



**TAL
TECH**

DC BUILDINGS – DECARBONIZATION EMPOWERED BY POWER ELECTRONICS

Dmitri VINNIKOV

Power Electronics Group

Department of Electrical Power Engineering and Mechatronics

Tallinn University of Technology

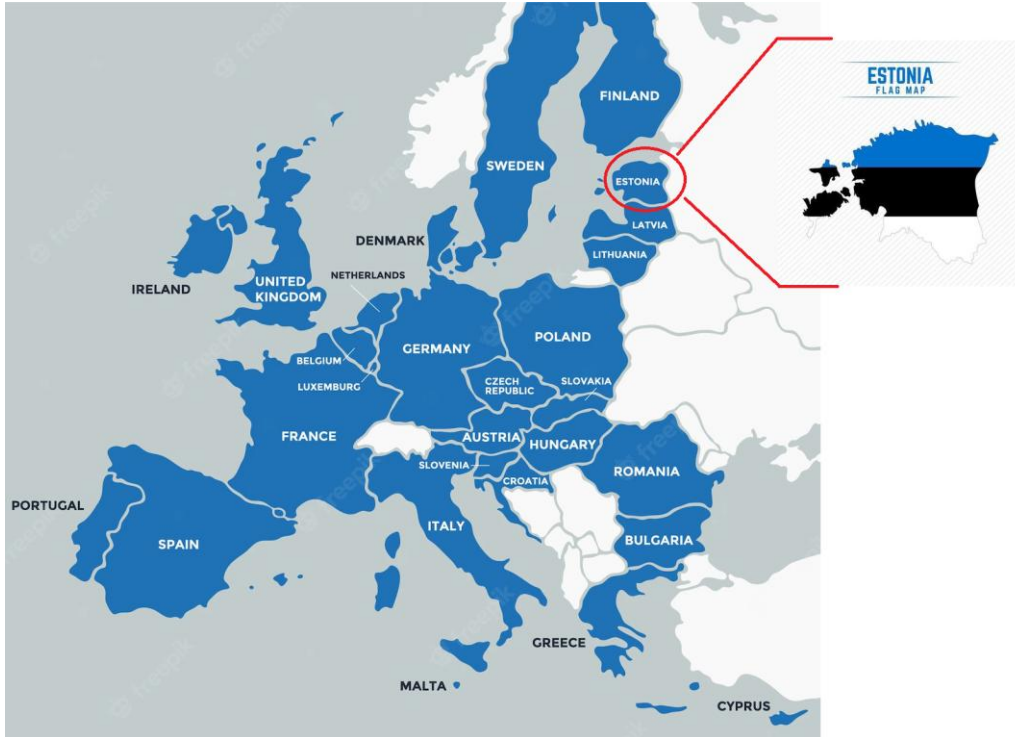


Centre of Excellence
in Energy Efficiency

WHERE I AM FROM

ESTONIA - A Destination for Tech Lovers

TALLINN - The Best-Preserved Medieval City in Northern Europe



- Population: 1.35 million
- Currency: Euro
- World's most digitally advanced society
- Estonia leads Europe in startups, unicorns, and investments per capita



- Population: 456,000
- Historic Centre (Old Town) of Tallinn is UNESCO world heritage site
- Annually welcoming over 3.2 million foreign visitors

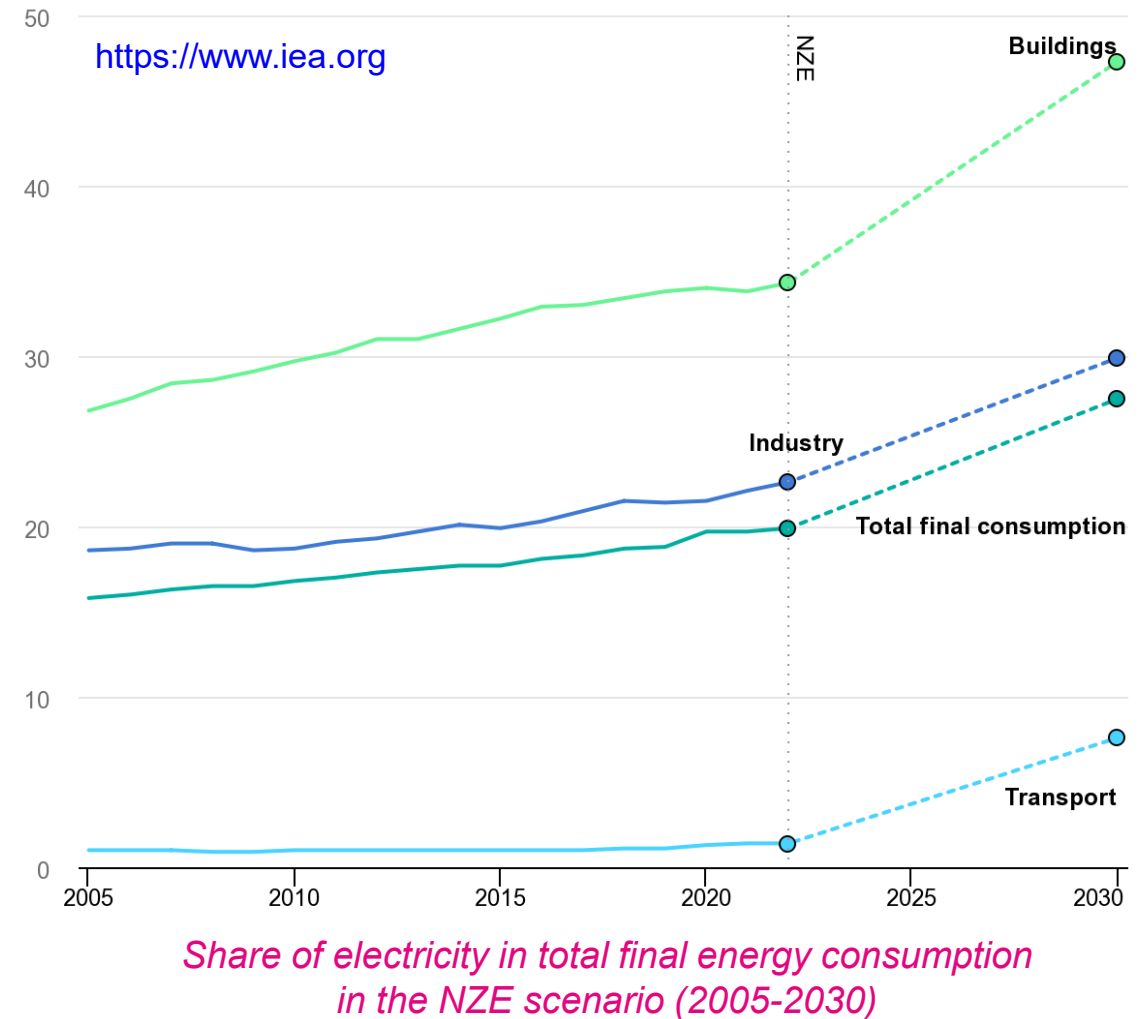
POWER ELECTRONICS GROUP OF TALTECH

LARGEST RESEARCH CENTER FOR APPLIED POWER ELECTRONICS IN BALTIC STATES



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
- 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

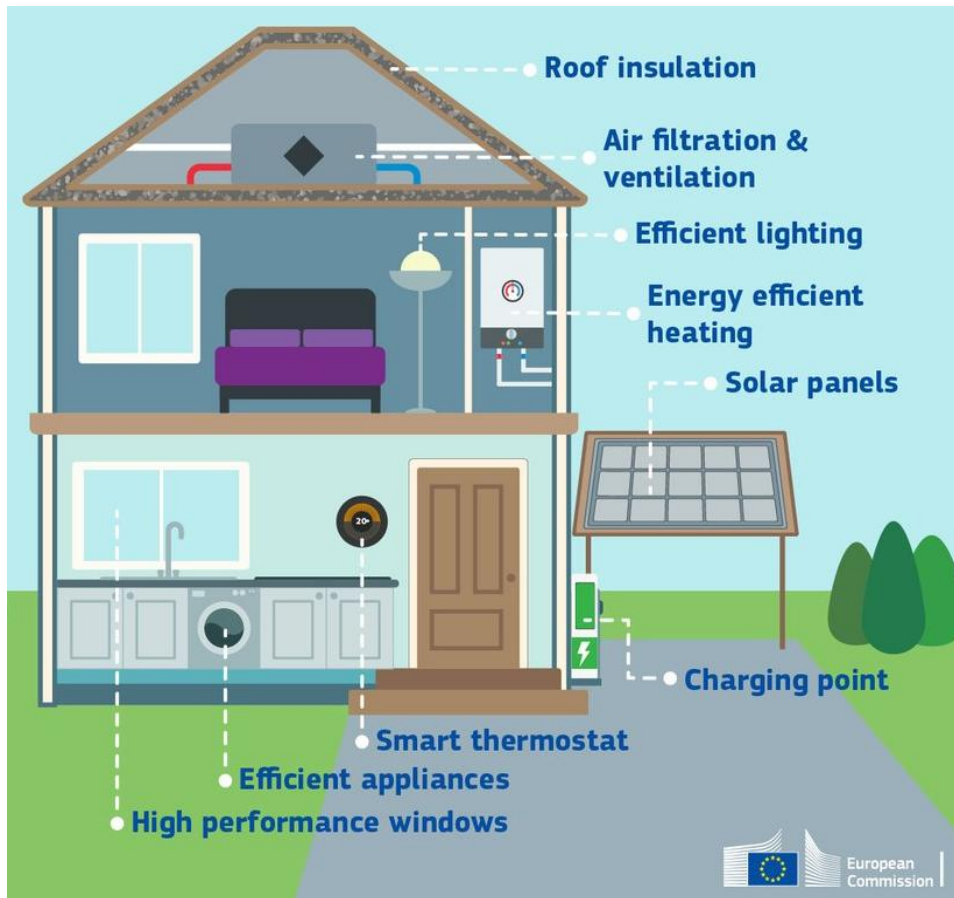


DECARBONIZATION OF BUILDING STOCK IN EU

- **Buildings** are responsible for approx. **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 or class A)**, i.e. must have a **high energy performance and very low energy needs**, covered largely by **onsite or 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 A₀)**, 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)**

ZEB AND POWER ELECTRONICS

- **ZEB = HIGH ENERGY PERFORMANCE + LOCAL RENEWABLE ENERGY GENERATION + “ALL-ELECTRIC” LIFESTYLE**
- **ENERGY PERFORMANCE 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
- In result, ZEB consumes **up to 4 times less energy** than the traditional „old school“ non-renovated building
- Most of the energy saving technologies used in ZEB are **power electronics based**



