WITH AC


Every problem has a solution😀😀

NEXT-GEN ELECTRICAL SYSTEM OF A ZEB

DC POWER DISTRIBUTION AND DC-FED APPLIANCES

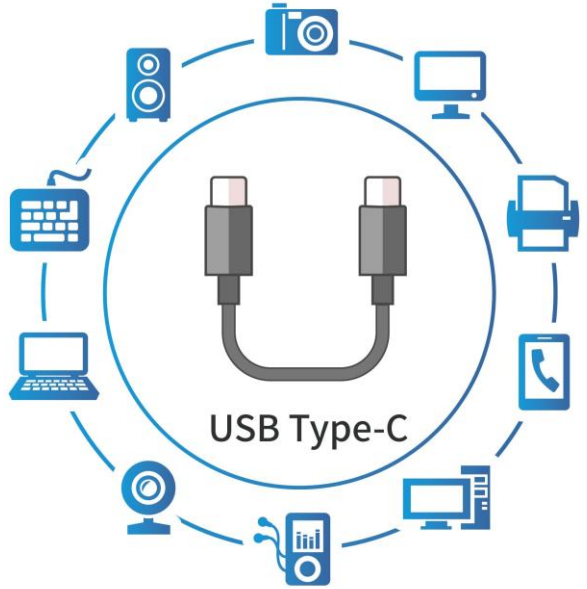


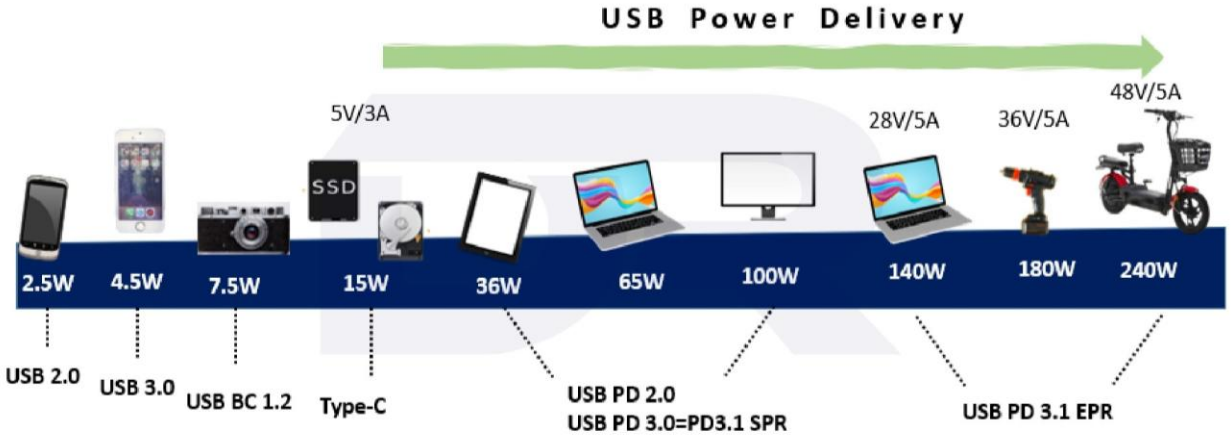
- *Increased efficiency and maximized self-consumption of renewable energy due to less energy conversion stages*
- *No reactive power issues – only active energy is delivered*
- *Simple coordination and control, better resilience and energy security*
- *Excellent interoperability and reduced e-waste*

TAL TECH

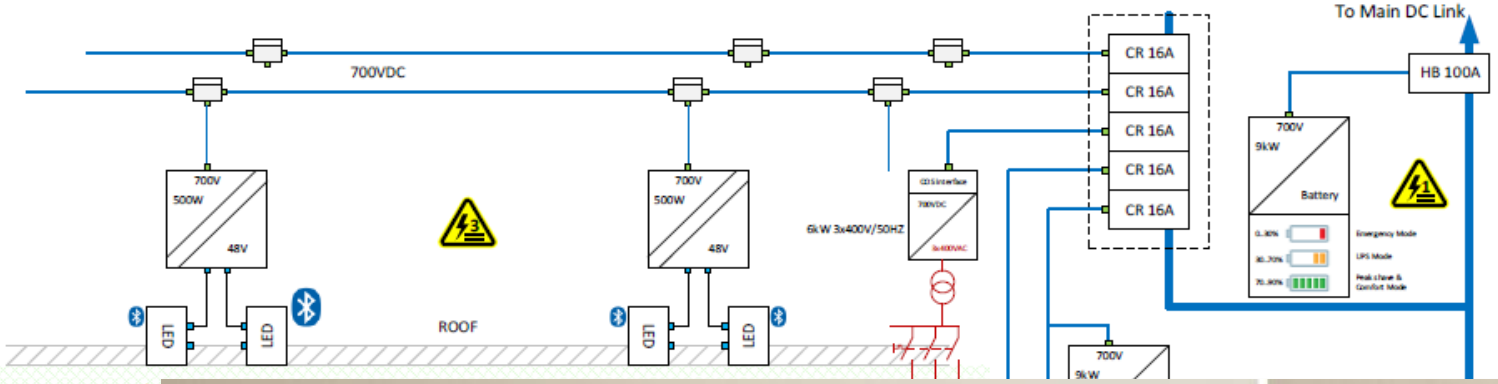
USB TYPE-C IS THE FIRST STEP TOWARD ENERGY-EFFICIENT AND INTEROPERABLE DC POWER DISTRIBUTION

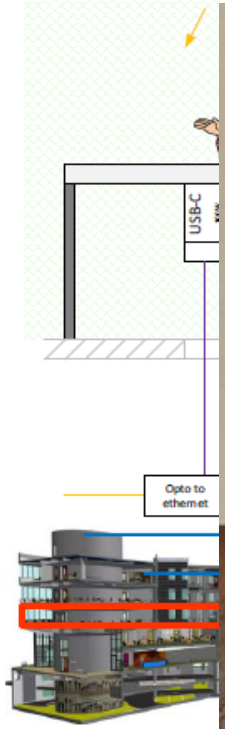
*Starting from 2025 the **USB Type-C became the common charging standard for small electronic devices in the EU**. Laptops will have to be equipped with a USB Type-C port by 28 April 2026.*

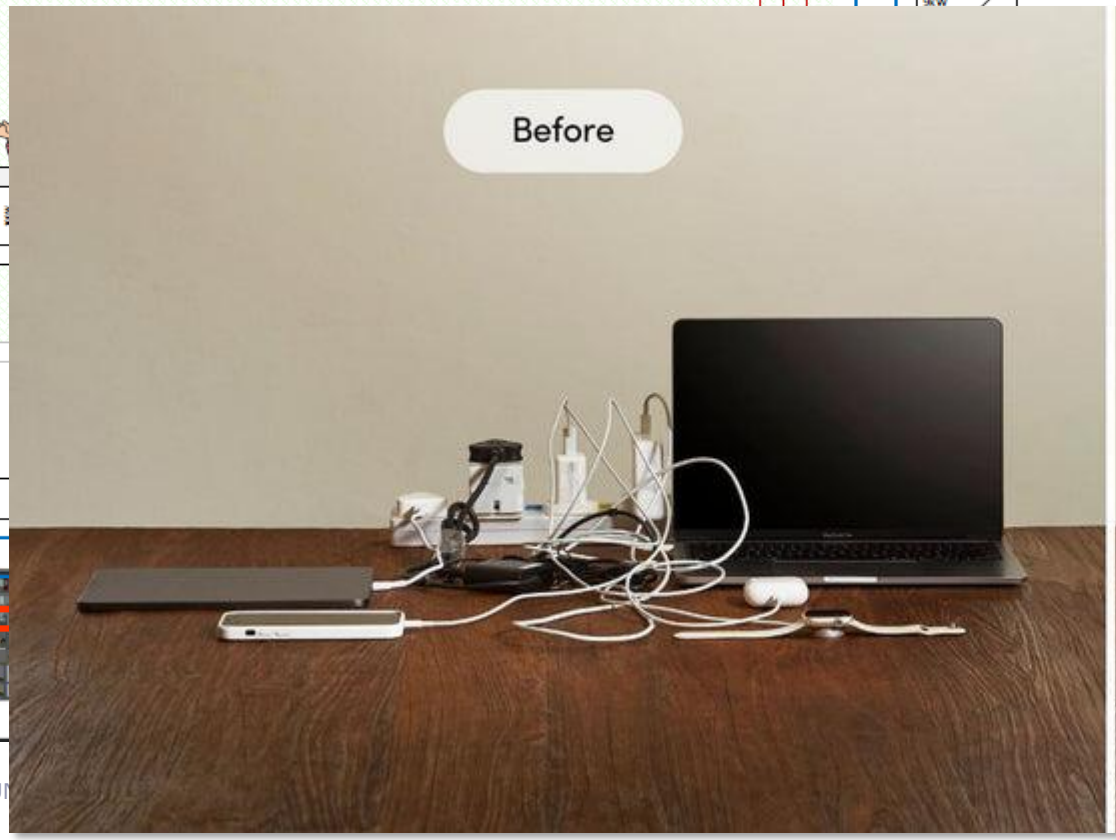


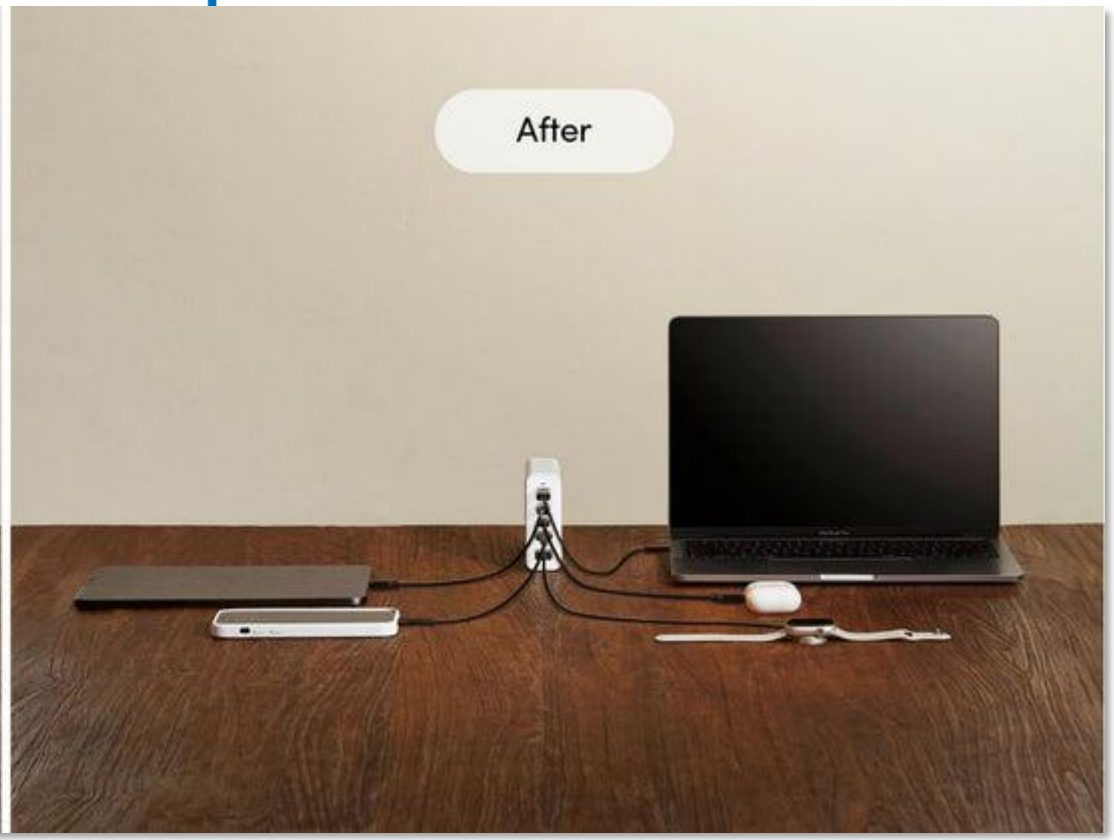


ENERGY NEUTRAL DC WORKSPACE



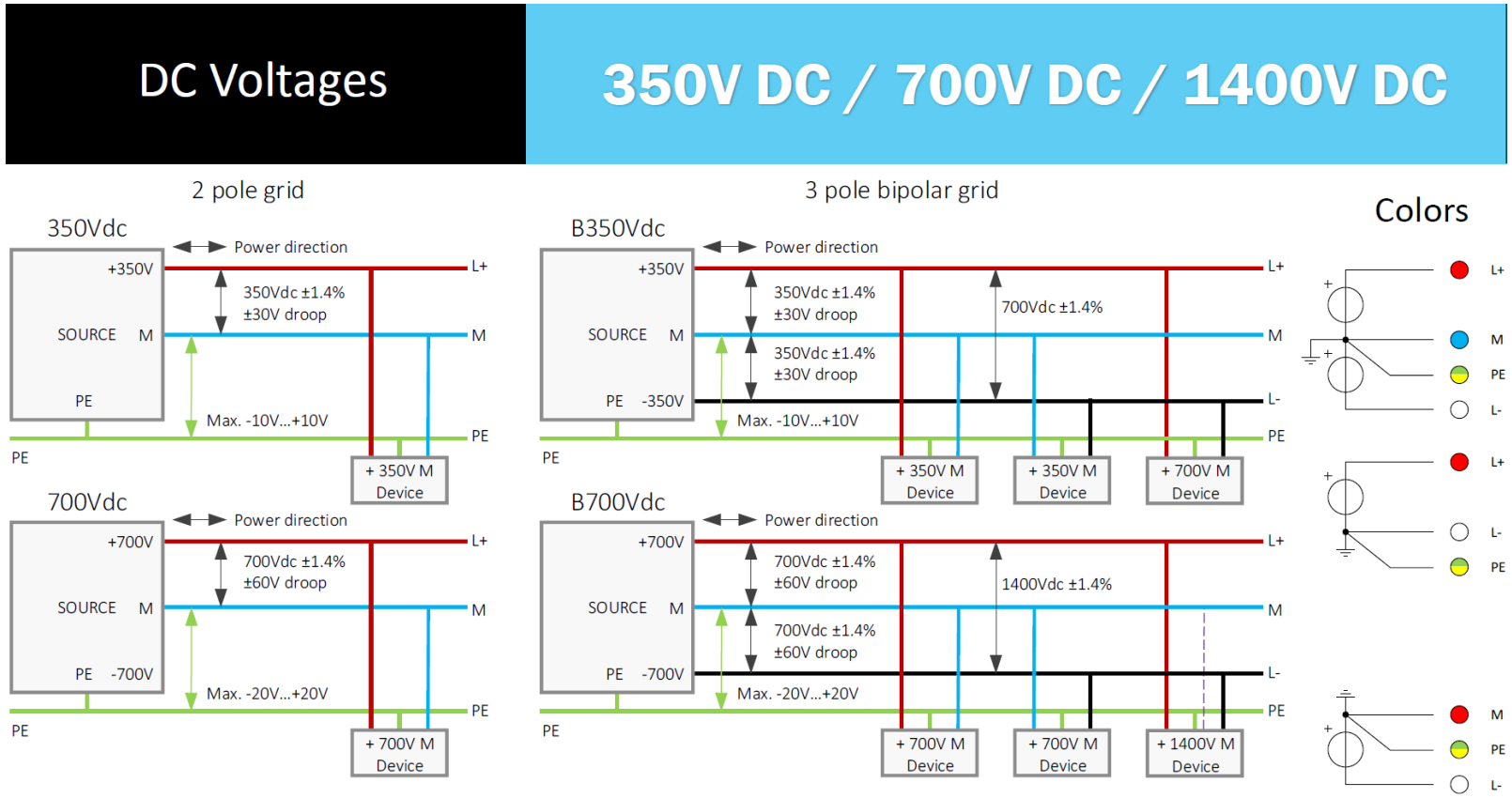






HISTORICAL CHOICE: FROM 230 VAC TO 350 VDC

- *The **LVDC** power distribution concept was proposed by **DC Systems** and implemented in Dutch standardization in **2018** (NPR9090 - Dutch Practical Guideline for the installations up to 1500 V DC)*
- ***350 VDC** is considered as a substitute for 230 VAC and **700 VDC** for 3x400 VAC*
- *The new **core colors for DC** installations are red, blue and white*
- *Starting **from 2021** the concept is continuously developed, improved and showcased by **Current/OS Foundation***



