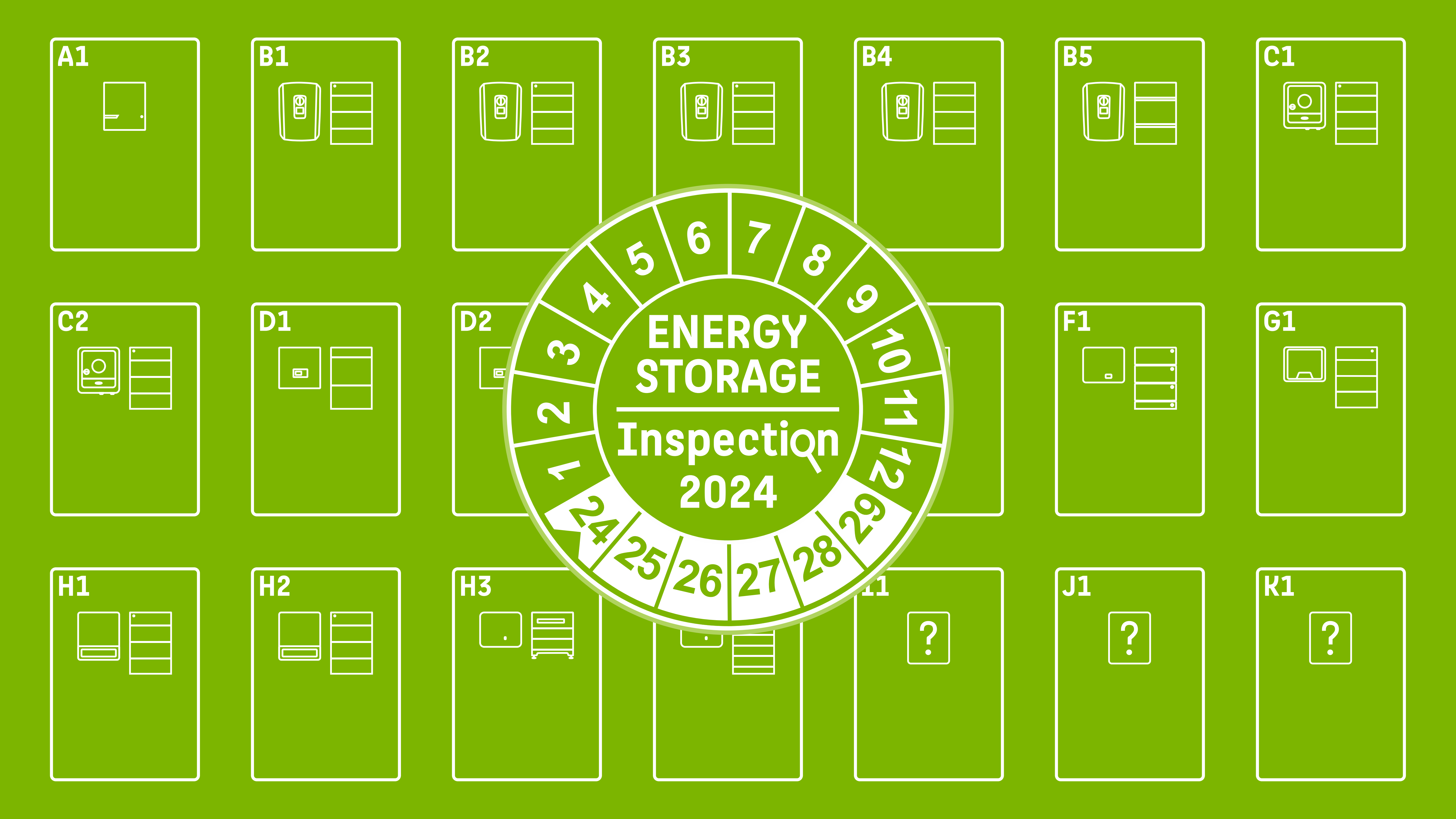

A1
B1
B2
B3
B4
B5
C1
C2
D1
D2
F1
G1
H1
H2
H3
J1
K1
ENERGY STORAGE
Inspection
2024
1 2 3 4 5 6 7 8 9 10 11 12
24 25 26 27 28 29

ENERGY STORAGE Inspection

Hochschule für Technik
und Wirtschaft Berlin

University of Applied Sciences

Supported by:

Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag

Research study

Energy Storage Inspection 2024

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Version

Version 1.0 (January 2024)