GOOD EXAMPLES OF BUILDING DECARBONIZATION



BAD EXAMPLES OF BUILDING DECARBONIZATION



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



BIPV



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

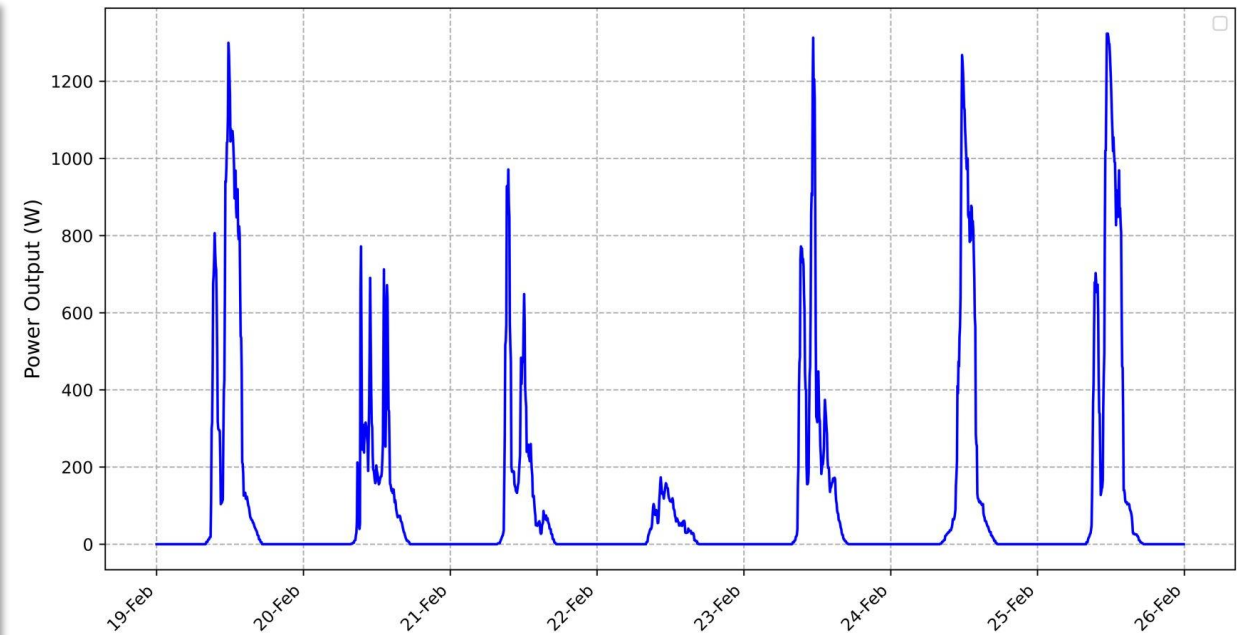
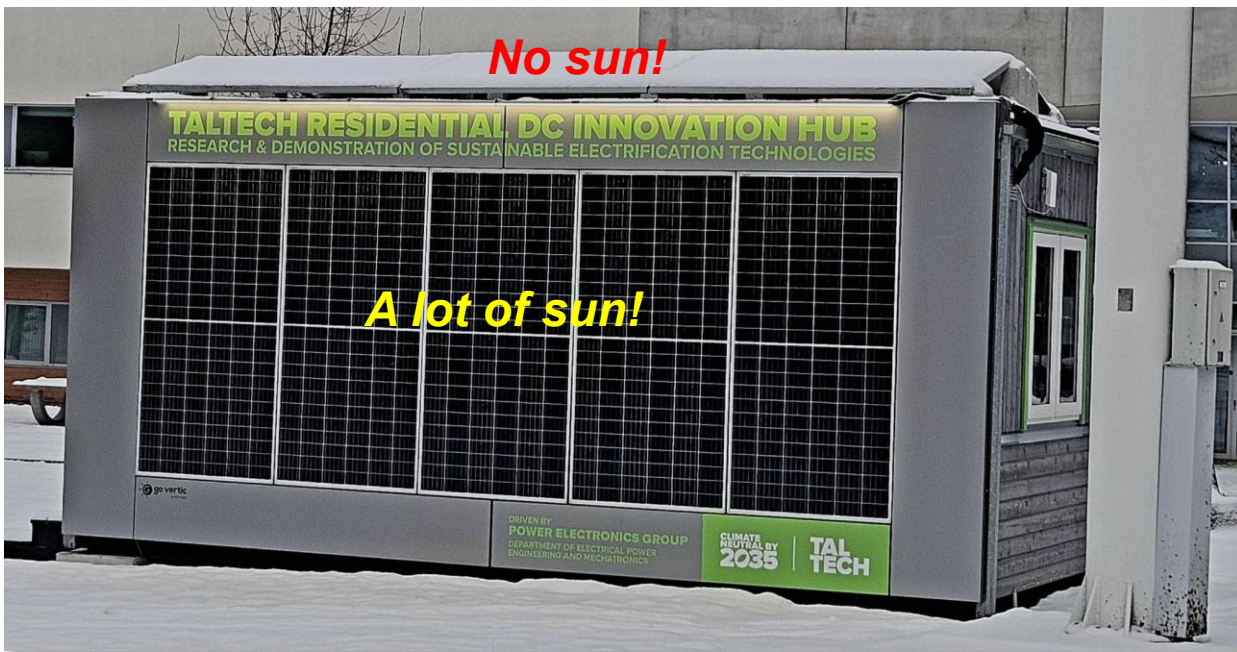


SOLAR FAÇADES



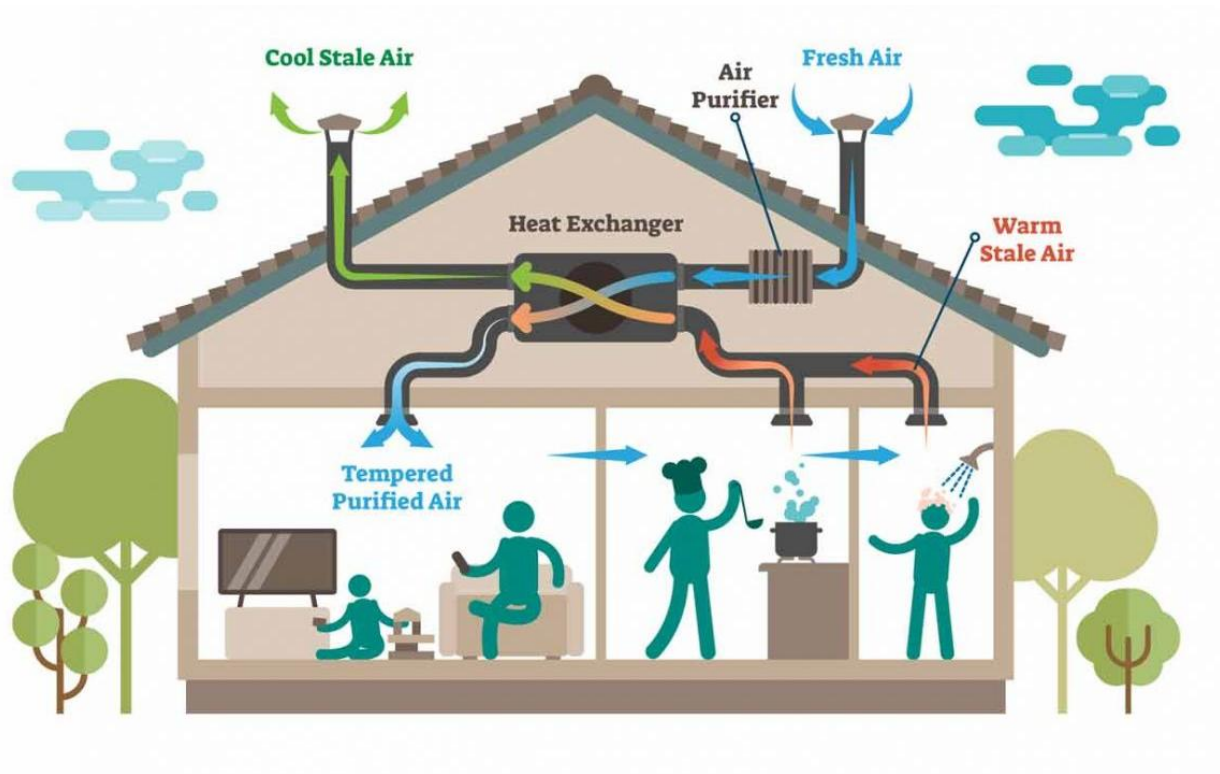
SOLAR FAÇADE – GENERATE WHEN OTHER DO NOT

- *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*



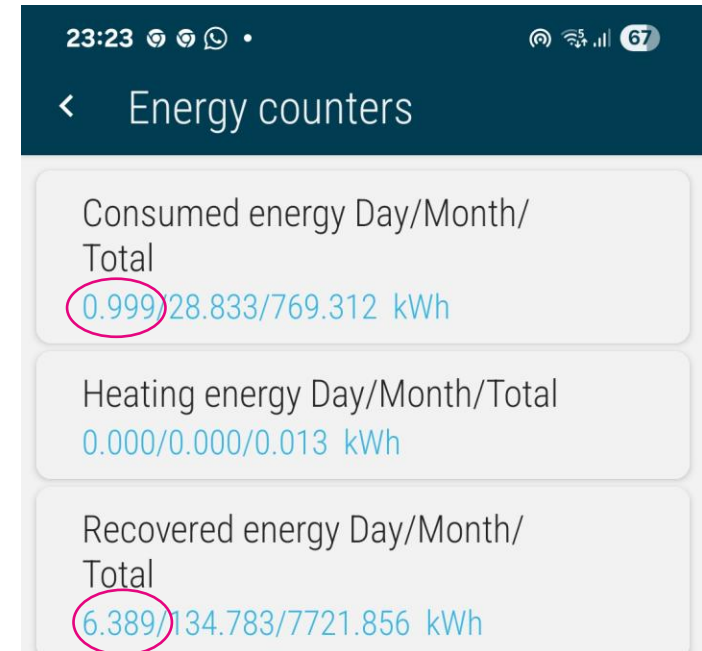
HEAT RECOVERY VENTILATION SYSTEMS

- **Improved energy efficiency:** reduces heating demand of the building 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