SYSTEMS

by Schneider Electric

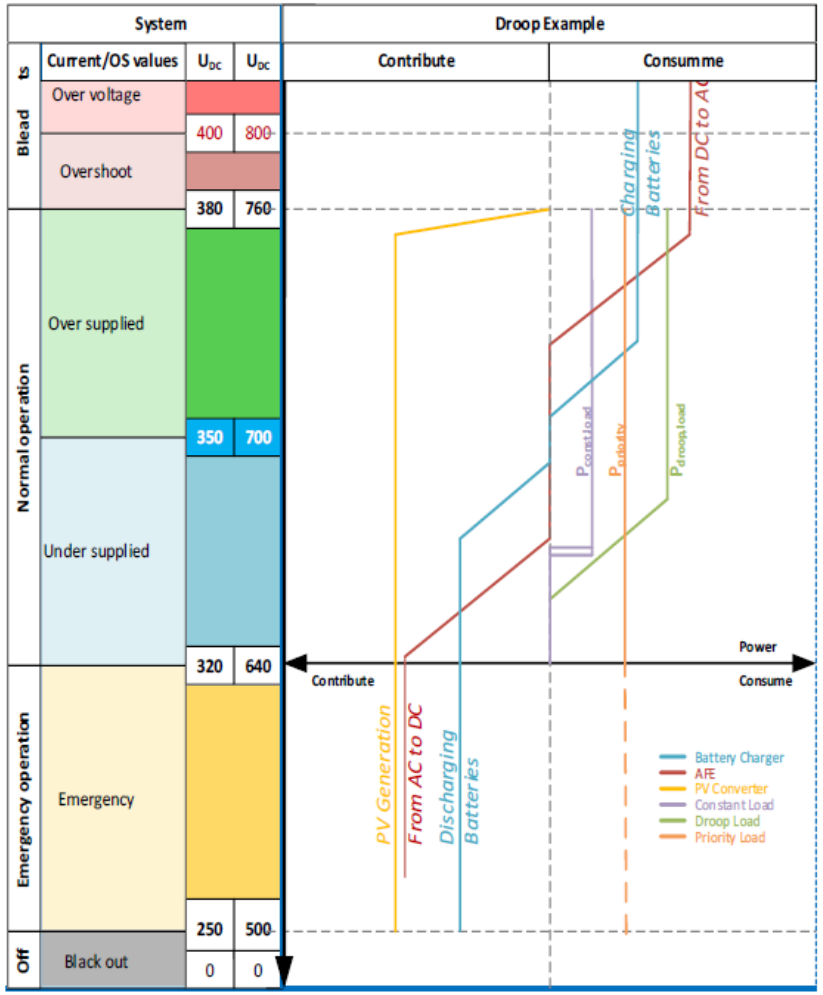
CurrentOS

E. L. Carvalho et al., "Grid Integration of DC Buildings: Standards, Requirements and Power Converter Topologies," in IEEE Open Journal of Power Electronics, vol. 3, pp. 798-823, 2022

POWER MANAGEMENT IN DC MICROGRIDS

https://currentos.org/technical-rules/

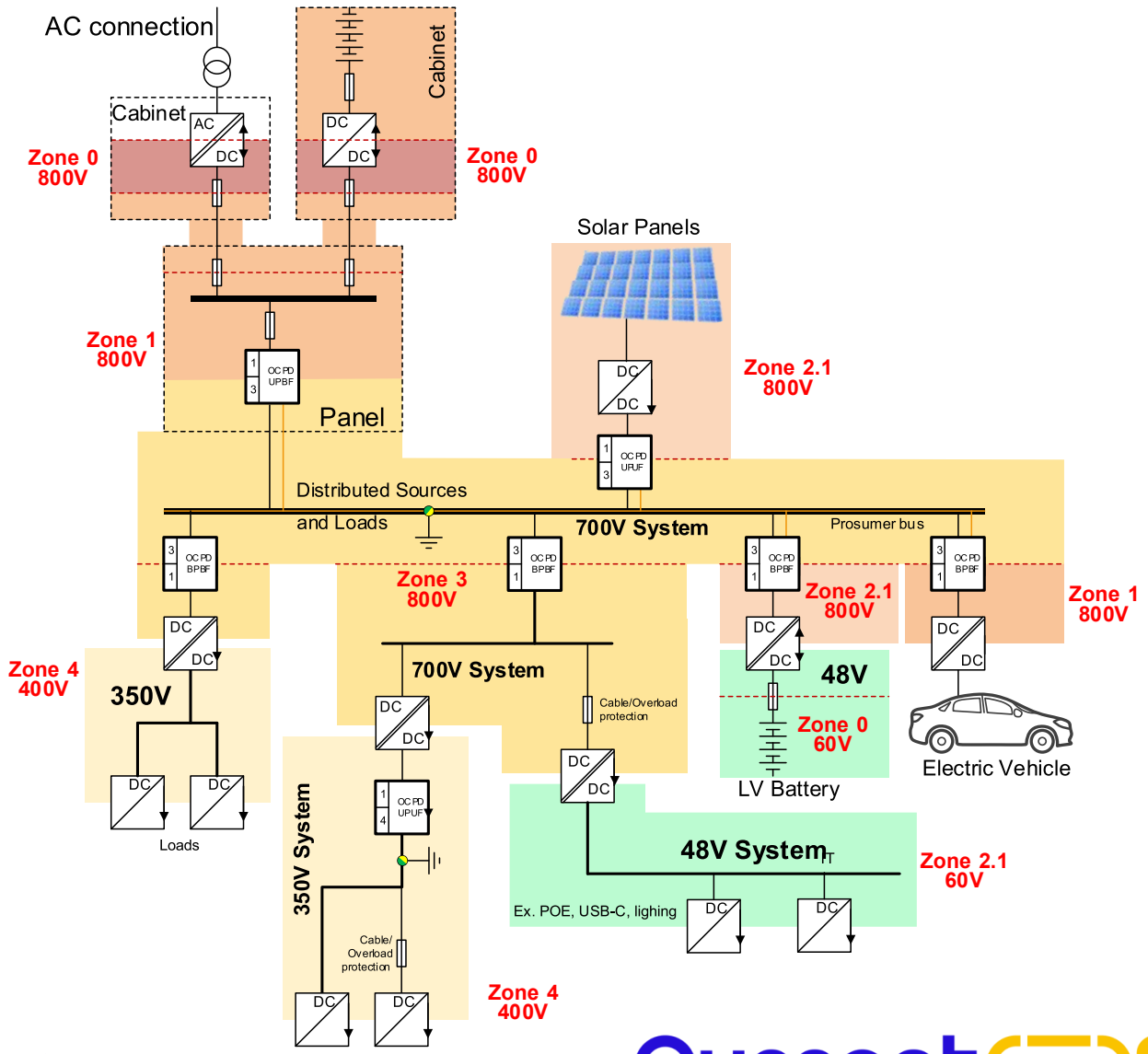
- Regulation principles based on voltage
- Voltage is a shared signal that reflects the power availability in the application to ensure the DC grid stability and energy management.
- AI is also used in order to take into account loads and production forecast and shape power demand from the main AC grid



Benefit: The installation is self-regulating. Droop control brings resilience and convergence.

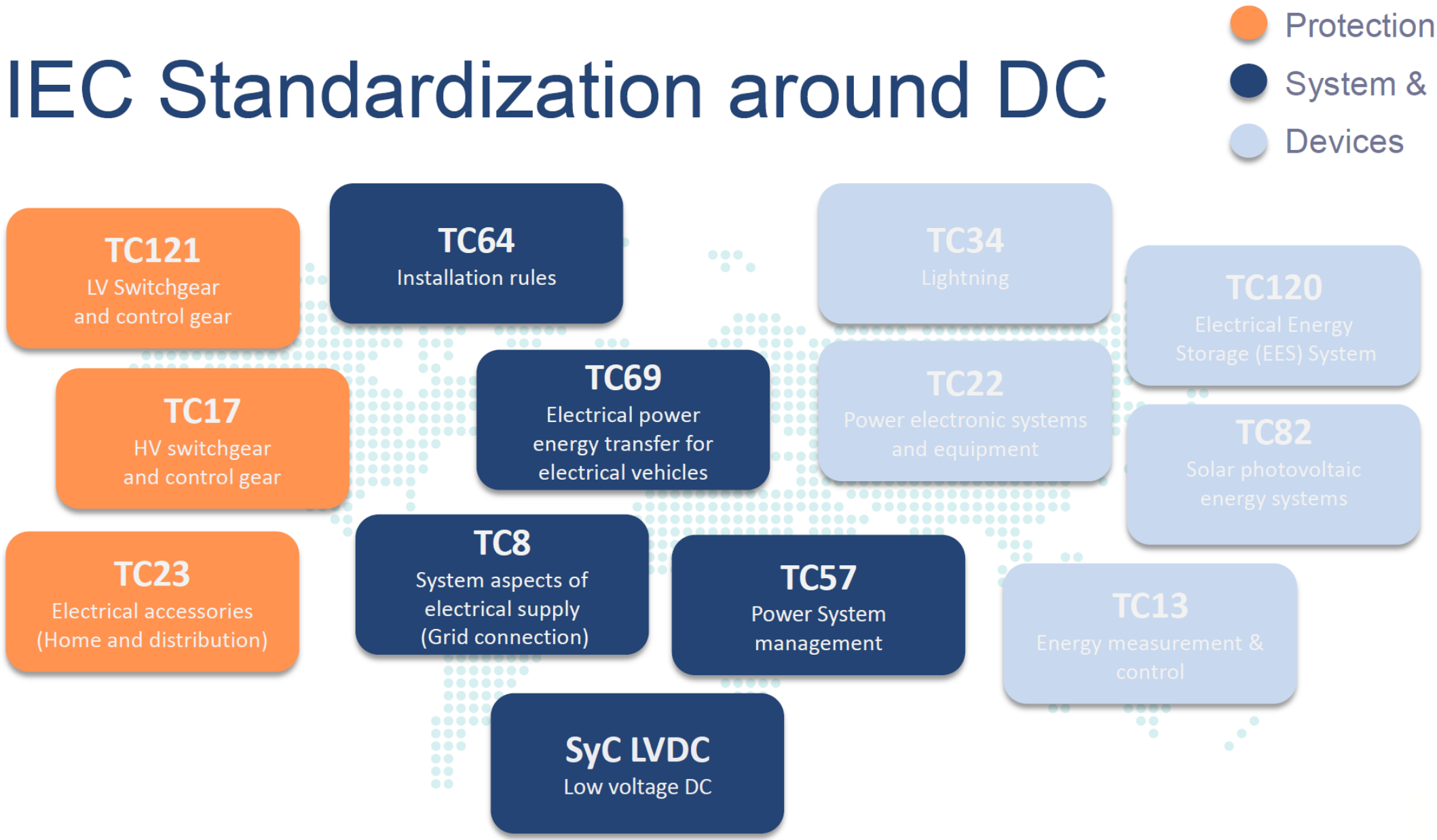
Current/OS Distributed Electrical System: Droop Control Explained (https://www.youtube.com/@Current-OS)

PROTECTION IN RESIDENTIAL DC MICROGRIDS



- ***Current/OS*** *requires DC Circuit Breakers faster than 50 ms used in protection* ***Zone 2.1*** *(energy stored limited to 600 J) and* ***Zone 1*** *(not limited stored energy), which would typically imply* ***electromechanical*** *technology for high currents*
- ***Current/OS*** *requires DC Circuit Breakers faster than 1 ms used in protection* ***Zone 2.2****, which would typically imply* ***hybrid technology*** *for high currents*
- ***Current/OS*** *requires DC Circuit Breakers faster than 10 µs used in protection* ***Zone 3****, which implies use of* ***solid-state circuit breakers (SSCBs)***
- *In* ***Zone 3****, RCD are mandatory when the circuit includes socket outlets*
- *SSCBs are very sensitive, which implies limits* ***on current ramp-rate*** *for device hot swap*
- *SSCBs could be* ***cost-sensitive*** *as they require high semiconductor area to provide low losses*

IEC Standardization around DC



SYSTEMS
by Schneider Electric

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Defining Standards
for Direct Current Microgrids

CurrentOS

Current/OS: open, independant, global DC partnership

- **Member of IEC SyC LVDC**
- **100+ partners** to date, more joining every month
- **Global**