Web

solar.htw-berlin.de/inspektion

WINNERS OF 2024

20 PV-battery systems under study

10 kW class		5 kW class
RCT POWER Power Storage DC 10.0 and Power Battery 11.5	1	**RCT POWER** Power Storage DC 6.0 and Power Battery 7.6
ENERGY DEPOT Centurio 10 and DOMUS 2.5	2	**FRONIUS** Primo GEN24 6.0 Plus and **BYD** Battery-Box HVS 7.7
FRONIUS Symo GEN24 10.0 Plus and **BYD** Battery-Box HVS 10.2	3	**KOSTAL** PLENTICORE plus G2 5.5 and **BYD** Battery-Box HVS 7.7

ENERGY STORAGE Inspection

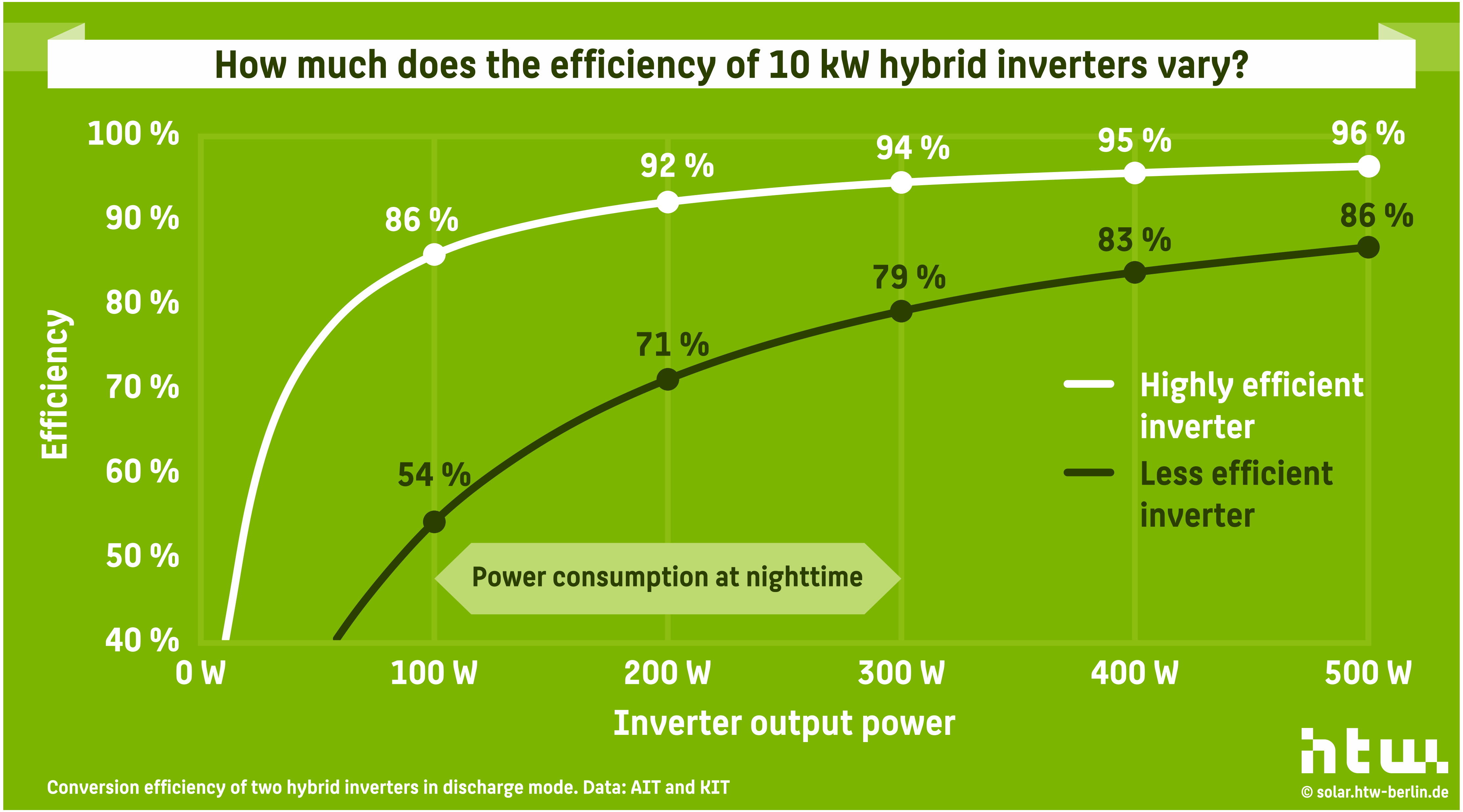
Test results based on the assessment with the SPI

The efficiency benchmarking is based on the System Performance Index SPI (5 kW) and SPI (10 kW).