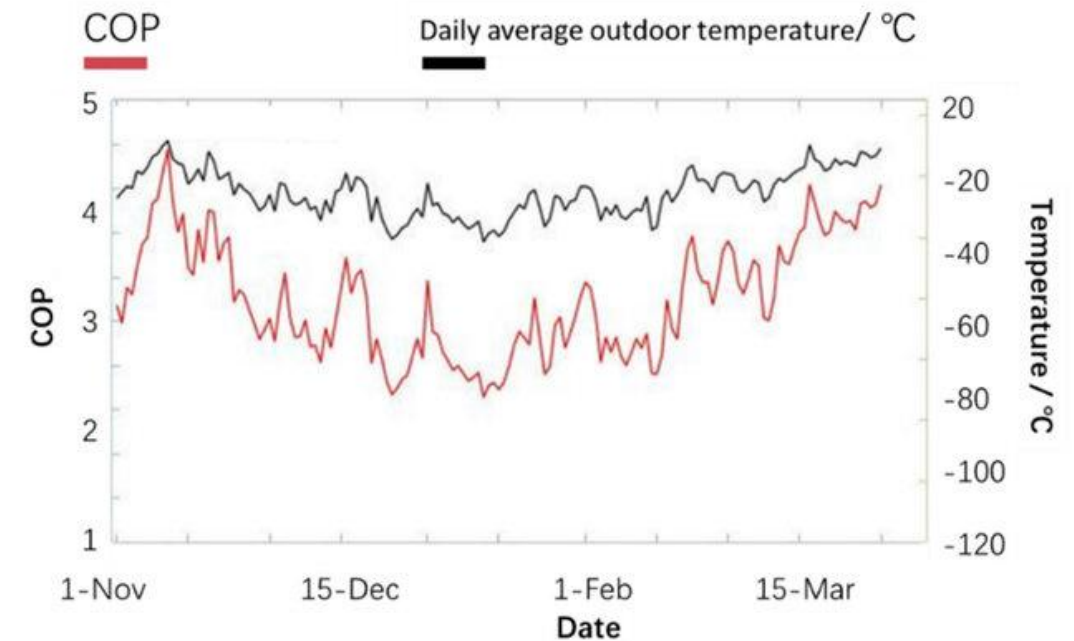
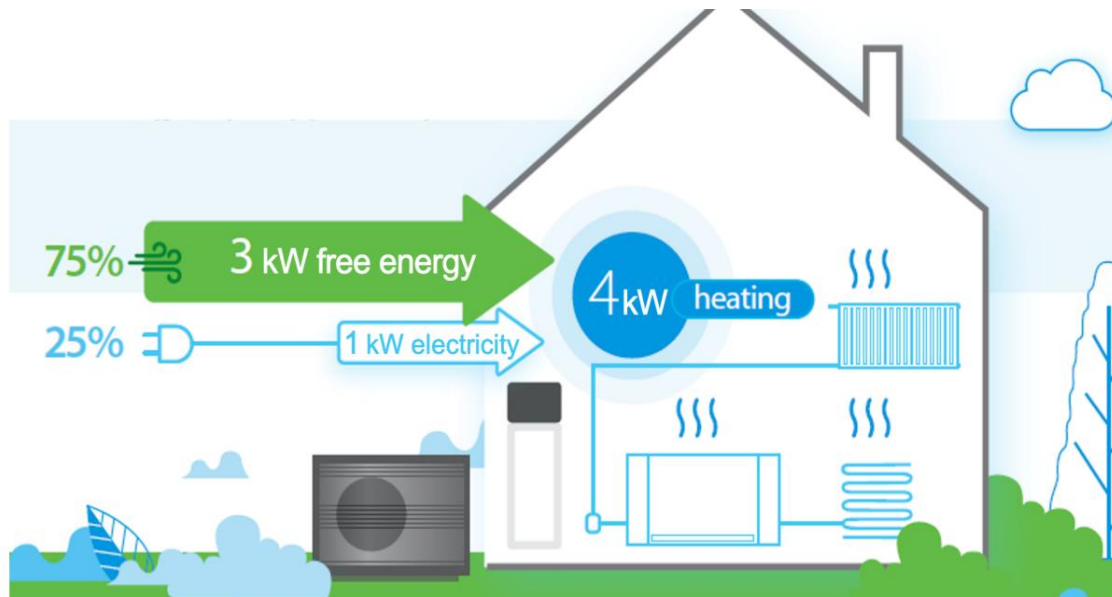
Temperature efficiency

	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

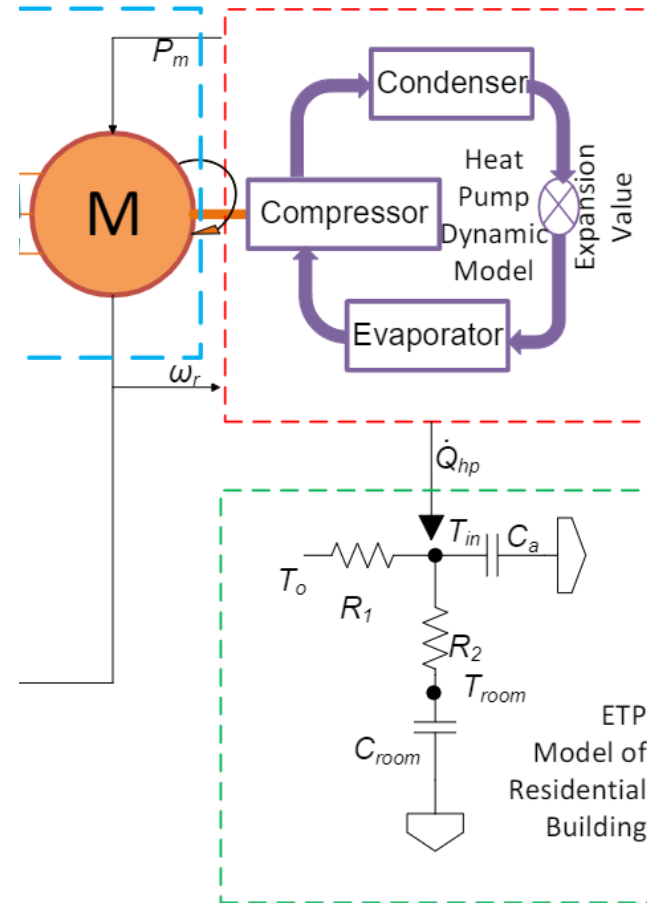
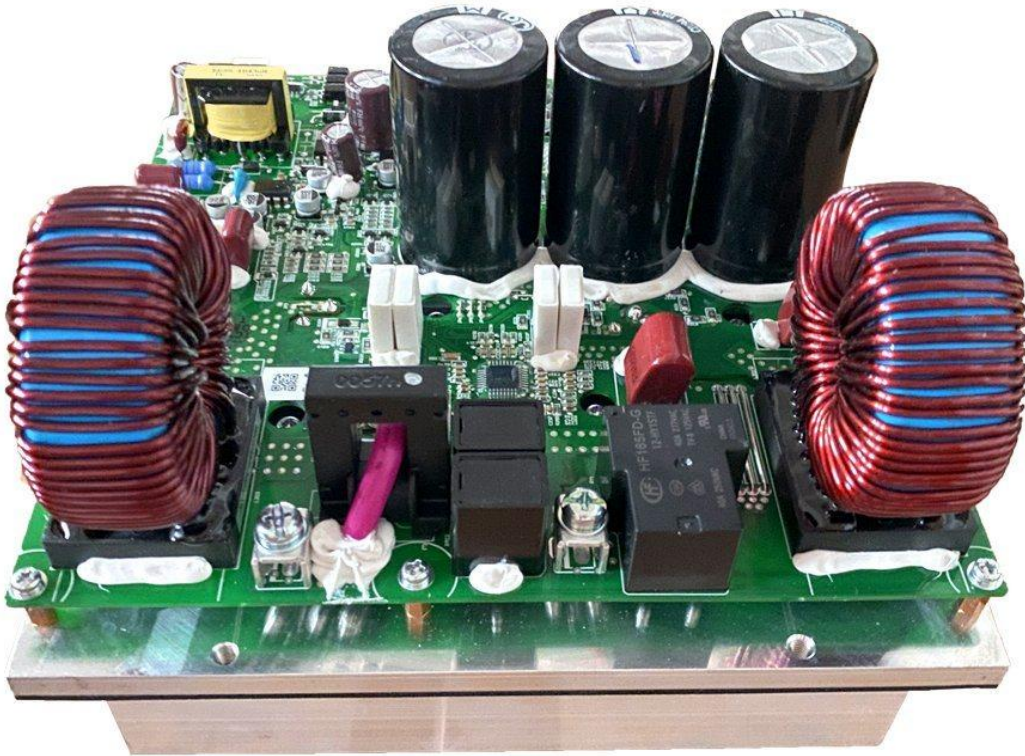
- **Excellent energy efficiency**: can deliver up to 5 times more heat energy to a home than the electrical energy it consumes (see COP – Coefficient of Performance or SCOP – Seasonal Coefficient of Performance)
- Used for **space heating/cooling** and providing **domestic hot water** for showers and 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**