25 countries represented in
  - North America
  - Europe
  - Asia

More information: https://currentos.org

CURRENT/OS PLENARY IN TALTECH (JUNE 5, 2025)

ODCA

direct current by zvei

Open Direct Current Alliance ODCA

International non-profit organization

- With **80+** members
- In **16** countries
- On **3** continents

What do we do

- Publish system reference document
- Networking
- Knowledge exchange
- Best practice sharing
- Contribute to IEC & UL standardization

https://odca.zvei.org/

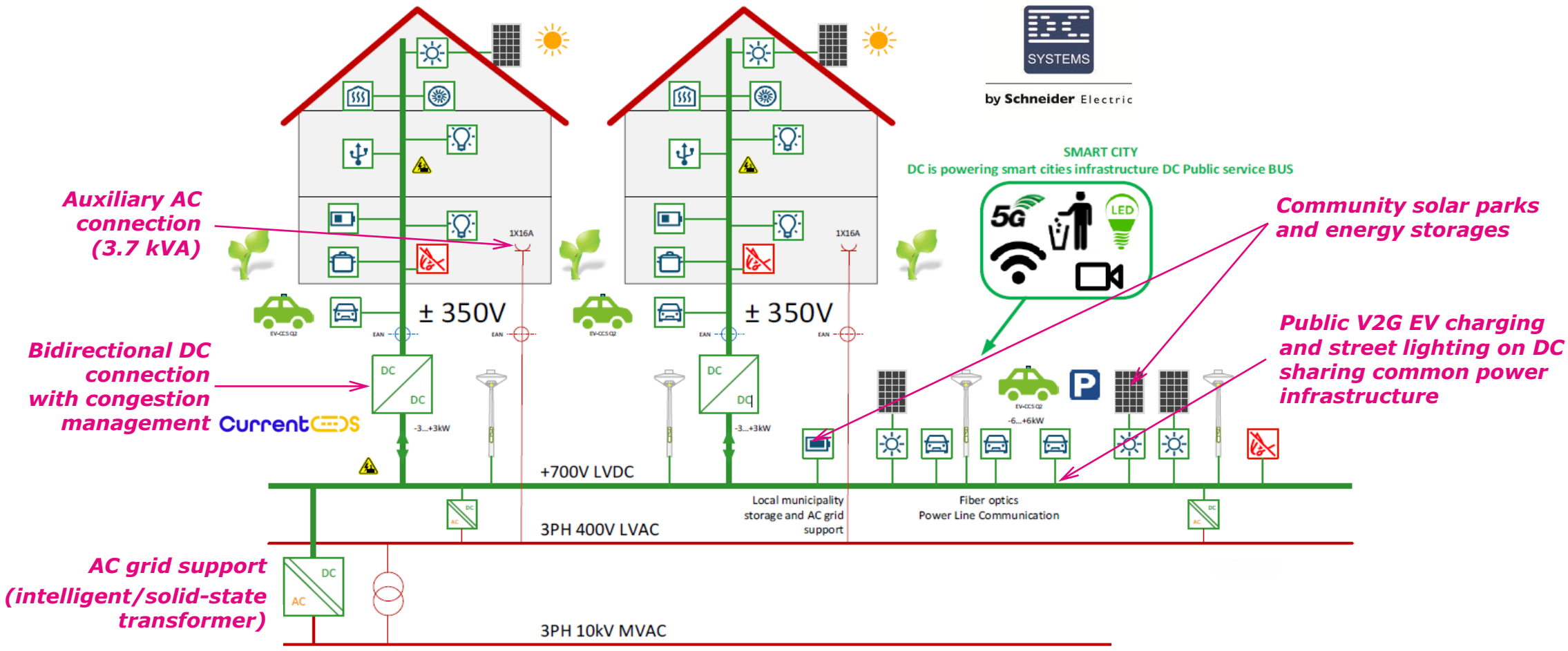
BENEFITS OF DC OVER AC IN HOUSEHOLDS*

DC OPENS A NEW DIMENSION IN ENERGY PERFORMANCE OF BUILDINGS

- *Up to **35% power loss reduction** due to more efficient power conversion and distribution and better utilization of the local renewable energy (solar photovoltaics, battery energy storage and heat pump)*
- *Up to **55% reduction** in distribution cabling mass (copper or aluminum)*
- *Up to **85% reduction** in the required connection capacity to the AC distribution grid*
- *Up to **20% reduction** in lifecycle costs when a building is fully converted to DC*
- ***100% power electronics enabled** technology with ultimate control flexibility, efficiency, power density and reliability*
- *Easy implementation of **Vehicle-to-Home (V2H)** and **Vehicle-to-Grid (V2G)** technologies*
- ***Resilient** power supply during blackouts with possibility to support grid stability (power consumption curtailment, phase balancing, etc.)*
- ***New revenue streams** for homeowners from participation in energy services and collective initiatives (EaaS, VPPaaS, energy communities, energy hubs, etc.)*

** EU Strategic Energy Technology Plan (implementation working group on DC technologies, subgroup on LVDC), September 12, 2024*

DC ELECTRIFICATION OF NEIGHBOURHOODS



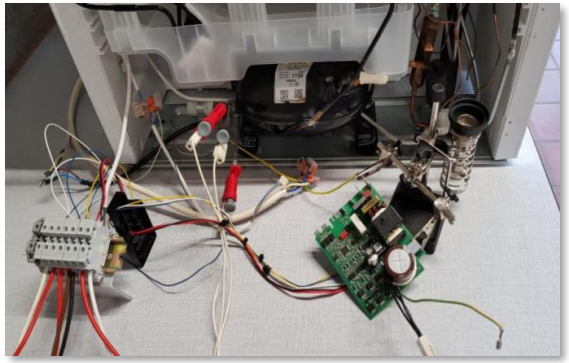
350 VDC TECHNOLOGY IS VERY FAST DEVELOPING

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.)*
- *Public light LED drivers (DC Systems B.V., Tridonic)*
- *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 TRIDONIC DCpportunities ferroamp BL!XT

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



SYSTEMS™

by Schneider Electric

A Local Team with Global Impact

- *Founded in 2009, part of Schneider Electric since 2021*
- *25+ professionals based in Aalsmeer (NL) covering everything from engineering and manufacturing to business development, application and support*

Experts in DC Solutions

- *Years of hands-on experience in designing and deploying hybrid AC/DC microgrids*
- *A comprehensive portfolio ranging from individual components to fully integrated DC systems*

Shaping the DC Future

- *Influencing and actively contributing to the development of industry standards through IEC standardization bodies*

Modular DC Bricks

Build your own DC grid with our Current/OS compliant products

ACTIVE FRONT END

- ✓ Bidirectional AC/DC converter
- ✓ Galvanic isolation
- ✓ 50, 100kW
- ✓ 700V, 350VDC

CURRENT ROUTER

- ✓ Solid-state circuit breaker
- ✓ 16A, 200A
- ✓ 700V, 350VDC
- ✓ Quick breaking: less than 8µs
- ✓ Residual Current Detection (RCD): 350V live parts touch safe!
- ✓ On the line arc detection
- ✓ Fully selective in all functions

DC-DC Converters & Battery Chargers

- ✓ 700V, 350V
- ✓ 300V/600V versions battery strings
- ✓ Protection device for DC Zone 3
- ✓ RCD; safety wire
- ✓ 15A string current buck boost

DC Sockets

- ✓ USB A
- ✓ USB C
- ✓ 350V / 48V

Projects

15 Projects
6 countries

https://www.dc.systems

DC SYSTEMS: DIRECT CURRENT EXPERIENCE CENTER

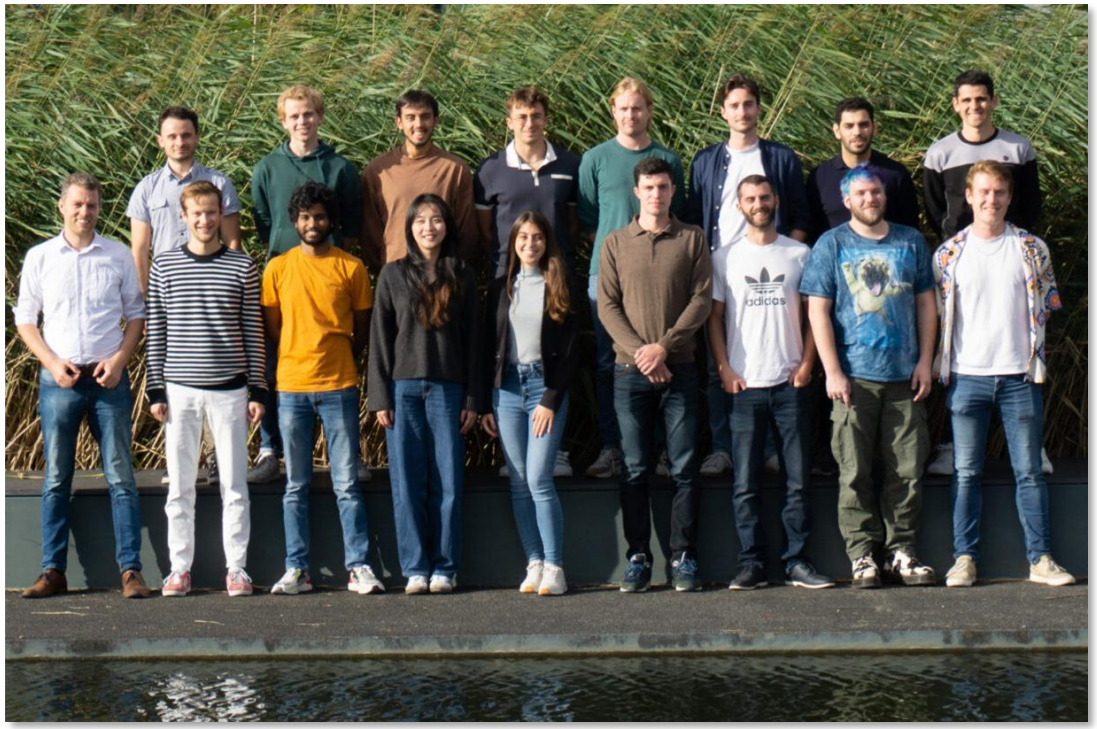
What to see

A hybrid AC/DC microgrid and a range of DC Applications, including:

- DC-powered office setups;
- Energy recovering industrial automation equipment,
- Solar technology;
- EV charging and more.

Book your visit via email at: experience.center@dc.systems

DCpportunities



Young and agile DC startup

- *Located in Delft, The Netherlands*
- *13 Employees incl. ca. 8 Interns & MSc Students*

Experts in DC Solutions

- *Next Generation Technology for DC Microgrids and Distribution Grids*
- *A comprehensive portfolio ranging from individual components to fully integrated DC systems*
- *Influencing and actively contributing to the development of DC standards*

350/700V DC Public Lighting Grid Delft

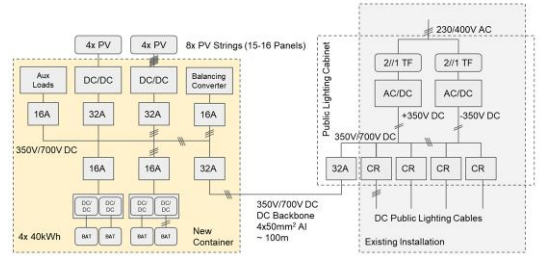
- 3x ca. 2km long rings
- Solid State Protection
- Ca. 280 light poles
- 1st ring operational since 2 weeks

Main Value of DC in Public Lighting Application:

- 75% Less Copper
  - 2.5mm² instead of 10mm² copper cable
- 75% Less Cabinets
  - 1 instead of 4 cabinets
- Residual Current Protection / Monitoring

DCpportunities

DC Opportunities Microgrid Nieuw Reijerwaard



DCpportunities

https://dc-opportunities.com/

DEMONSTRATION FACILITY IN GREEN VILLAGE, TU DELFT

DCpportunities

https://dc-opportunities.com/dcmicrogrids/meshed-350-700v-dc-microgrid-at-the-green-village/

MAIN CHALLENGES OF DC TODAY

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

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

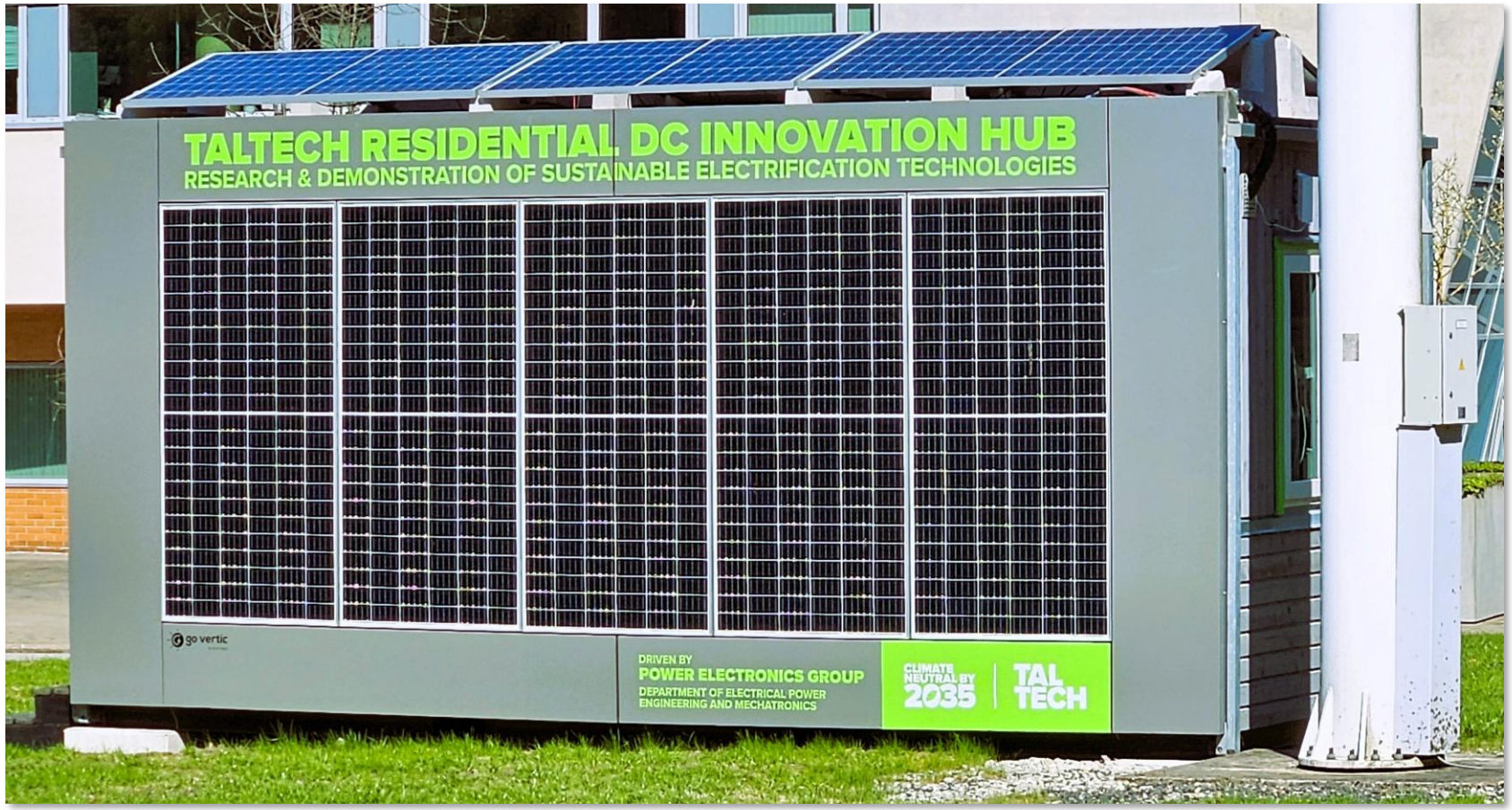
Non-profit joint venture of TalTech aimed at increasing the awareness, pushing forward the innovation and acceleration of the industrial uptake of the residential DC nanogrid technology in Estonia, Baltic states and Northern Europe

- ✓ *organization of national and international seminars and workshops on residentilal DC nanogrids, DC buildings and districts*
- ✓ *research, development and showcasing of innovative DC technologies incl. TalTech Residential DC Innivation Hub*
- ✓ *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

THE FIRST DC EXPERIENCE CENTER IN NORTHERN EUROPE



- ***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*
- ***https://taltech.ee/en/i3dc-initiative***

TAL TECH CLIMATE NEUTRAL BY 2035 i³ DC Accelerates Energy Transition ETAG go vertic ENERGIA PARTNER CRAMO CurrentOS ODCA direct current by zvei

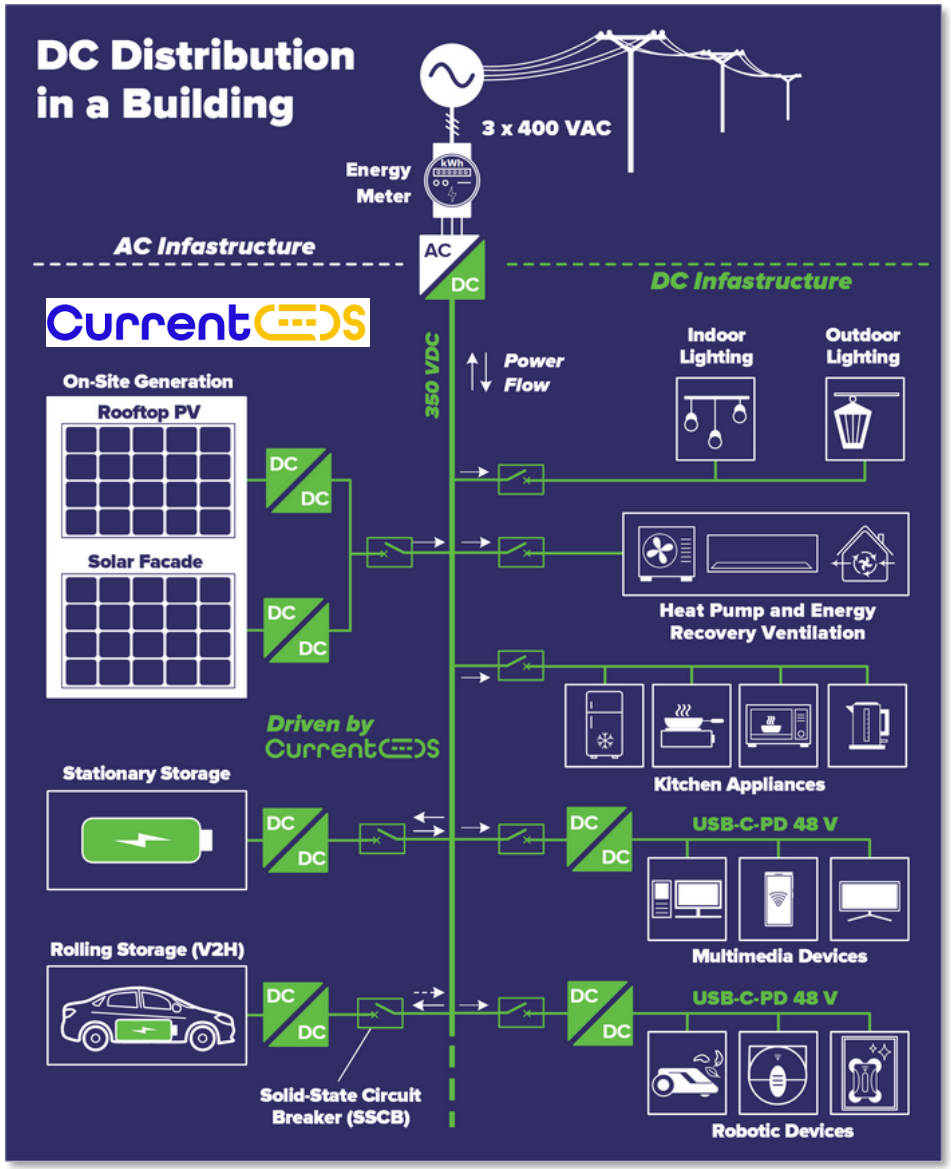
TALTECH RESIDENTIAL DC INNOVATION HUB

THE FIRST DC EXPERIENCE CENTER IN NORTHERN EUROPE

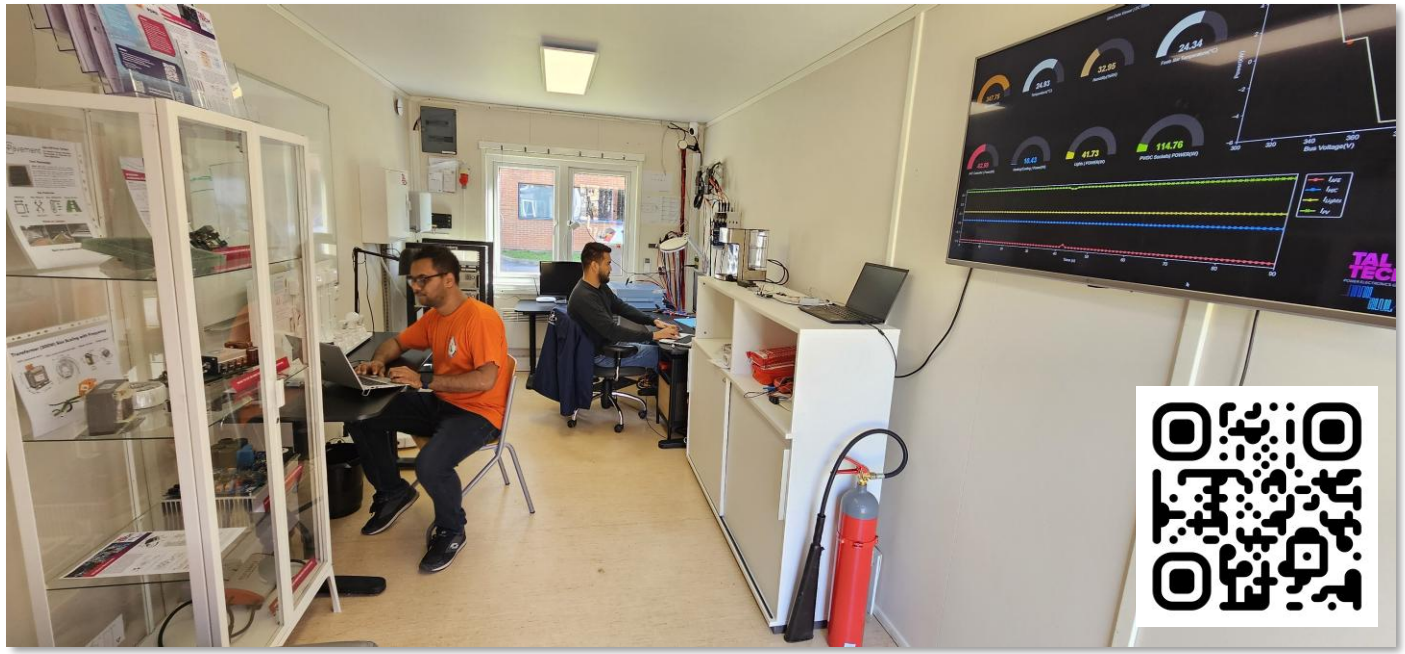
OFFICIAL PARTNER

Shift2DC

SmartGY SUM



- *Thermally insulated for year-round operation*
- *2 energy-neutral working places for researchers*
- *350V±30V DC droop-controlled microgrid (by Current/OS)*
- *Solar facade composed of 5 c-Si PV modules*
- *Solar roof with 3 south-facing and 3 north-facing c-Si PV modules*
- *Battery energy storage*
- *LED lighting and heat pump fed from DC (both are energy neutral)*
- *Solid-state protection (both commercial and research samples)*
- *DC appliances (continuous development)*
- *Data logging and visualization*



2020: HOW IT STARTED - UBIK SOLUTIONS

JOINT UNDERTAKING OF ESTONIAN BUSINESS AND ACADEMIA

2023: RELOCATION TO TALTECH

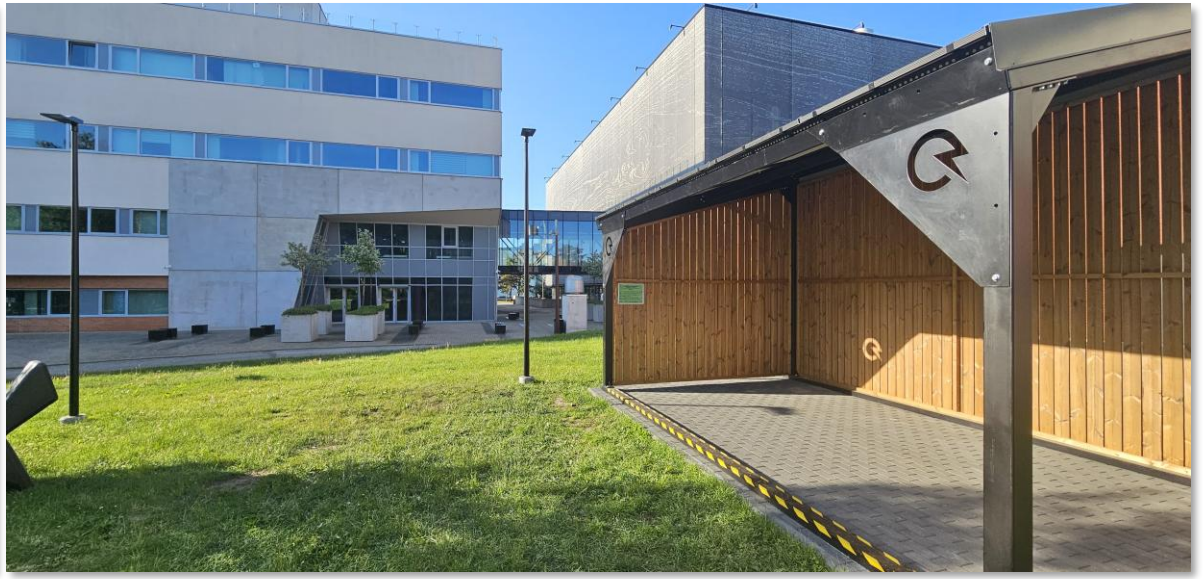
TALTECH ENERGY STUDENTS' HANDS-ON PROJECT

2024: FORMAL OPENING AND 1ST DC PICNIC

RISING THE AWARENESS ON DC ELECTRIFICATION TECHNOLOGIES

2025: TALTECH GREEN INNOVATION AWARD

2025: EXPANSION, NEW PARTNERS AND R&D TOPICS



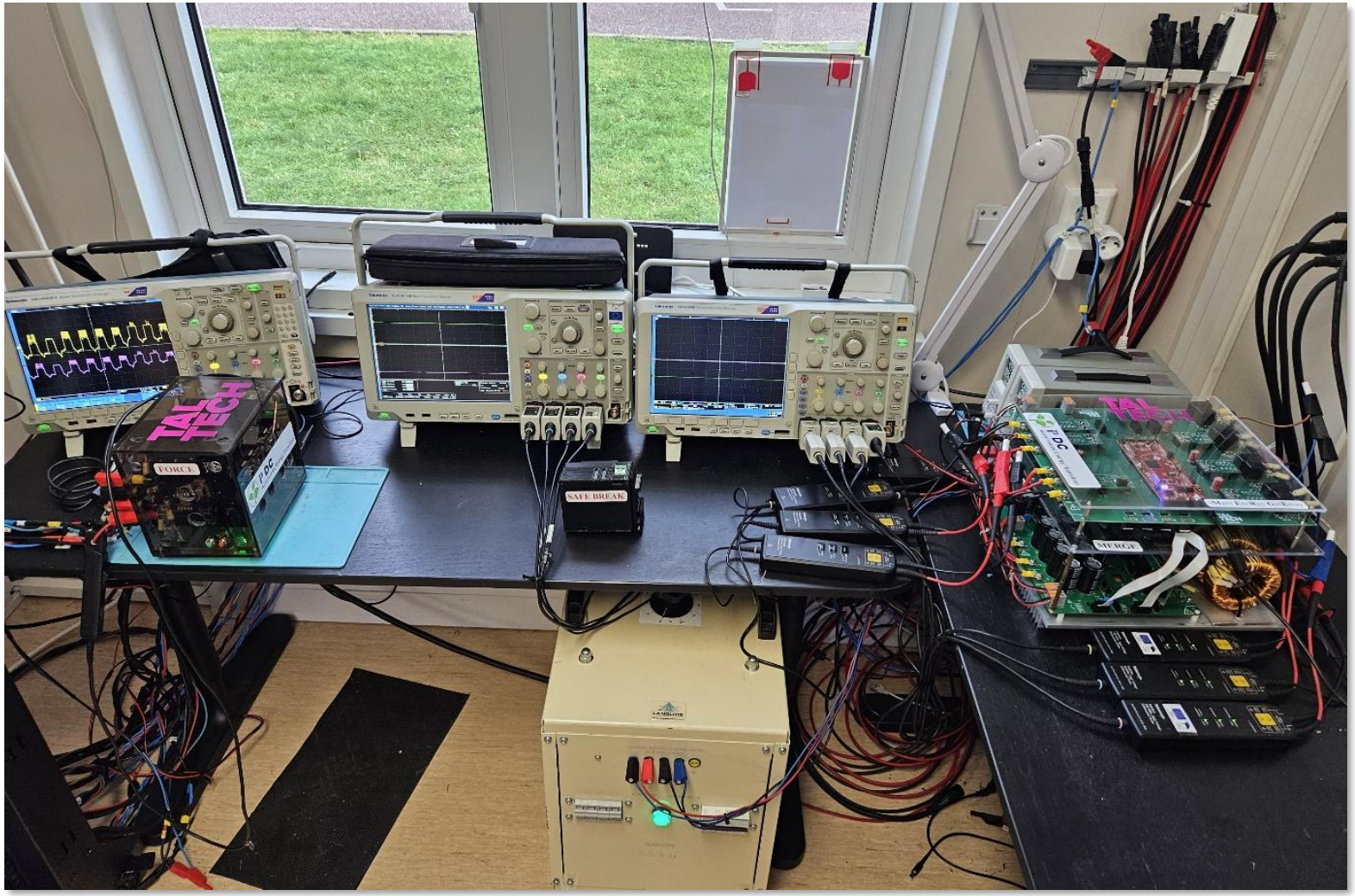
SOLARSTONE AIROBOT

DAIKIN TRIDONIC CAFA

NEW R&D DIRECTIONS

- *Droop-controlled residential DC HVAC systems*
- *Droop-controlled DC appliances and lighting systems*
- *DC neighbourhoods*
- *Urban DC infrastructure*
- *Use of DC in mil- and defence-tech applications*