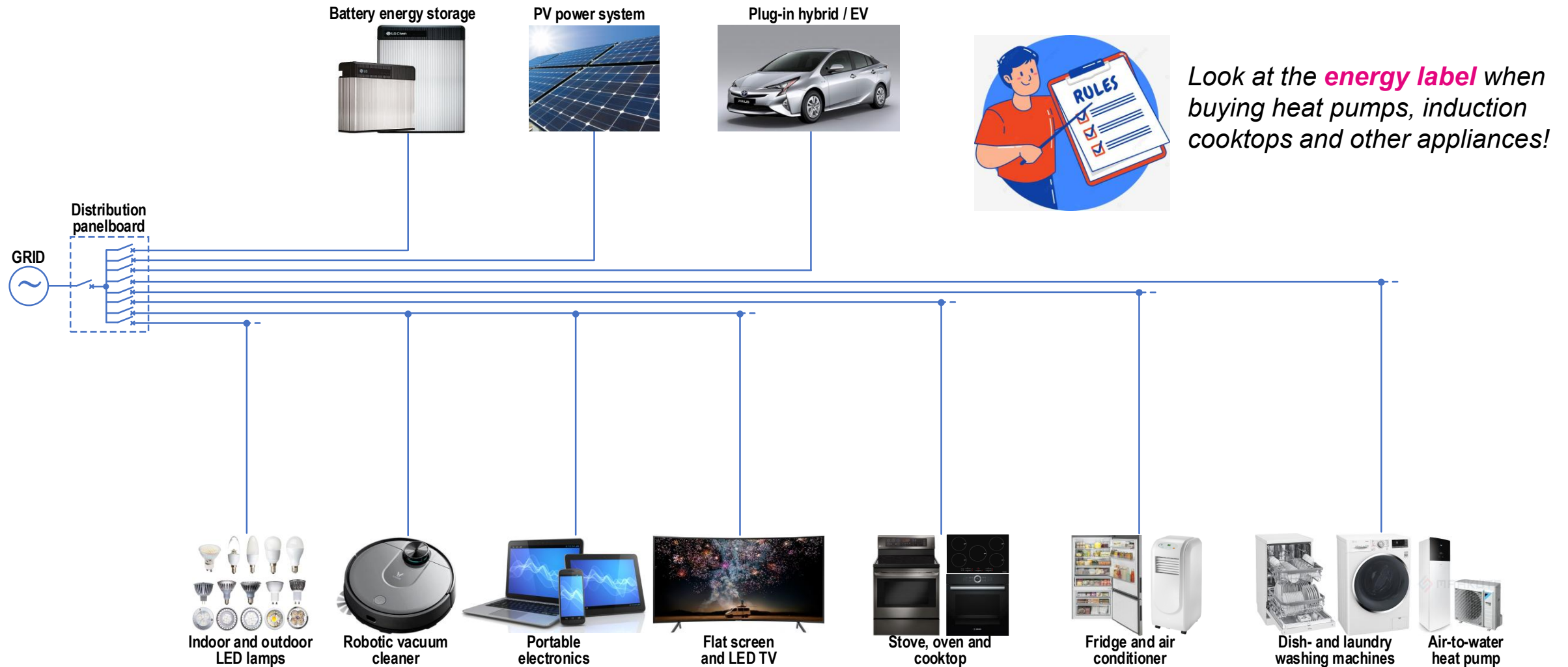
▪ Source: daikin.ie

HEAT PUMPS USE POWER ELECTRONICS

▪ Source: daikin.ie



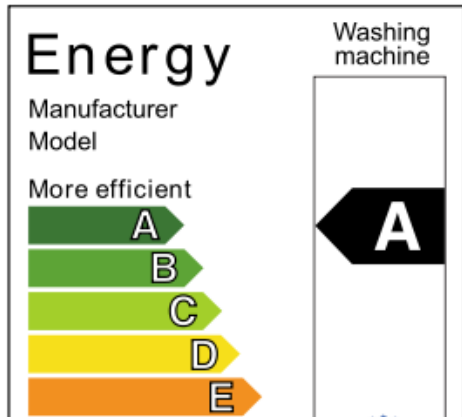
DECARBONIZATION OF BUILDINGS: „ALL-ELECTRIC“ LIFESTYLE WITH ZEB



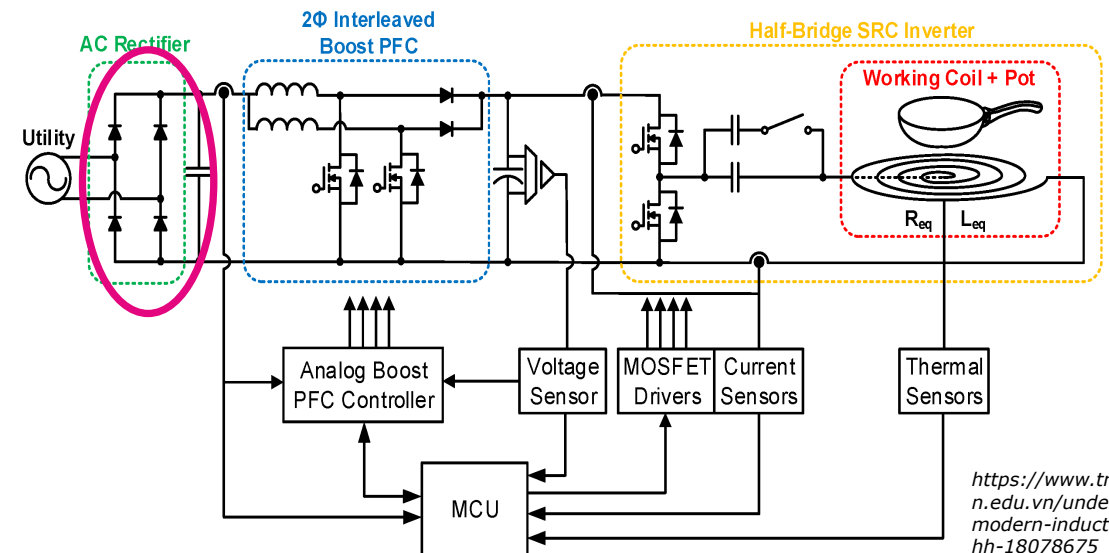
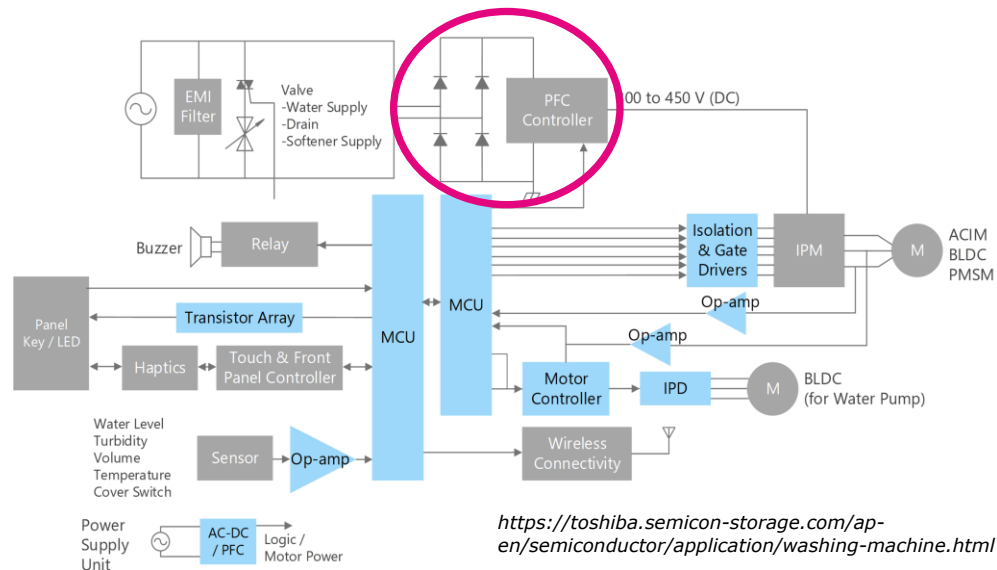
Look at the **energy label** when buying heat pumps, induction cooktops and other appliances!

CLASS-A ENERGY-EFFICIENT APPLIANCES

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



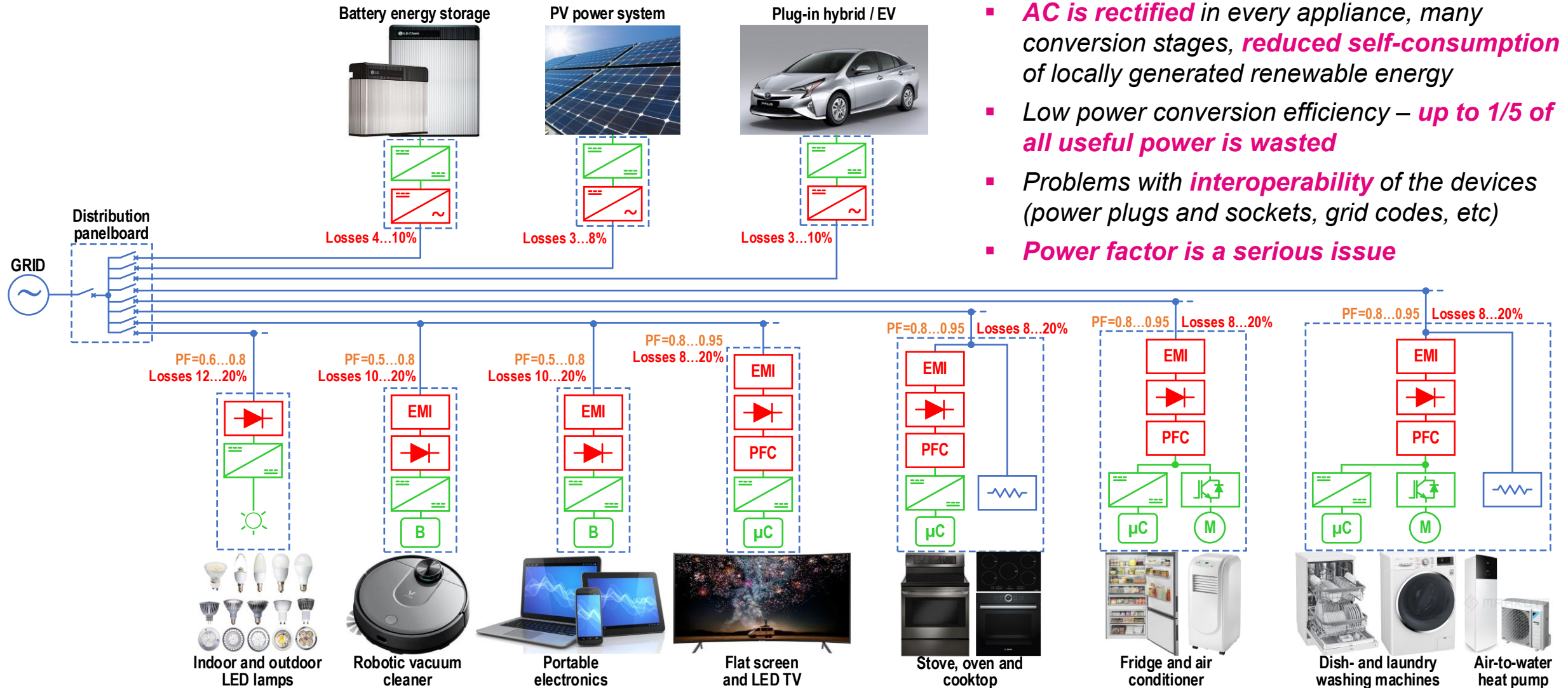
THEY ALL USE DIRECT CURRENT (DC) FOR OPERATION !!!



<https://www.truongquoctesaigon.edu.vn/understanding-how-modern-induction-cooker-works-18078675>

AC-BASED ELECTRICAL SYSTEM OF A ZEB TODAY

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



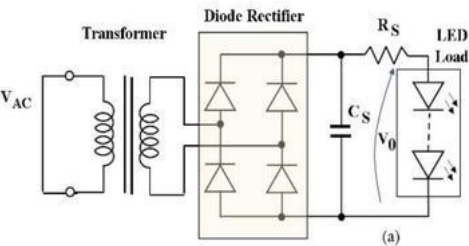
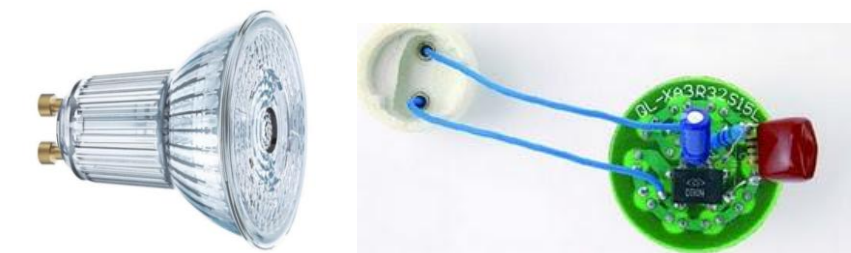
- **AC is rectified** in every appliance, many conversion stages, **reduced self-consumption** of locally generated renewable energy
- Low power conversion efficiency – **up to 1/5 of all useful power is wasted**
- Problems with **interoperability** of the devices (power plugs and sockets, grid codes, 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	lthd	1	—	74.420	%
8	PF	1	—	0.5534	

Laptop/Phone chargers (65 W)



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	lthd	86.841	%
8	PF	0.4858	
9	Udc	19.243	V
10	Idc	-3.022	A
11	P	-58.16	W