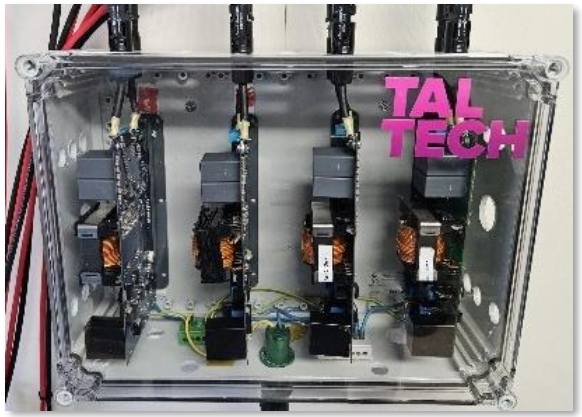
OUR NOVEL TECHNOLOGIES UNDER TEST IN DC INNOHUB



SAFEBREAK

MERGE

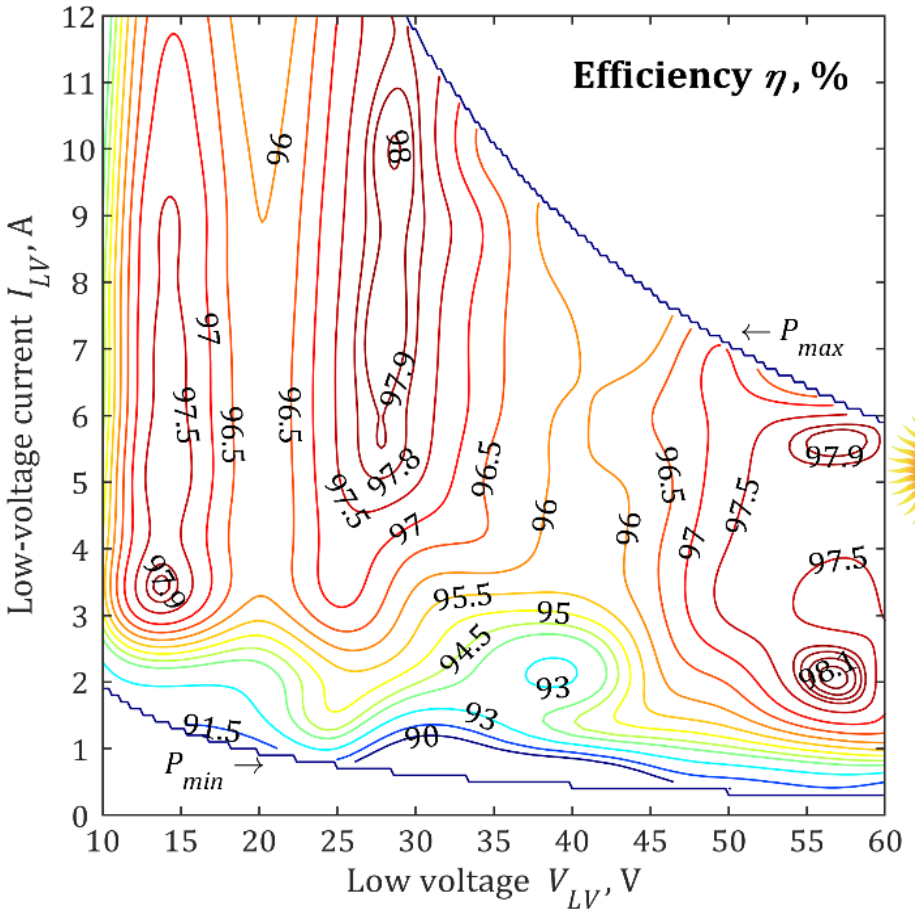
FORCE

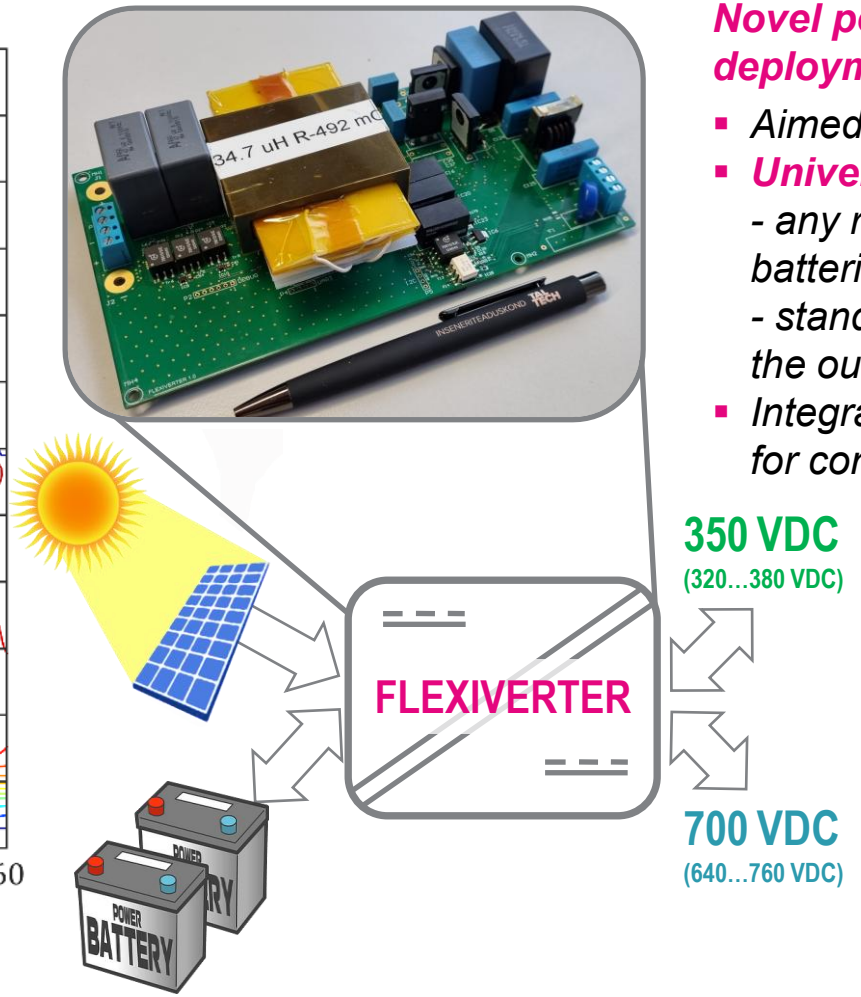


FlexiVerter

FLEXIVERTER – FLEXIble conVERTER

Power electronics “LEGO” for next-gen DC homes





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

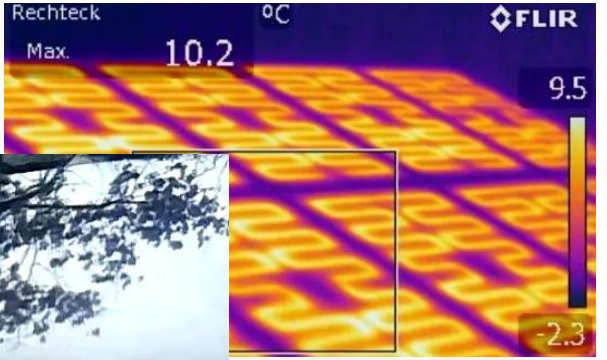
- *Aimed at nano-producers (<800W)*
- ***Universal compatibility:***
  - any residential PV module and 24V or 48V batteries at the input
  - standard 350±30V or 700±60V microgrid at the output
- *Integrated soft-start and solid-state protection for compatibility with **CurrentOS** protocol*

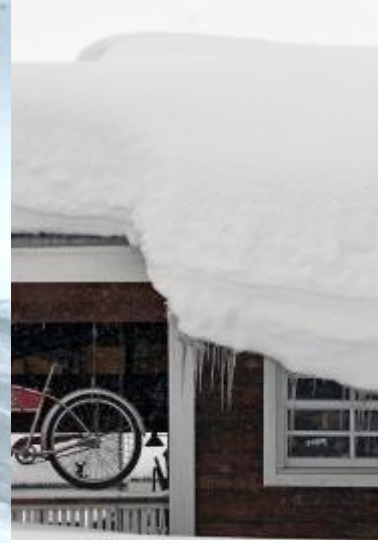
Features:

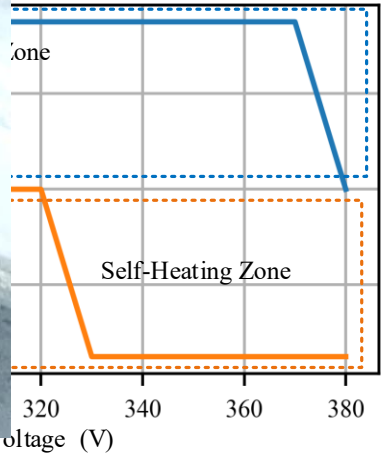
- *Peak efficiency **>98%***
- *Input source type **identification***
- *DC microgrid ready – **droop control** for battery and **power clipping** for PV*
- ***Global** maximum power point tracking verified*
- ***Integrated** design*
- *Generic **off-the-shelf components** used*

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.

FLEXIVERTER – NEW OPPORTUNITIES



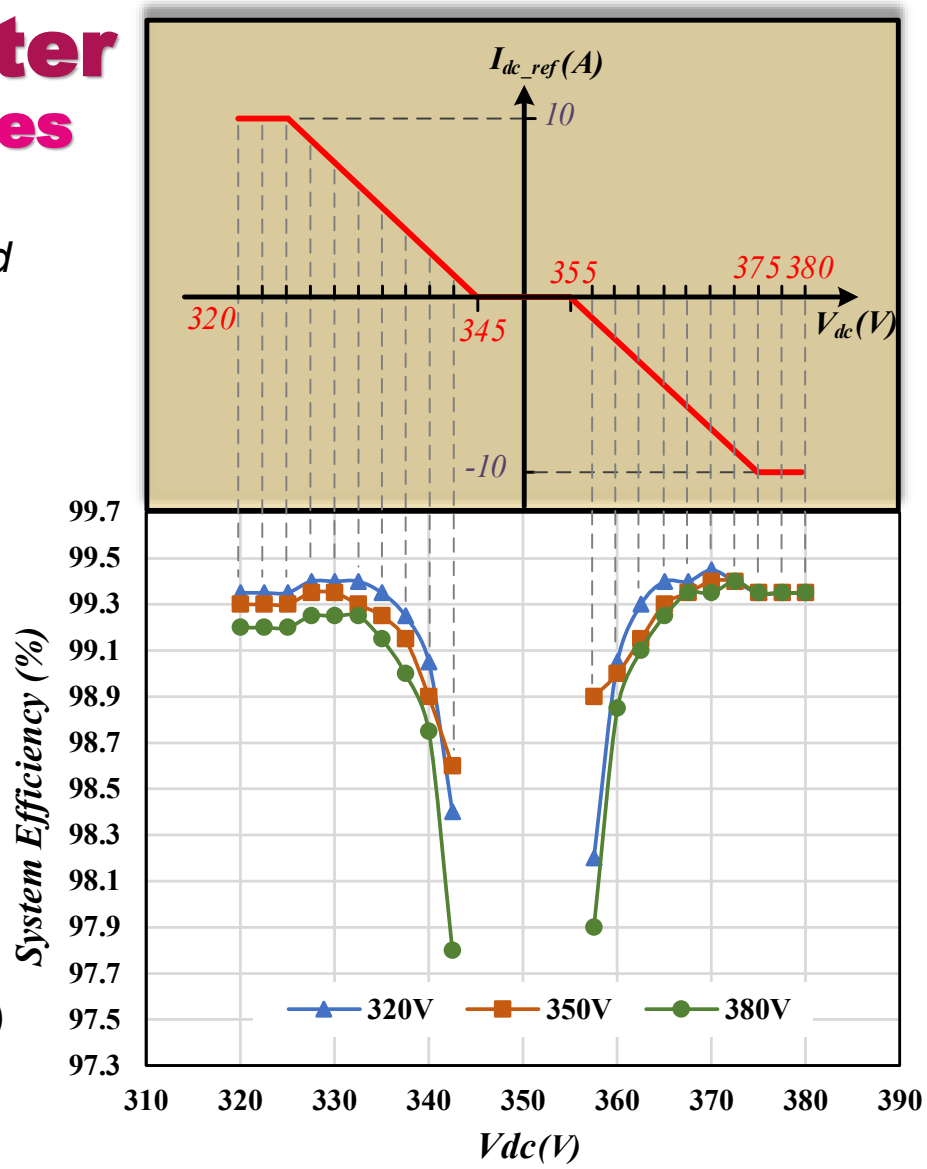




FORCE – Fractional pOweR ConvErter

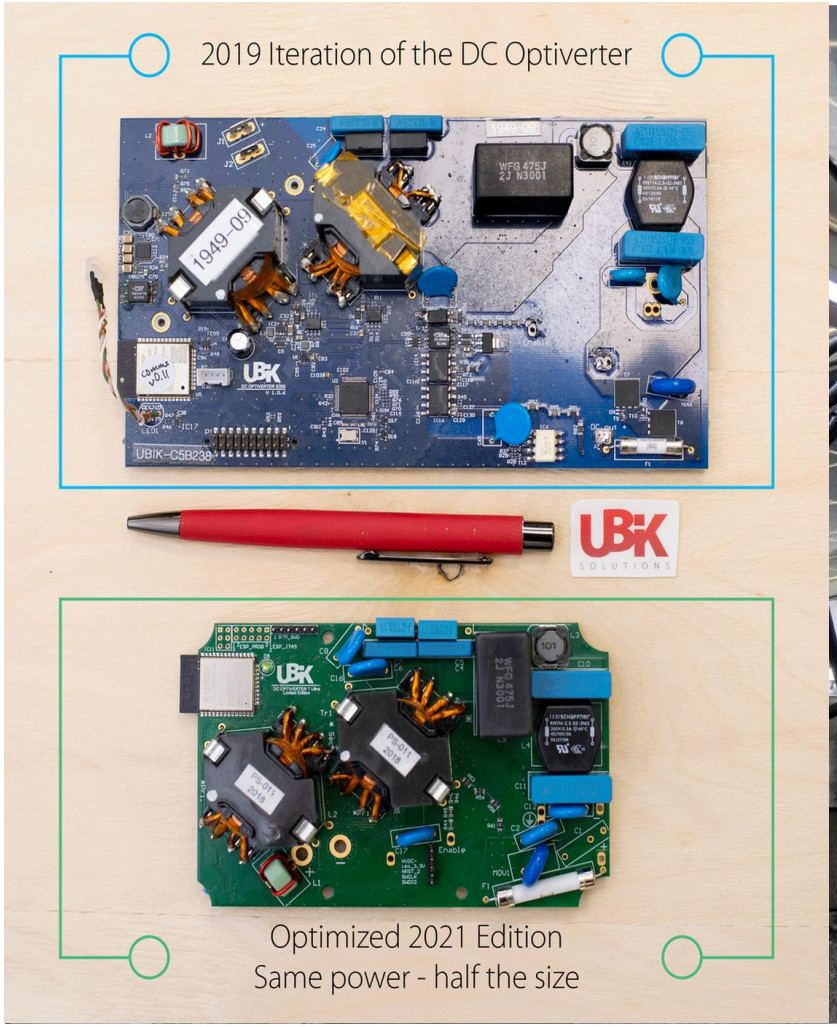
For efficient integration of second-life batteries

- *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.

OPTIVERTER – A Hybrid of Photovoltaic OPTImizer and MicroconVERTER

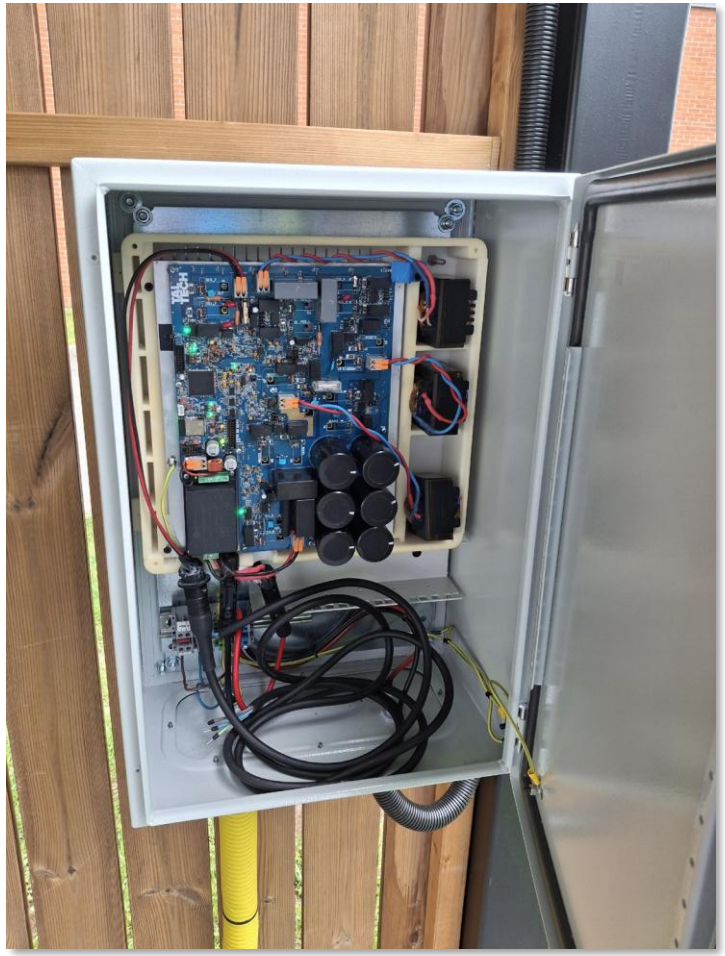


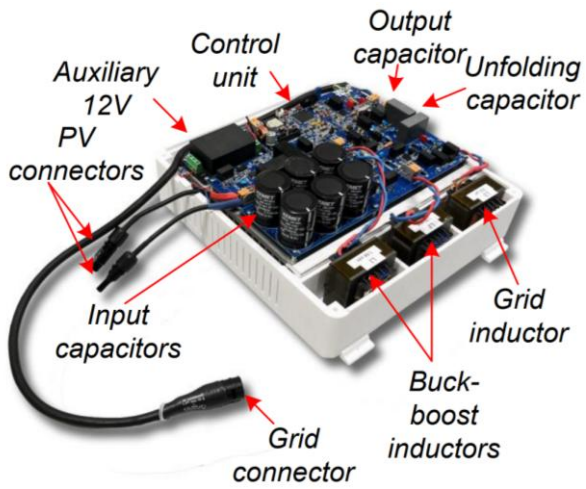
- *An entirely **novel PV MLPE technology***
- *Can be paired with all commercial **60- and 72-cell** PV modules*
- ***Fast GMPPT** and ultimate shade tolerance resulting in up to 30% better energy harvest*
- *Can be plugged either in **the 350 VDC or in 700 VDC** microgrids*
- ***Fully compatible** 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.

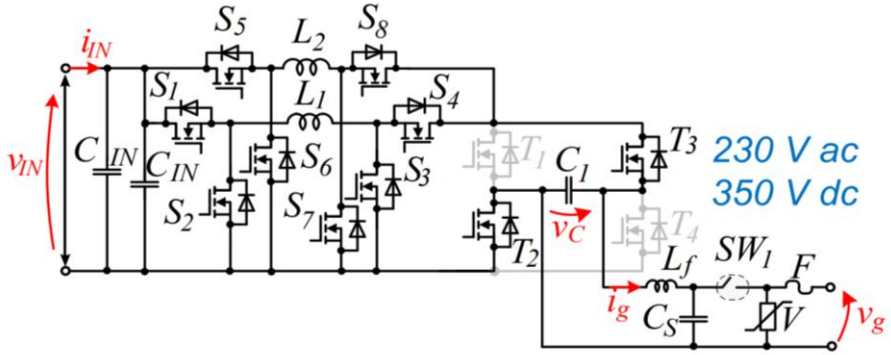
UNIVERSAL PV SERIES STRING OPTIMIZER

A dual-purpose PV converter suitable for application in DC and AC grids





Parameter	Value
Grid voltage	350 V (dc) / 230 V (ac)
Input voltage range	100…550 V
MPPT voltage range	150…450 V
Maximum input current	12 A
Output power range	0.1...5 kW (dc) / 0.1...3.6 kVA (ac)
Maximum efficiency in DC mode	99.2 %
Maximum efficiency in AC mode	97.4 %



***DC-ready technology**: a unique device that can be used either in **AC or DC grids without any modification in the hardware** thus giving confidence to the DC investors and flexibility to the end-users!*

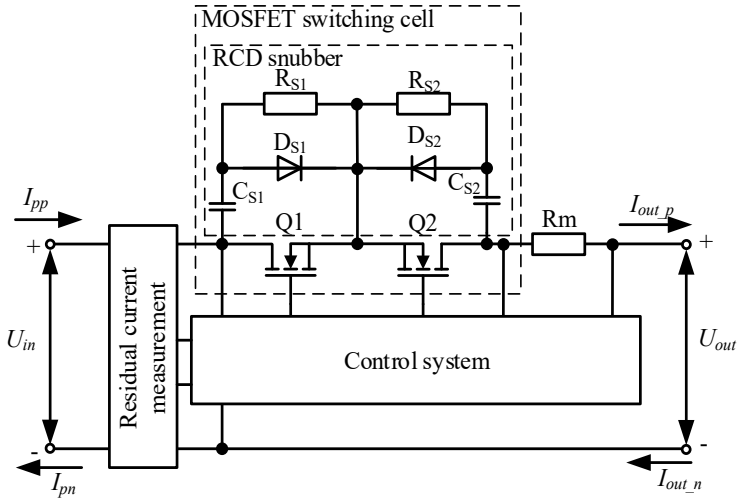
O. Husev, O. Matiushkin, D. Vinnikov, C. Roncero-Clemente and S. Kouro, "Novel Concept of Solar Converter With Universal Applicability for DC and AC Microgrids," in IEEE Transactions on Industrial Electronics, vol. 69, no. 5, pp. 4329-4341, May 2022

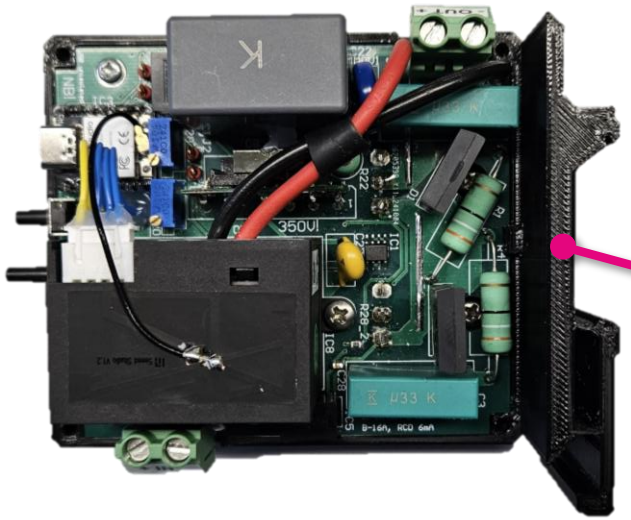
O. Matiushkin, O. Husev, D. Vinnikov and J. Kurnitski, "DC-Ready Photovoltaic Solar Converter," PCIM Europe 2023; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management, Nuremberg, Germany, 2023, pp. 1-7

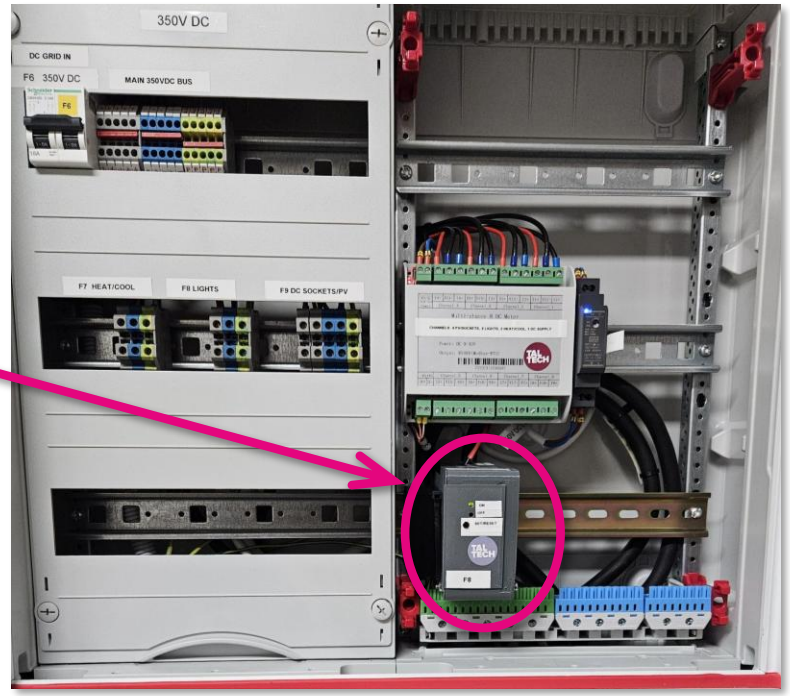
SAFEBREAK – SAfe and Fast DC Electronic BREAKer

Multifunctional SSCB for residential prosumer DC nanogrids

- *Optimized for **350 VDC/16A** residential applications*
- *Utilizes SiC JFETs for **low R_{DSon}**, efficiency **99.8% @ 16A***
- ***Fast speed** – short circuit detected within 10 µs*
- *Min. voltage: 100 VDC*
- *Max. input voltage: 440 VDC (overvoltage protection at 380 VDC)*
- *Contains **residual current sensor** for ultimate safety*
- *Max. allowed residual current: 6 mA*
- ***Bidirectional operation** (prosumer-ready)*
- ***Connectivity**: WiFi, USB. **Telemetry**: current, voltage, faults*
- *MQTT smart connection to **Energy Management System***