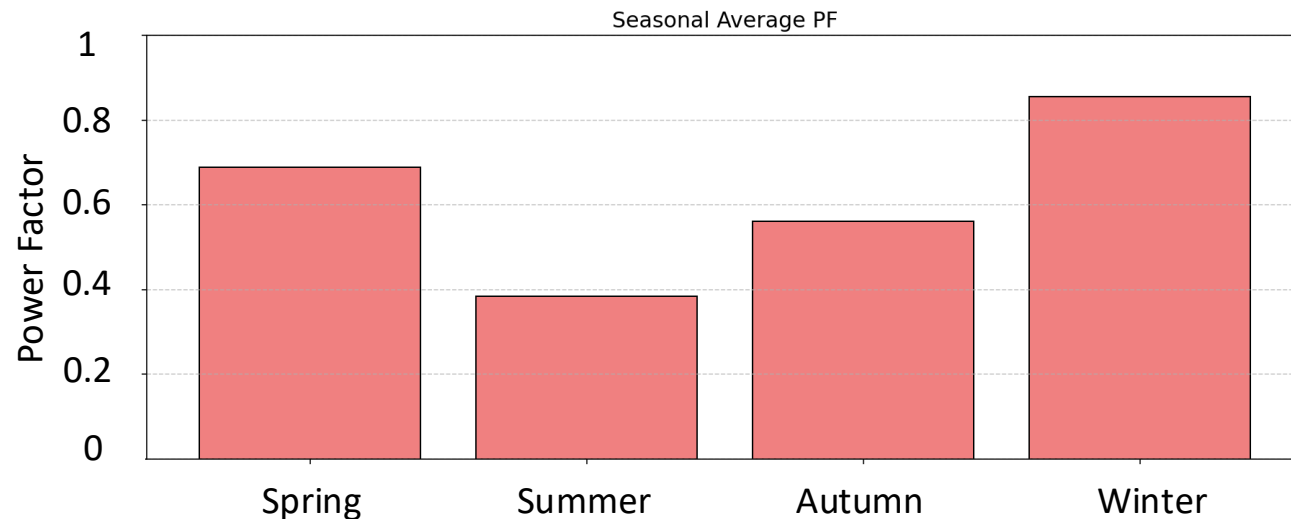
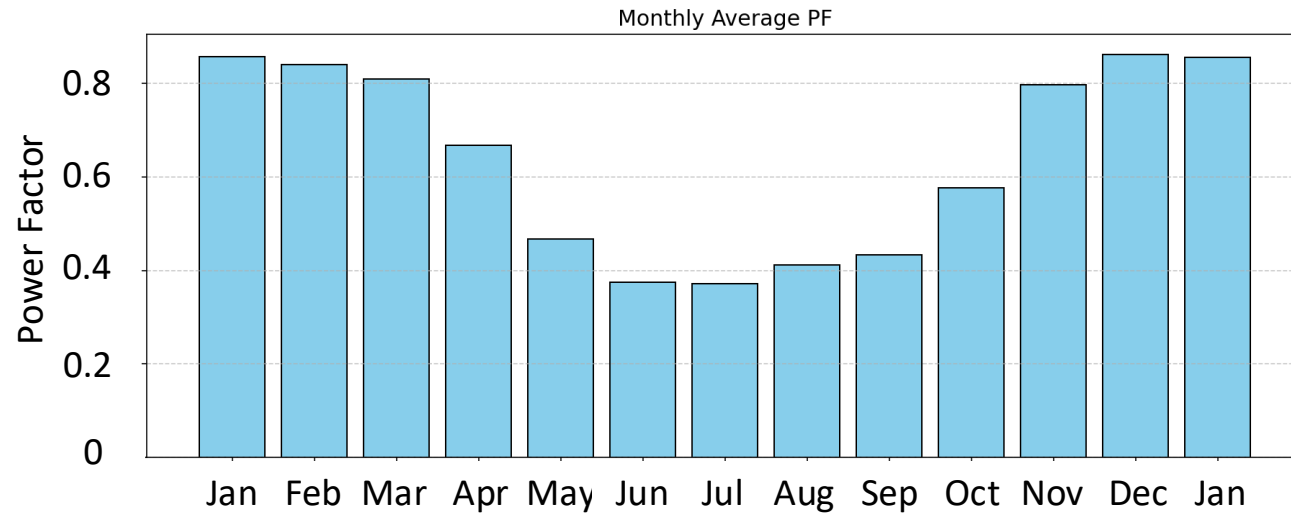
FULL-ELECTRIC LIFESTYLE WITH AC

A CLOSER LOOK AT THE POWER FACTOR ISSUE

176.7 m² single-family detached home



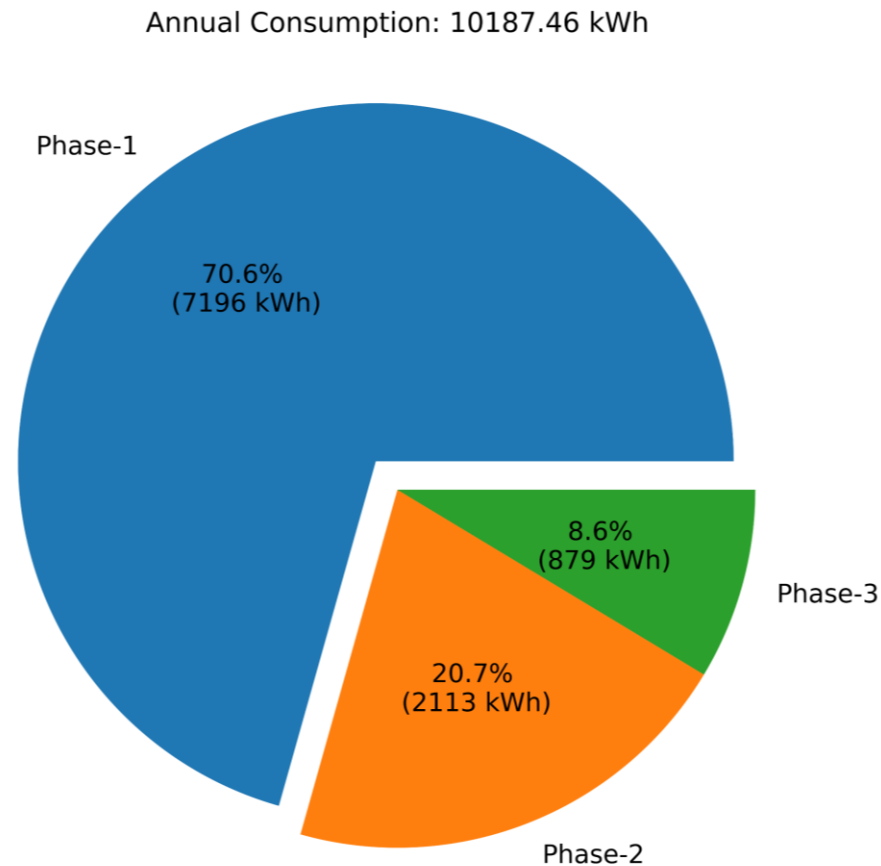
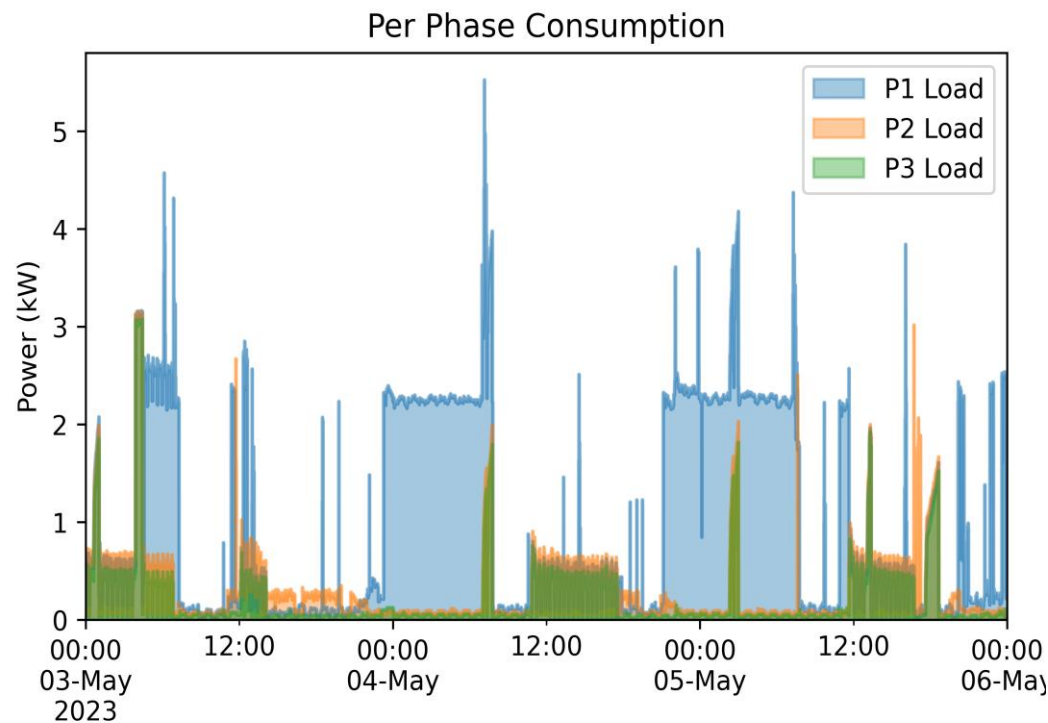
Location	Estonia, Tallinn
Total power of PV	5 kWp
Model of HP	Thermia Atec HP 11
Electric car	BMW i3
COP of HP	COP 3.8 (+7/+45 °C)
Habitants	4