DEVELOPMENTS IN PROGRESS

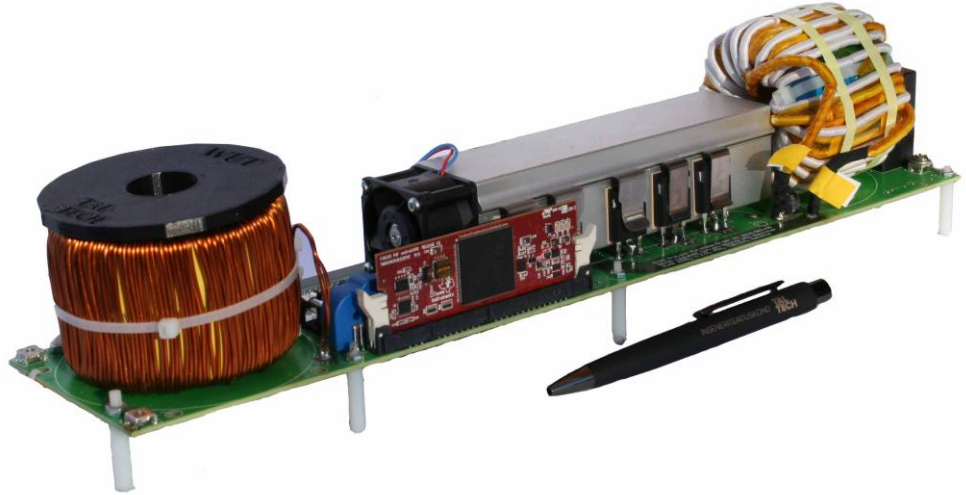
MERGE: Smart energy gateway for integration of DC homes to AC grid

- *Bidirectional power router for prosumer DC buildings*
- *High-frequency galvanic isolation*
- *Input 230/400 VAC, output 350 VDC, 5…10 kW*
- *Droop control according to Current/OS*
- *Efficiency curve optimized for part-load operation based on statistical data (>97 %)*
- *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 Trans. on Ind. Electronics, vol. 71, no. 9, pp. 10601-10611, Sept. 2024

UbiCharge: Ubiquitous low-power EV opportunity Charger

- *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 100…1000 VDC*
- *Droop controlled according to Current/OS (in emergency bands)*
- *High weighted efficiency of >97%*
- *Low-cost single-stage design*

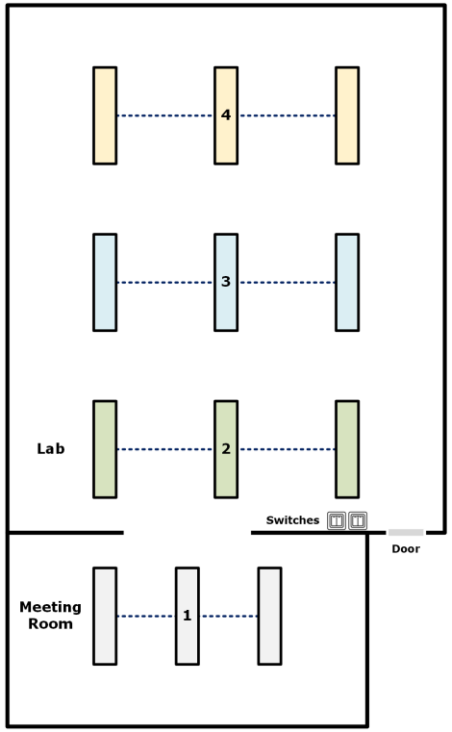


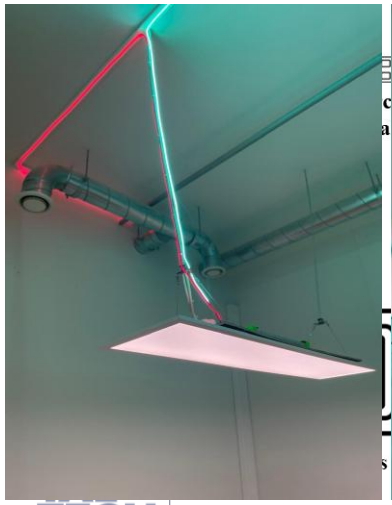
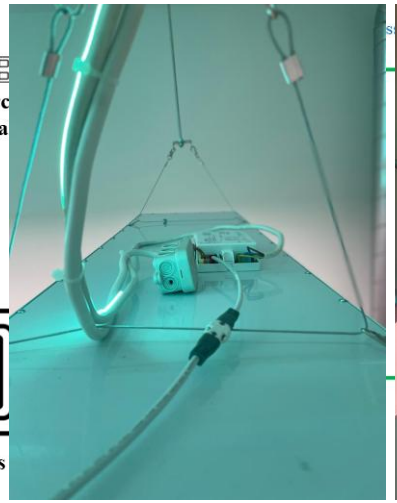
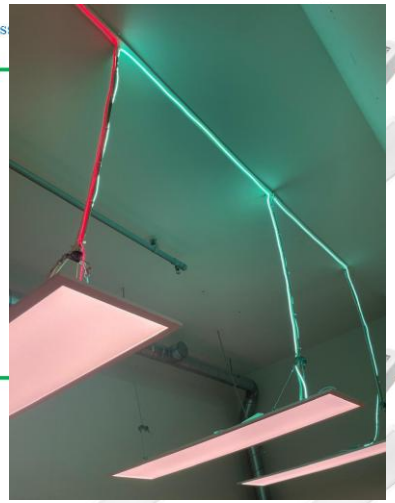
D. Zinchenko et al. "High-Efficiency Single-Stage On-Board Charger for Electrical Vehicles," in IEEE Transactions on Vehicular Technology, vol. 70, no. 12, pp. 12581-12592, Dec. 2021

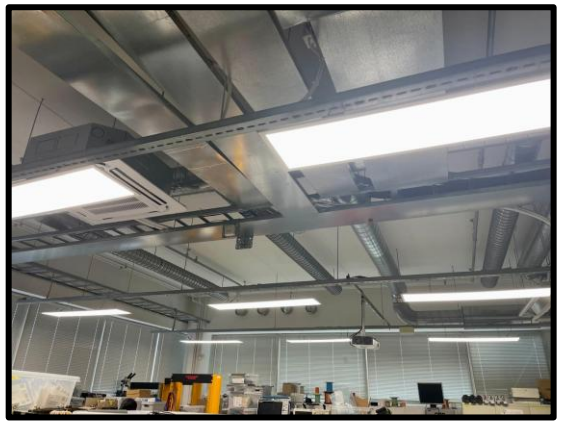
OUR UPCOMING DC TECHNOLOGY SHOWCASES (1)

DROOP-CONTROLLED OFFICE LIGHTING

- *Research and demonstration project in collaboration with **Tridonic** and **Current/OS***
- ***Tridonic** has just released first Current/OS-compatible LED driver with DALI support*
- *Currently we have partnered with them to **test, co-develop and improve***
- ***Project key features:***
  - ***Four** groups of 3x LED Tridonic luminaries compatible with*
  - ***AC/DC converter** from MeanWell for forming 350VDC grid*
  - ***Wireless** control incl. dimming via **DALI** protocol*
  - ***Droop control** with emergency lighting mode (in development)*

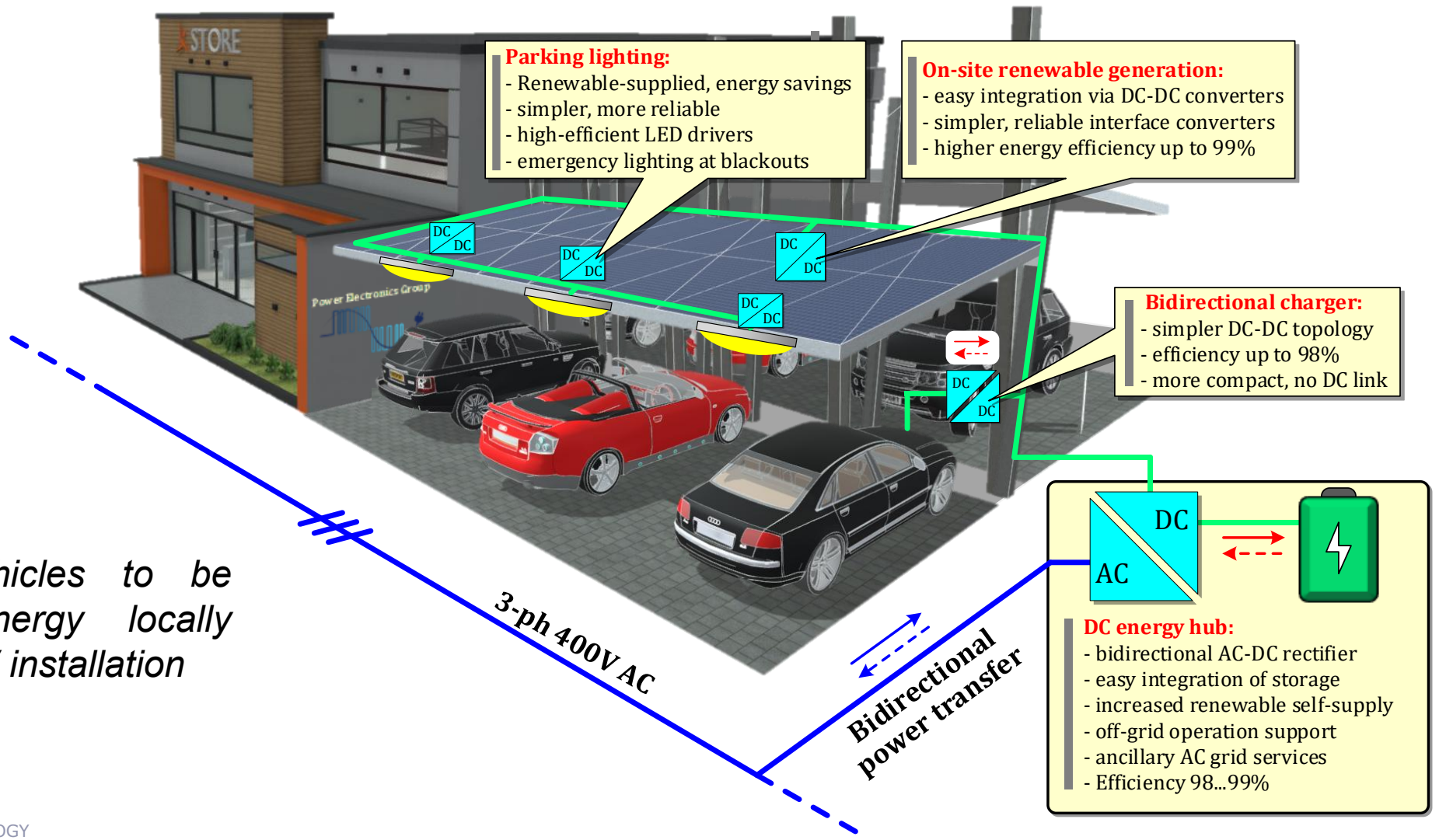


OUR UPCOMING DC TECHNOLOGY SHOWCASES (2)

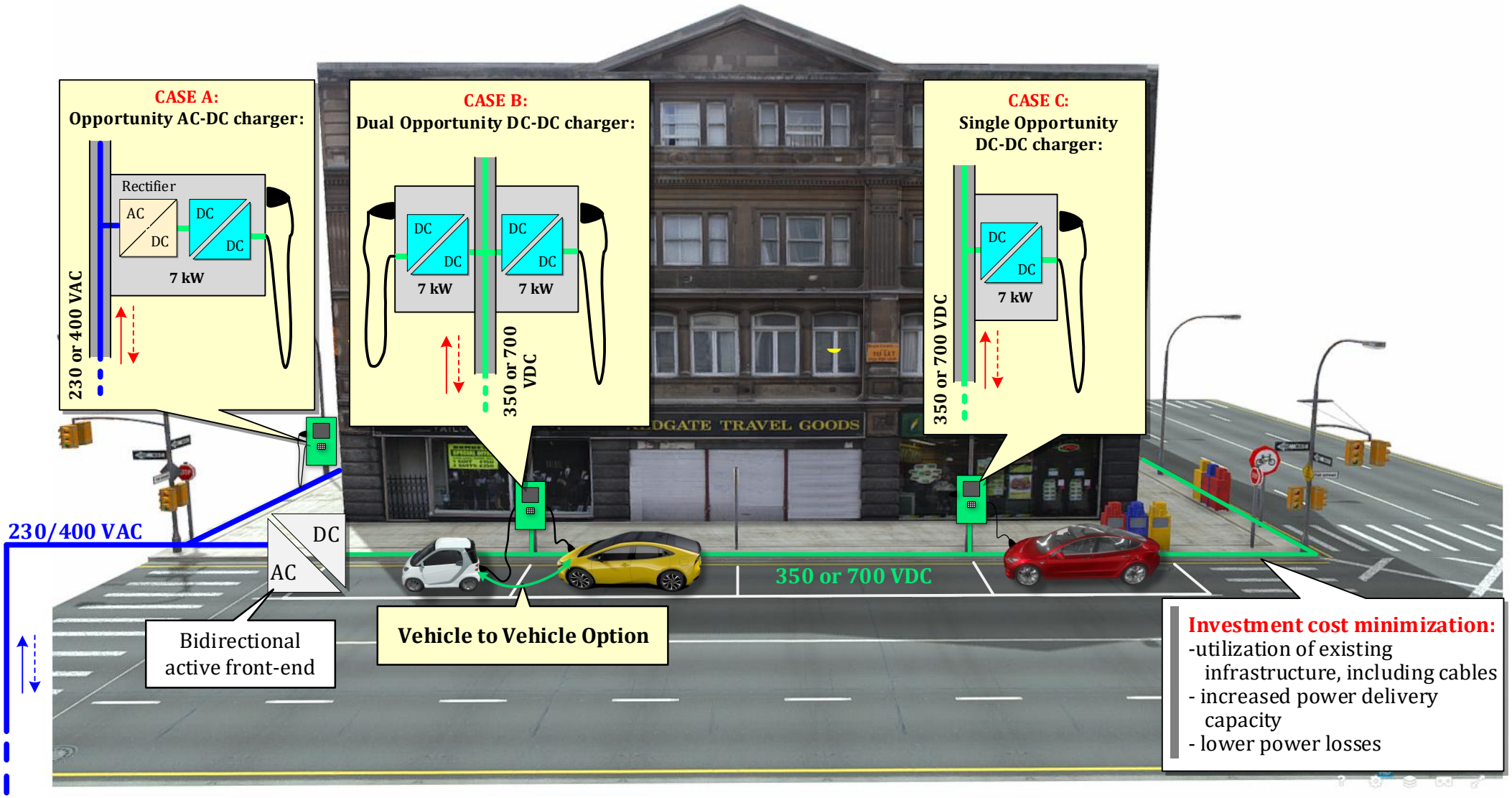
ENERGY-NEUTRAL CAR PARKING

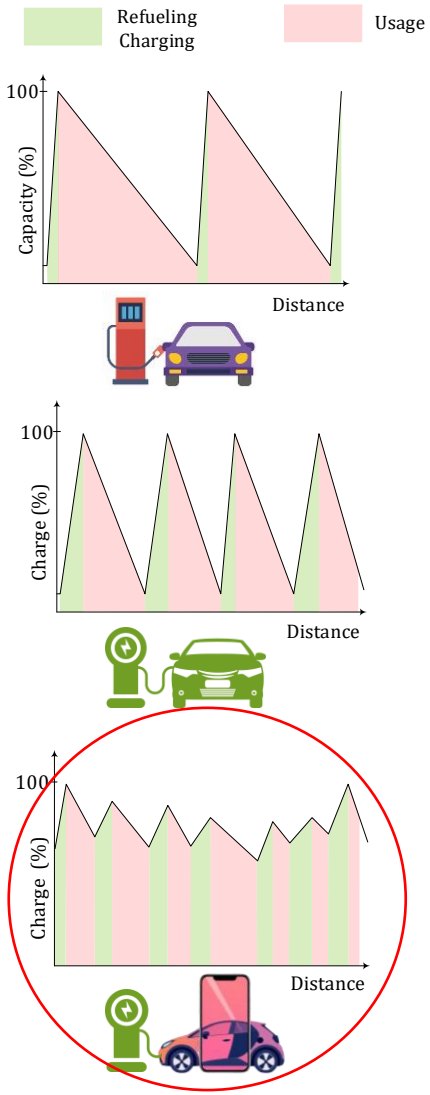


Enables electric vehicles to be recharged using energy locally generated from the PV installation

OUR UPCOMING DC TECHNOLOGY SHOWCASES (3)

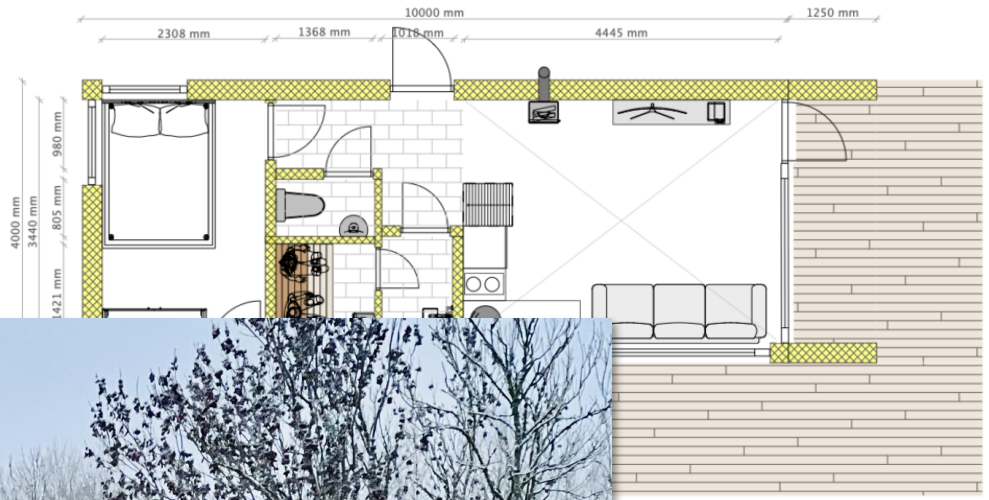
DC STREET LIGHTING NANOGRID WITH OPPORTUNITY V2G CHARGERS





OUR UPCOMING DC TECHNOLOGY SHOWCASES (4)

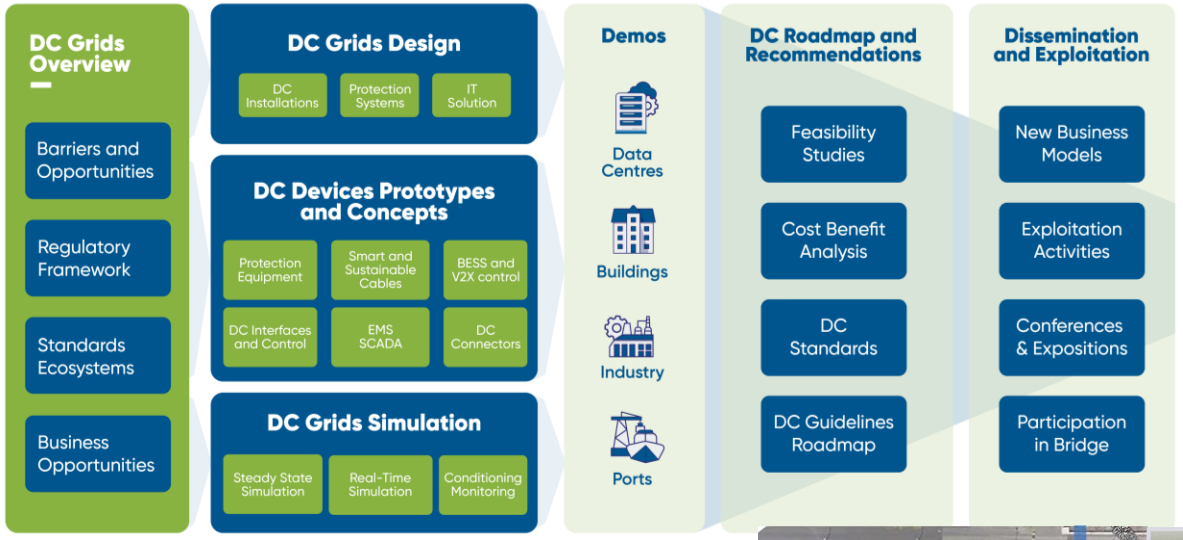
A+ GRID-INTERACTIVE PREFAB DC HOUSE



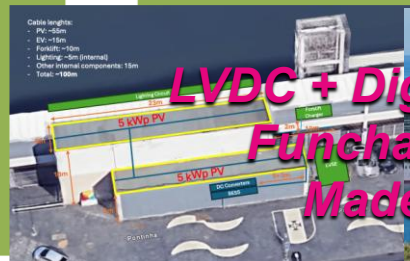
SHIFT2DC – EU PROJECT SHOWCASING DC TECHNOLOGY

- ***Key figures:*** *21 partners + 6 affiliates, 11 M€, 13 countries, 4 demos*
- ***Key objectives:*** *15+ industry solutions, tools for sizing and design, comprehensive tutorial-style deliverables on standardization/protection/modeling, droop control-based energy management, etc.*
- ***Main targets/demos:*** ***DC*** *buildings,* ***DC*** *data centers,* ***DC*** *ports (digital twin), and* ***DC*** *industry*
- ***TalTech's role:*** *WP4 "Demos" leadership and development of 2 innovative DC-DC solutions*

Concept



Demos



TALTECH STUDENT DC CLUB (Est. 2025)

ESTONIAN DC INNOVATION WORKSHOPS

November 25, 2021

November 22, 2023

December 15, 2022

November 27, 2024

TAL TECH | TALLINN UNIVERSITY OF TECHNOLOGY

i³ DC
Accelerates Energy Transition

International workshop series involving academia and industry to facilitate wide-scale adoption of the residential DC microgrids

6TH ESTONIAN DC INNOVATION WORKSHOP

SHAPING DC FUTURE – ESTONIA'S OUTLOOK

December 3, 2025 at 11:00 CET – Join us (online)!

TAL TECH POWER ELECTRONICS GROUP
IEEE ESTONIA SECTION
IES/PELS/IAS/PES JOINT SOCIETIES CHAPTER
Estonian Research Council
Centre of Excellence in Energy Efficiency

The 6th Estonian

DC Innovation Workshop

Shaping Estonia's DC Future

December 3, 2025 – 9:30

TalTech – Student House (Tudengimaja)
Ehitajate tee 5, Tallinn 19086, Estonia

Powered by:
i³DC initiative
inform, inspire, and innovate

i³ DC Accelerates Energy Transition
in cooperation with CurrentDS ODCA direct current by zvei

About

DC microgrids are set to reshape energy supply, echoing trends in electric aircraft and ships. Broader adoption, however, is still held back by immature technologies, missing standards, and a lack of market-ready power electronics. The aim of this workshop is to bring together experts from academia, industry, and policy to discuss the latest developments and innovation potential DC microgrids.

*With the 2006 Estlink high voltage DC interconnection and the 2013 launch of the world's first nationwide electric vehicle DC fast-charging network, Estonia has already laid key foundations for its DC-powered future. **The 6th workshop** will be focused on the Estonia's DC future and how local developments connect to wider European efforts. Special attention will be given to the transfer of research results into industrial applications as well as the role of pilot projects, such as TalTech Residential DC Innovation Hub, in accelerating uptake. The workshop will highlight how companies, researchers, and policymakers can jointly shape the energy transition by building DC competences that strengthen both national resilience and global competitiveness.*

*This event is organized by the **i³DC initiative**, a non-profit venture of TalTech aimed at increasing awareness, pushing forward innovation and accelerating the industrial uptake of the residential DC microgrids. It is co-funded by the European Union through the project "Cooperation between universities to promote doctoral studies" (2021-2027.4.04.24-0003).*

LET'S DC-fy THE WORLD TOGETHER!

TAL TECH | TALLINN UNIVERSITY OF TECHNOLOGY
i³ DC Accelerates Energy Transition
Centre of Excellence in Energy Efficiency

PEMC 2026 IN TALLINN – SAVE THE DATE!

THE 22ND IEEE POWER ELECTRONICS AND MOTION CONTROL CONFERENCE (PEMC2026) – September 23-25, 2026

CO-SPONSORED BY THE IEEE IES

You can expect:

- *Highly relevant program on power electronics, controls, electrical drives, robotics and their industrial applications*
- *~150 papers to be presented*
- *Tutorials from world-renown experts: J. Kolar, M. Malinowski, F. Blaabjerg, A. Rathore, etc.*
- *Conference venue next to the Tallinn's Old Town – a UNESCO World Heritage Site*
- *Entertaining social events for attendees, special events for students and WiE members*
- *Luncheons and coffee breaks*

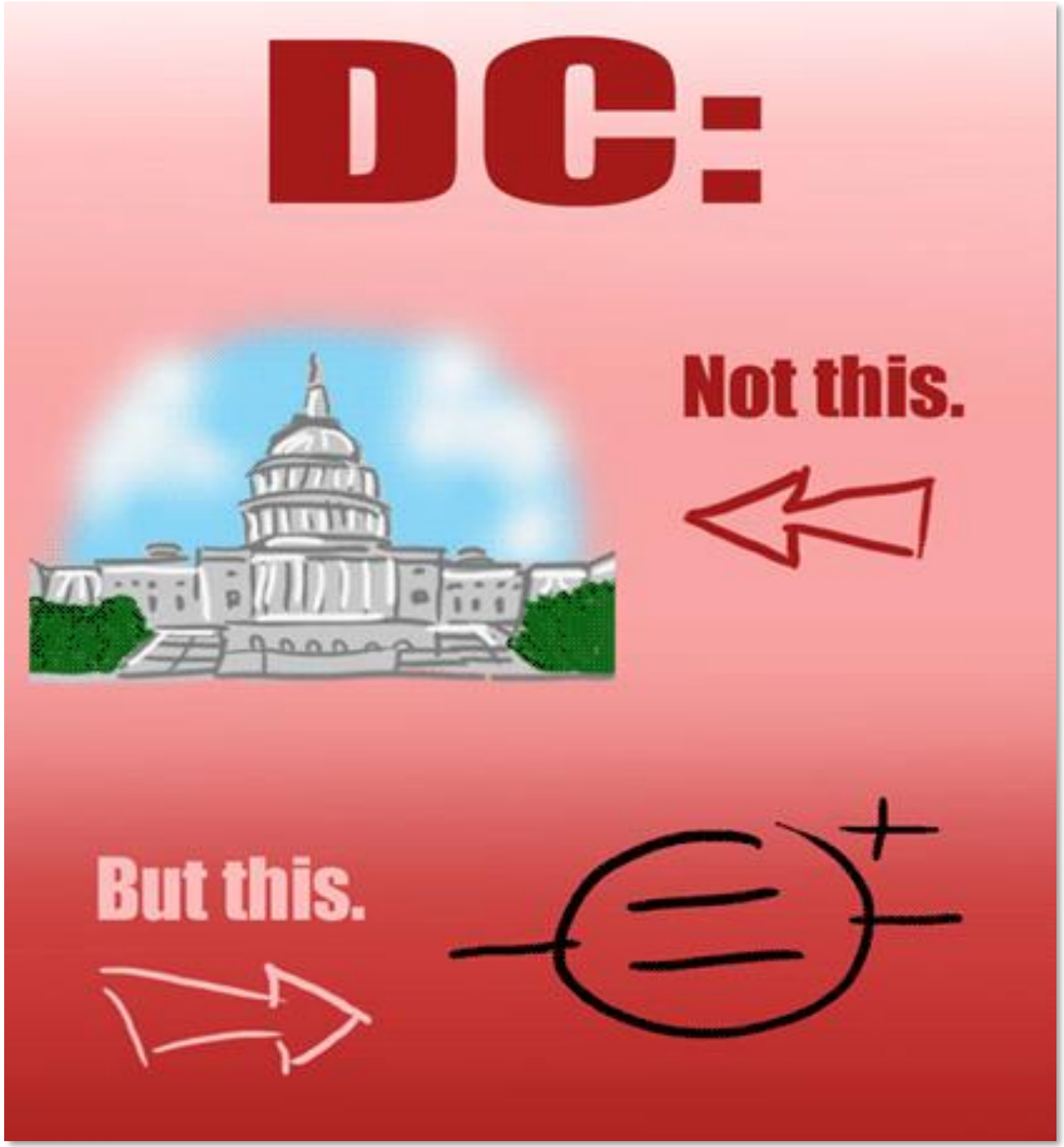
FOLLOW US

The most recent news and activities you will find in our LinkedIn groups

Power Electronics Group

i³ DC
Accelerates Energy Transition

- *https://taltech.ee/en/power-electronics-research-group (to be updated)*
- *https://taltech.ee/en/i3dc-initiative*



CALL FOR COLLABORATION!!!

We will welcome
collaboration on DC buildings
with interested partners
all over the World!

Feel free to contact us at
i3dc@taltech.ee

Centre of Excellence in Energy Efficiency

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QUESTIONS

– POWER ELECTRONICS GROUP –

Your Reliable Partner in Power Electronics

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