FULL-ELECTRIC LIFESTYLE WITH AC

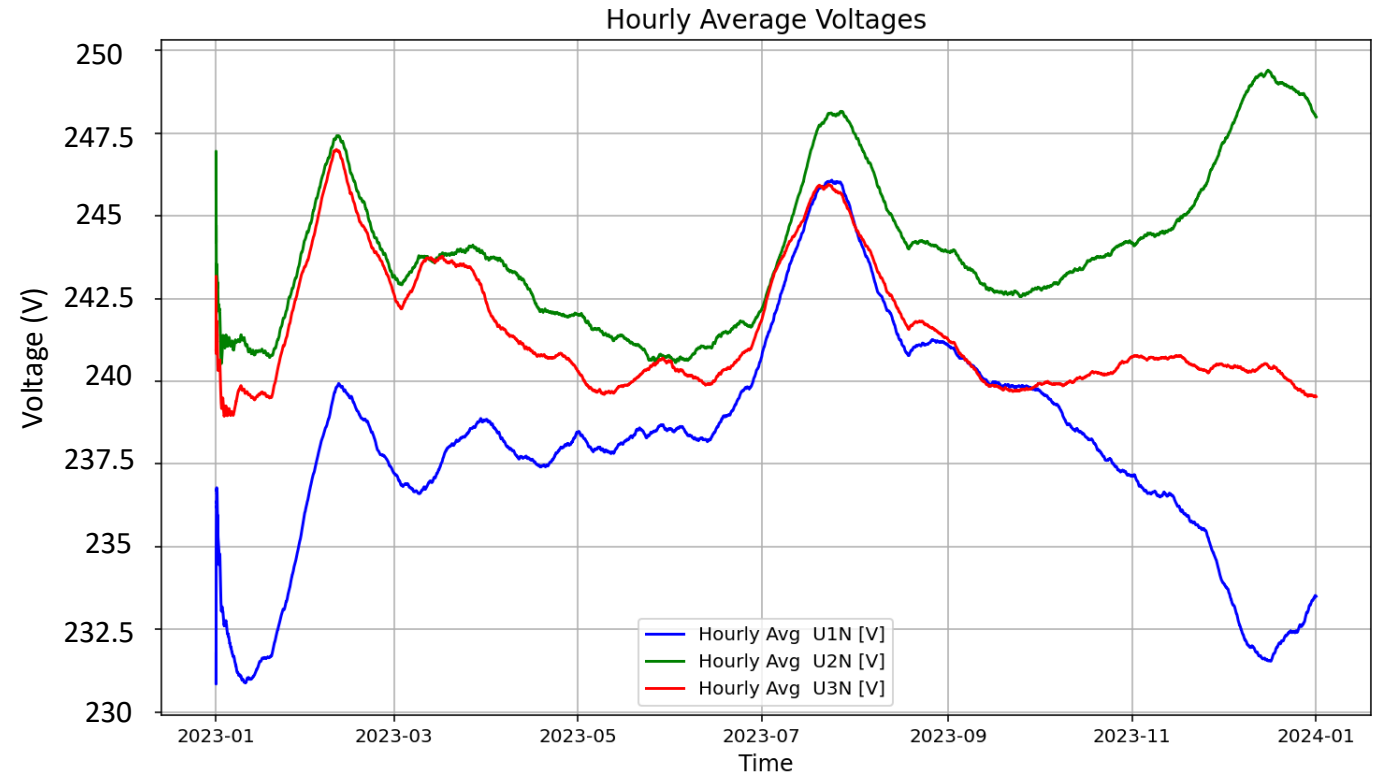
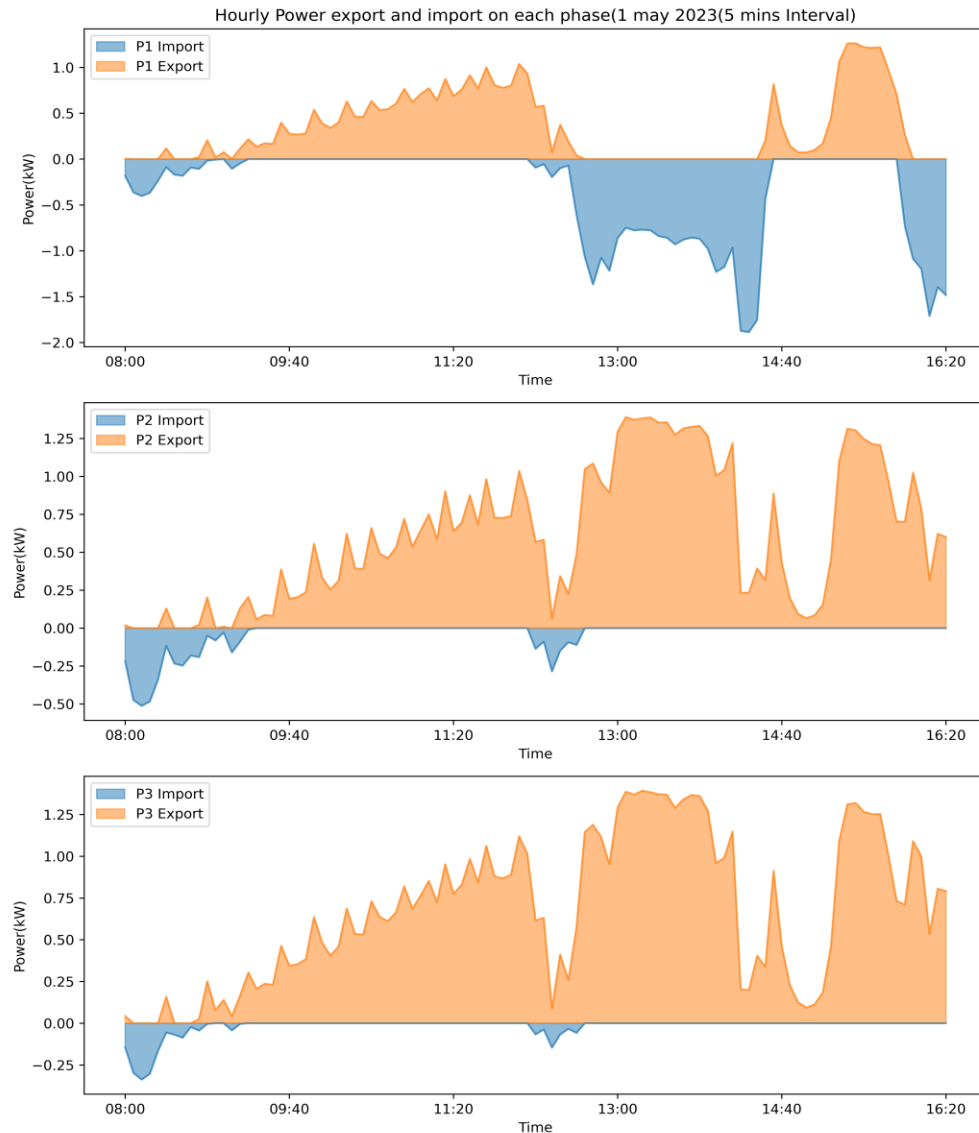
A CLOSER LOOK AT THE PHASE LOAD IMBALANCE

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



FULL-ELECTRIC LIFESTYLE WITH AC

ENERGY EXPORT/IMPORT BALANCE and VOLTAGE IMBALANCE ISSUES



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

Electronic waste or e-waste

Is the fastest growing waste stream

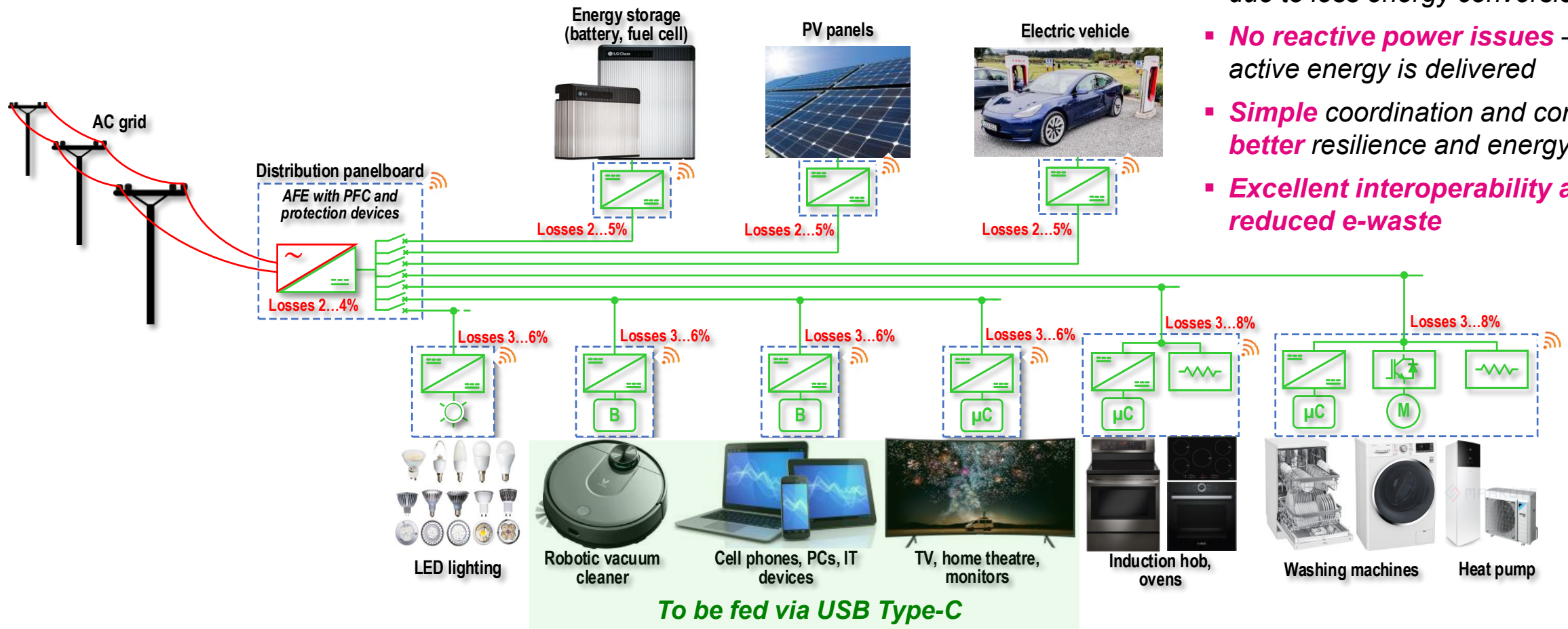


Every problem has a
solution 😊😊



NEXT-GEN ELECTRICAL SYSTEM OF A ZEB

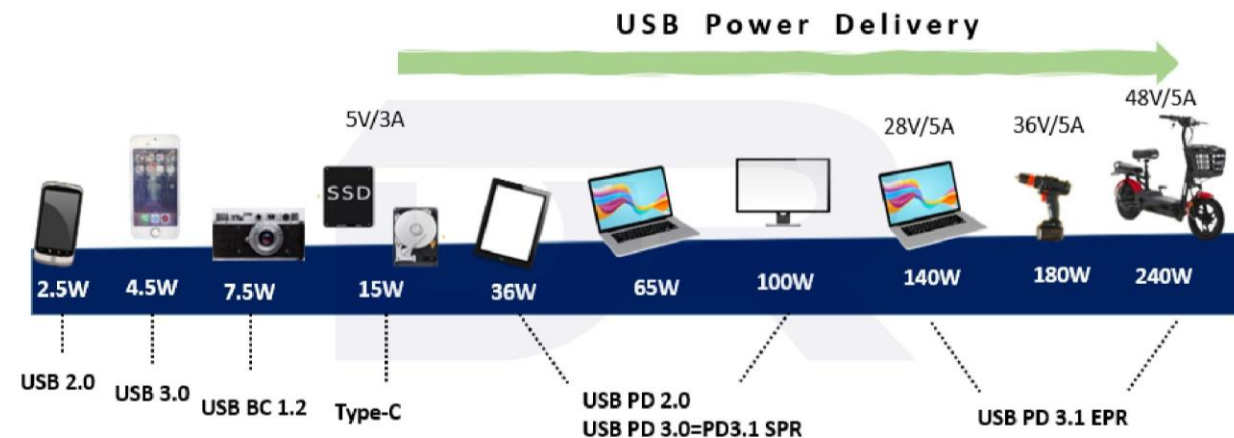
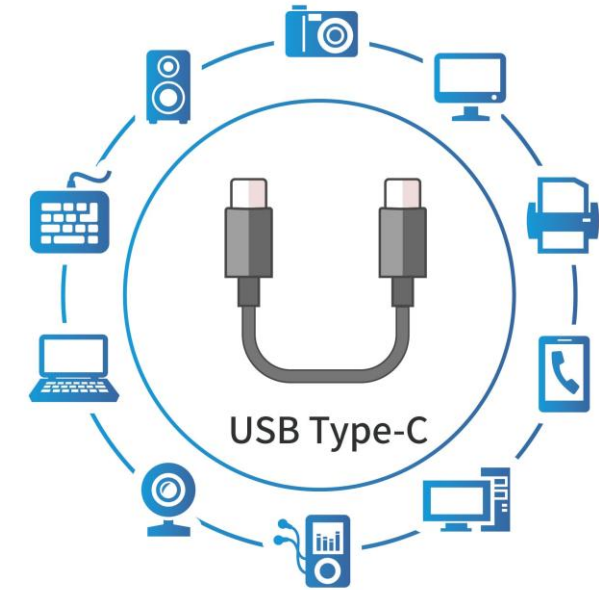
DC POWER DISTRIBUTION AND DC-FED APPLIANCES



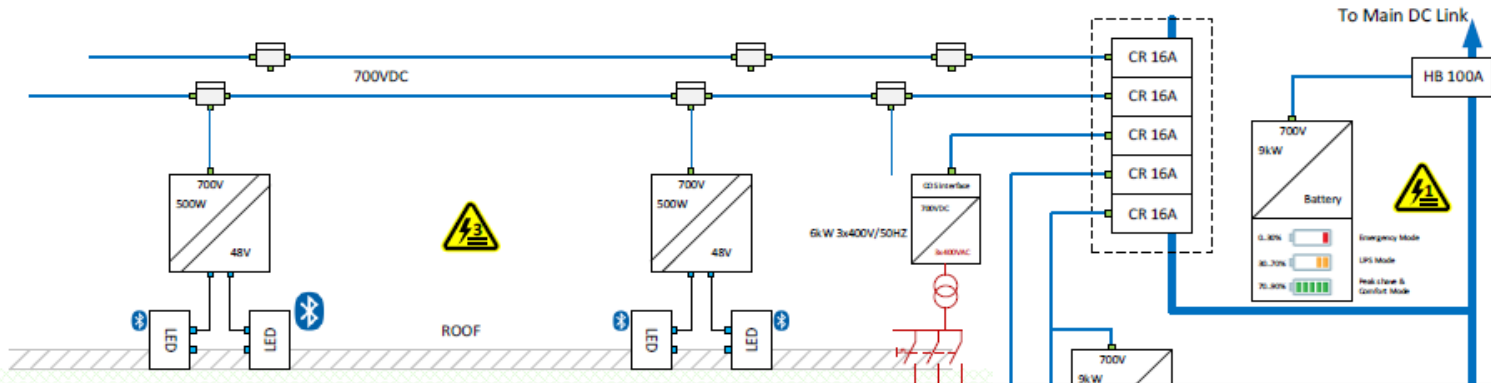
- **Increased** efficiency and **maximized** self-consumption of renewable energy due to less energy conversion stages
- **No reactive power issues** – only active energy is delivered
- **Simple** coordination and control, **better** resilience and energy security
- **Excellent interoperability** and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

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)
- Starting **from 2021** the concept is continuously developed, improved and showcased by **Current/OS Foundation**
- **350 VDC** is considered as a substitute for 230 VAC and **700 VDC** for 3x400 VAC*
- Residential DC installations can be realized either with a **unipolar** or **bipolar architectures**
- **Droop control** based power management, where voltage is used as a shared signal that reflects the power availability. The installation is **self-regulating** featuring excellent **resilience****
- Residential DC installations require ultrafast **solid-state circuit breakers (SSCB)** with tripping times less than **10 µs**. In combination with **residual current detection** and **arc fault mitigation** the SSCBs help eliminating safety concerns associated with DC and ensure **ultimate safety** of residents and property



by Schneider Electric

Current OS

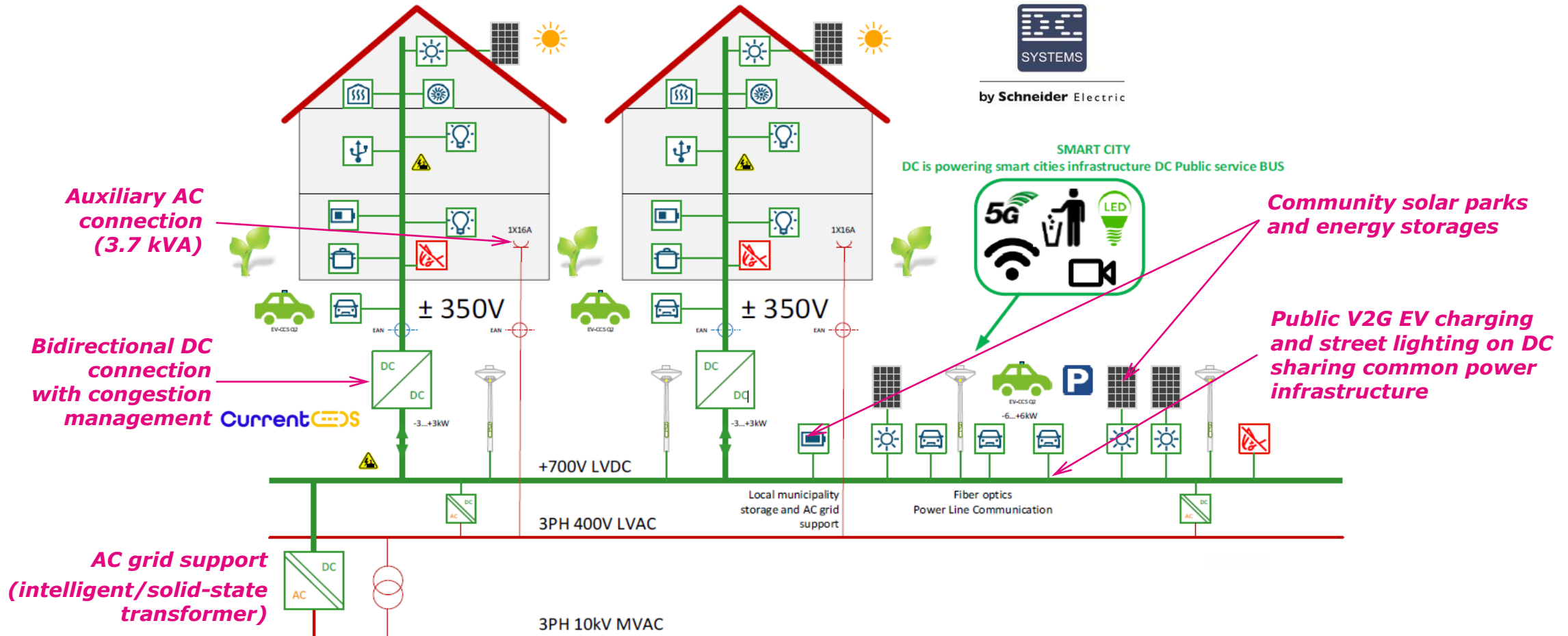
BENEFITS OF DC OVER AC IN HOUSEHOLDS*

DC OPENS A NEW DIMENSION IN ENERGY PERFORMANCE OF BUILDINGS

- **100% power electronics enabled** technology with ultimate control flexibility, efficiency, power density and reliability
- 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
- 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.)

DC ELECTRIFICATION OF NEIGHBOURHOODS

DC enables new revenue streams for homeowners from participation in energy services and collective initiatives (EaaS, VPPaaS, energy communities, energy hubs, etc.)



MAIN CHALLENGES OF DC TODAY

- *Lack of international standardization and certification schemes*
- *Lack of market-ready power electronic systems and appliances*
- *Lack of public awareness and technology demonstration*

General Motors EV1 (1996)



Tesla Model S (2012)



- Global DC partnership
- Member of IEC SyC LVDC
- 100+ partners to date, more joining every month
- 25 countries represented in
 - North America
 - Europe
 - Asia
- Universities join for free
- <https://currentos.org>



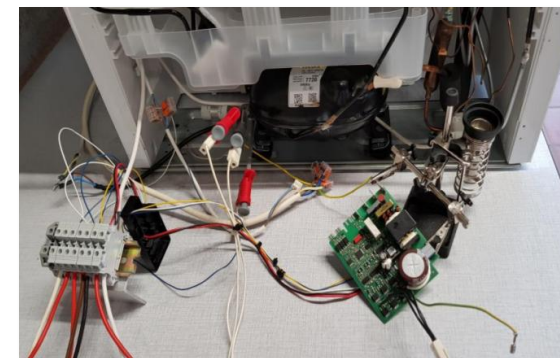
350 VDC TECHNOLOGY IS VERY FAST DEVELOPING

RECENTLY IS A TECHNOLOGY VALIDATION AND DEMONSTRATION PHASE (2020-2027)

- 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) 100 W 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.



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



DC TECHNOLOGY DEMONSTRATION FACILITIES (1)



by **Schneider Electric**

DIRECT CURRENT EXPERIENCE CENTER (AALSMEER, NL)

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

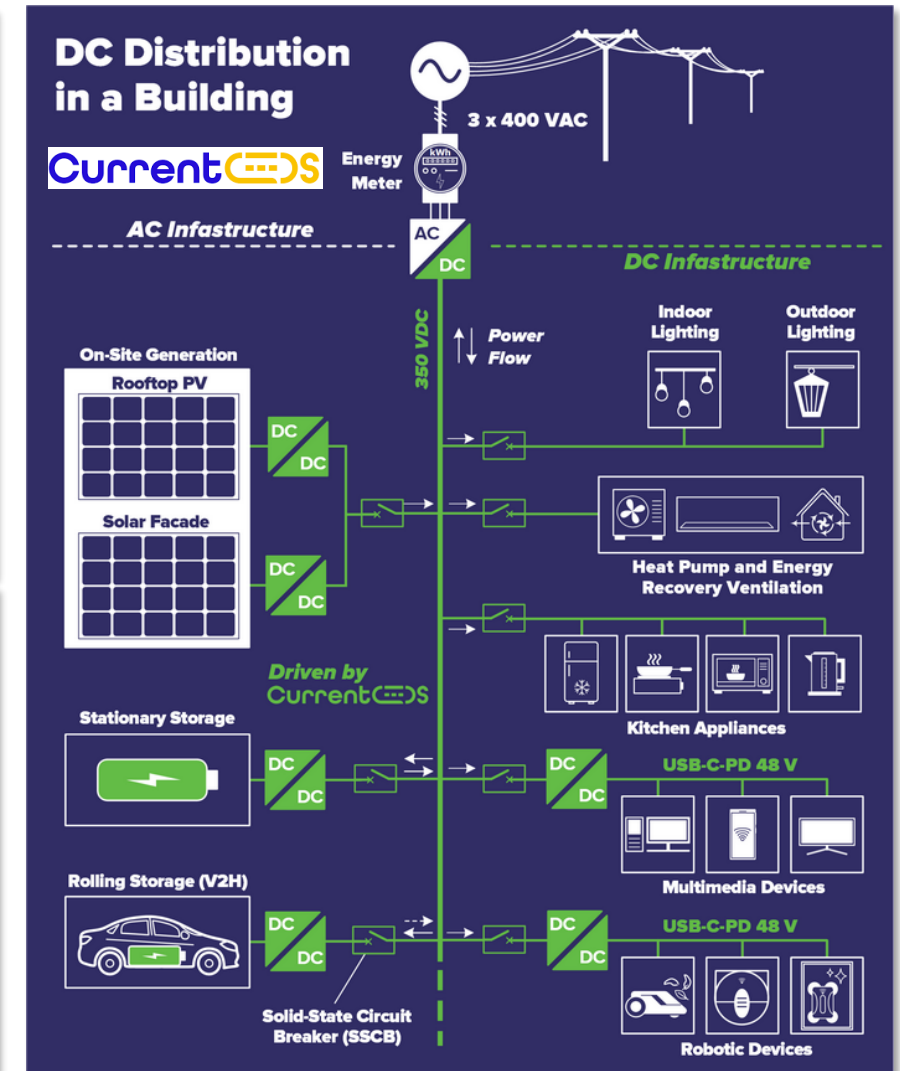


Book your visit via email: experience.center@dc.systems

DC TECHNOLOGY DEMONSTRATION FACILITIES (2)

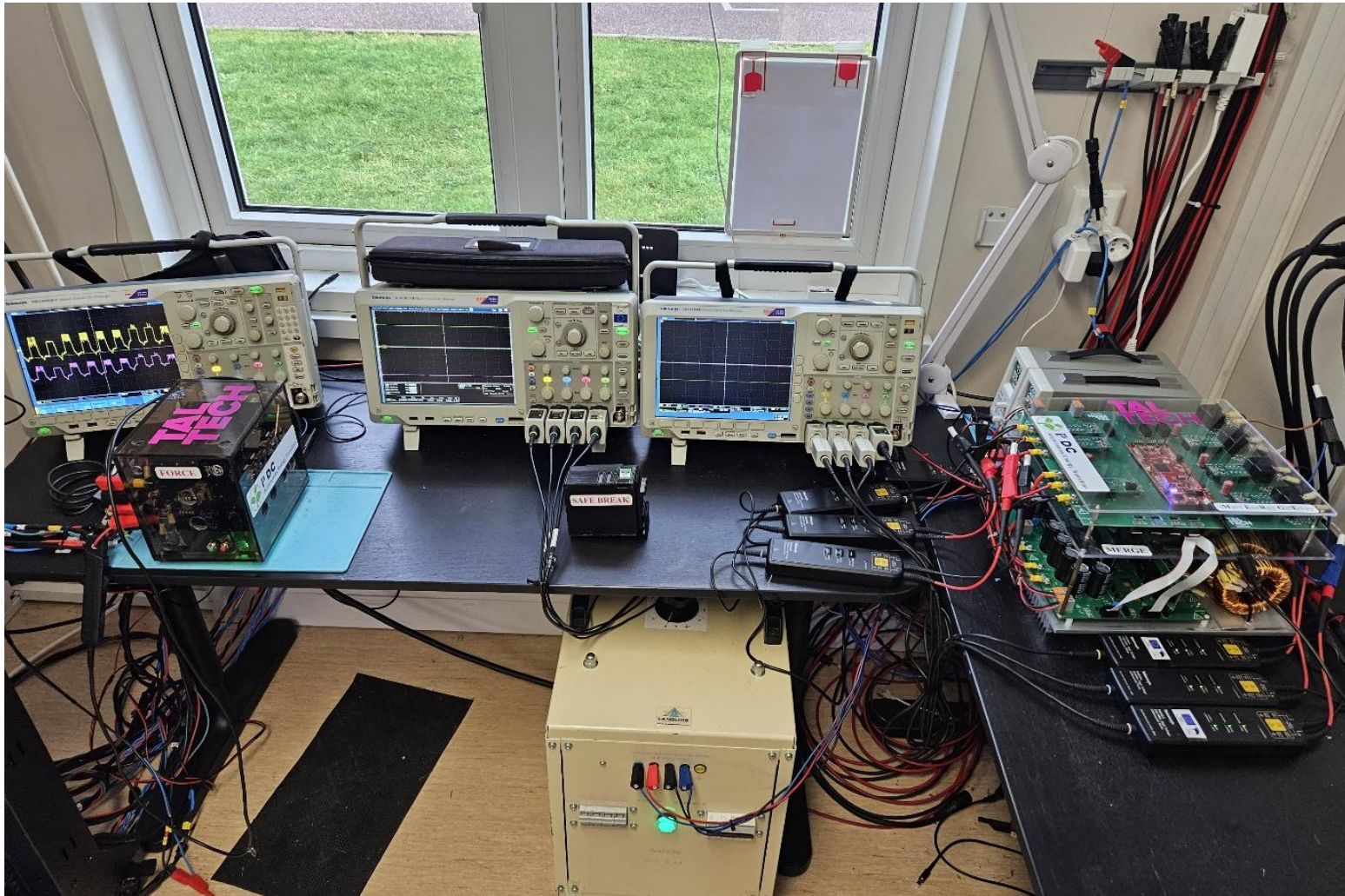
TALTECH RESIDENTIAL DC INNOVATION HUB (TALLINN, ESTONIA)

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OUR NOVEL TECHNOLOGIES UNDER TEST IN DC INNOHUB



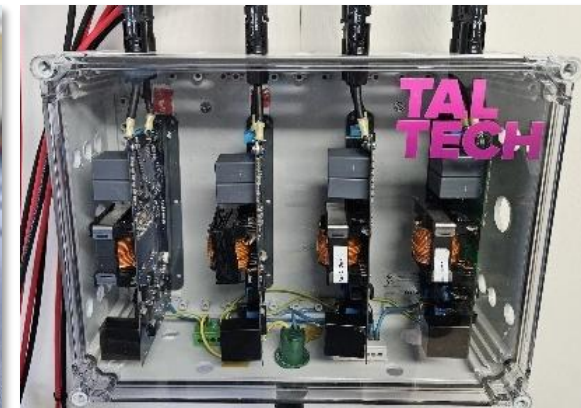
SAFEBREAK



MERGE



FORCE



FlexiVerter

*i*³ DC INITIATIVE: *inform inspire & innovate*



i³ DC

Accelerates Energy Transition

TAL TECH
POWER ELECTRONICS GROUP

IEEE
ESTONIA SECTION
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Estonian Research Council

Centre of Excellence in Energy Efficiency

**The 6th Estonian
DC Innovation Workshop
Shaping Estonia's DC Future**

The 5th Estonian DC Innovation Workshop
Boosting Energy Efficiency, Security & Resilience

November 27, 2024, TalTech – NRG Building – Room NRG-226, Ehitajate tee 5/10, 19086, Tallinn



CurrentCDS



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.W. Kolar, M. Malinowski, F. Blaabjerg, A. Rathore, etc.*
- *12 IES SYPA awards at \$1,500 USD each will be granted*
- *Entertaining social events for attendees, special events for students and WiE members*
- *Luncheons and coffee breaks*

IEEE PEMC 2026

22nd International Power Electronics and Motion Control Conference
Sept. 23–25, 2026 — Tallinn, Estonia

Power Electronics
and Motion Control
Conference



CALL FOR
PAPERS



IEEE PEMC is the biennial conference initiated by the Power Electronics and Motion Control (PEMC) Council, which has been standing strong for over 50 years since 1970. It is devoted to modern research topics of power electronics, control systems, electrical drives, robotics, and related topics. This exciting event brings together researchers and industry experts to share ideas and experiences on frontier technologies, breakthroughs, and innovative solutions and applications. It creates an opportunity to meet world-class scientists presenting **keynotes, tutorials, and invited papers**.

Join this event to be among the leaders of society's transformations towards sustainability!

MAIN TOPICS

- Power Electronics and Drives in Transportation
- Power Electronics in Future Power Grids

TECHNICAL TRACKS

- Power Electronics and Drives in Transportation
- Power Electronics in Power Grids
- Power Electronics in Electrical Energy and Heat Generation
- Power Electronics and Drives in Industry
- Power Supplies and Special Converters
- Semiconductor Devices
- Power Electronic Converter Design and Control
- Electrical Machines and Actuators
- Motion Control, Adjustable Speed Drives and Robotics
- Machine Learning in Power Electronics and Drives
- Sensors, Measurement & Observation Techniques
- Education and other related topics
- Multiphase Machines and Drives

SPECIAL SESSIONS

PEMC2026 invites special session proposals on **focused topics** within the conference, convened by 2-4 experts.

PAPER SUBMISSION

Prospective authors are invited to submit **full papers** in English, following instructions on the website. The conference proceedings will be submitted to **IEEE Xplore**.

TUTORIALS

PEMC2026 invites tutorial proposals on emerging topics from academic and industry experts. Companies are welcome to showcase their innovations at the exhibition!

VENUE

The conference will be held at the Original Sokos Hotel Viru.



IMPORTANT DATES

Tutorial proposal submission **1 Feb. 2026**
Special session proposal submission **1 Feb. 2026**
Full paper submission **1 Mar. 2026**
Notification of paper/tutorial acceptance **15 May 2026**
Final paper/tutorial materials submission **20 Jun. 2026**
Early bird registration fee **30 Jun. 2026**

<http://pemc2026.com/> — pemc2026@taltech.ee

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

DC:



Not this.



But this.



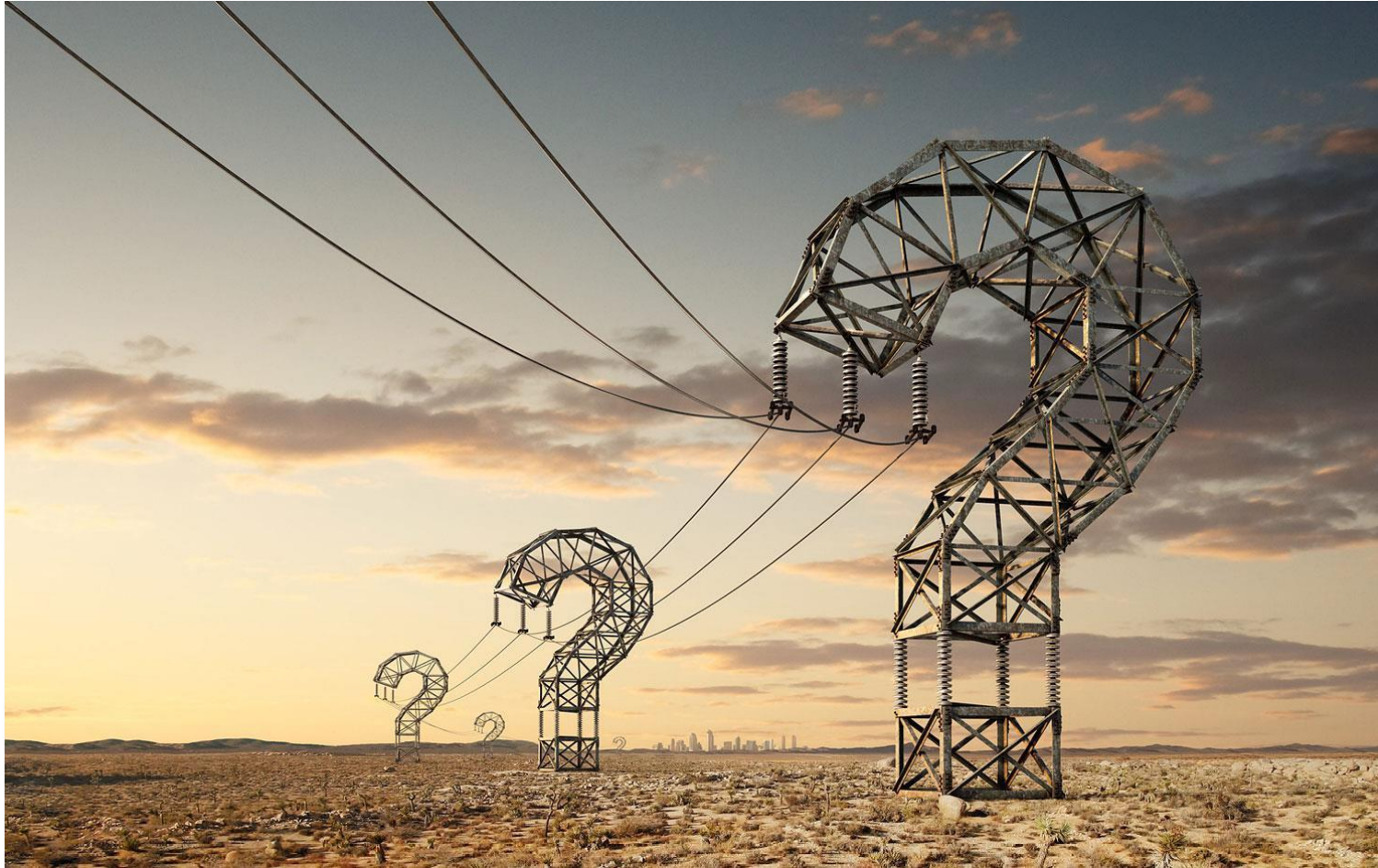
CALL FOR COLLABORATION!!!

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

Feel free to contact us at
i3dc@taltech.ee



QUESTIONS



– POWER ELECTRONICS GROUP –
Your Reliable Partner in Power Electronics