ENERGY STORAGE Inspection 2024

Top performance		Worst performance
97.8 % VARTA	Battery efficiency	87.9 % ANONYMOUS
97.8 % RCT POWER	Inverter efficiency	91.2 % ANONYMOUS
0.2 s ENERGY DEPOT	Settling time	13.7 s ANONYMOUS
2 W VARTA	Standby power consumption	64 W ANONYMOUS

Inverter efficiency: Average efficiency during discharging, Standby power consumption in the discharged state.

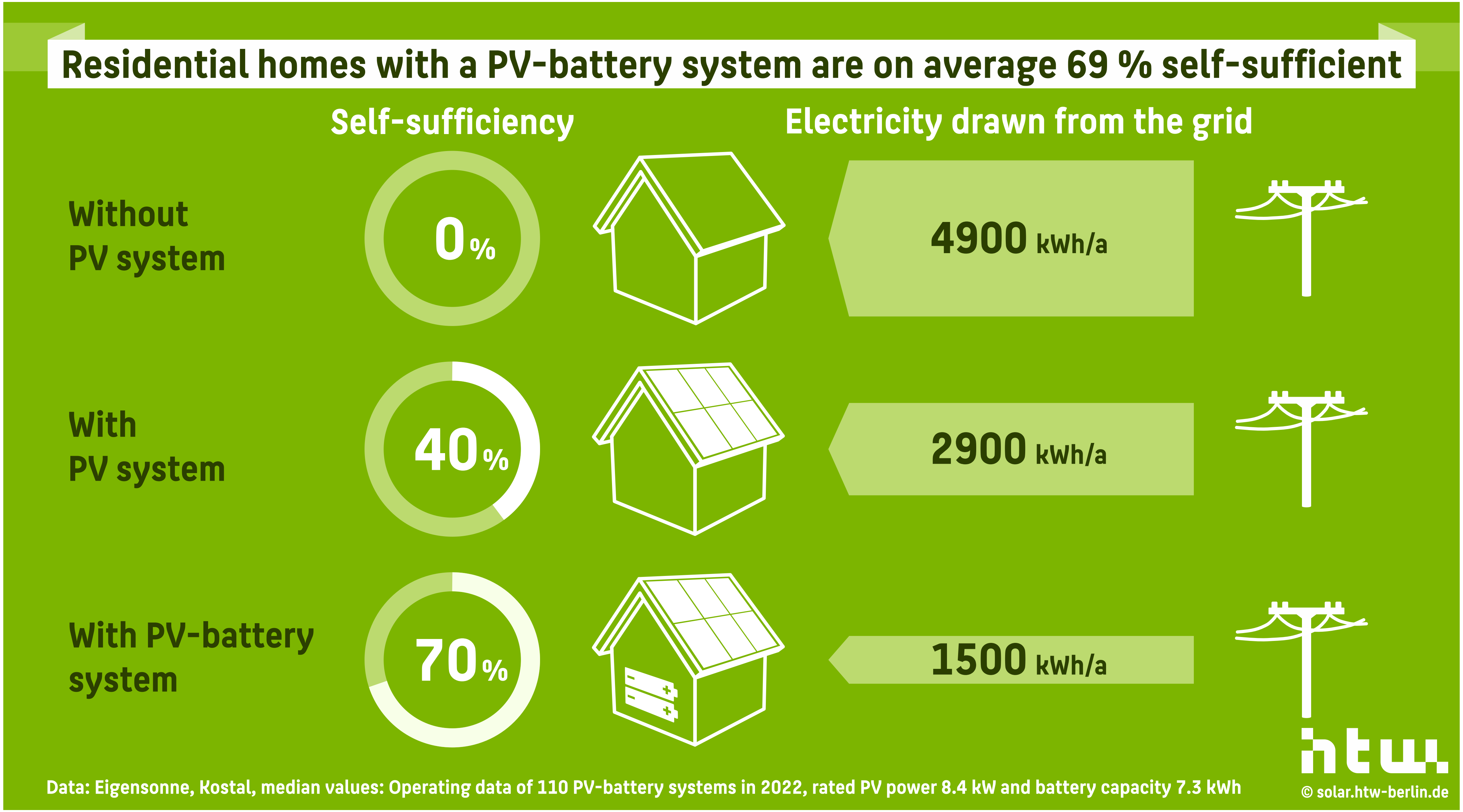

How much does the efficiency of 10 kW hybrid inverters vary?
100 %
90 %
80 %
70 %
60 %
50 %
40 %
Efficiency
0 W
100 W
200 W
300 W
400 W
500 W
Inverter output power
86 %
92 %
94 %
95 %
96 %
54 %
71 %
79 %
83 %
86 %
Highly efficient inverter
Less efficient inverter
Power consumption at nighttime
Conversion efficiency of two hybrid inverters in discharge mode. Data: AIT and KIT
© solar.htw-berlin.de

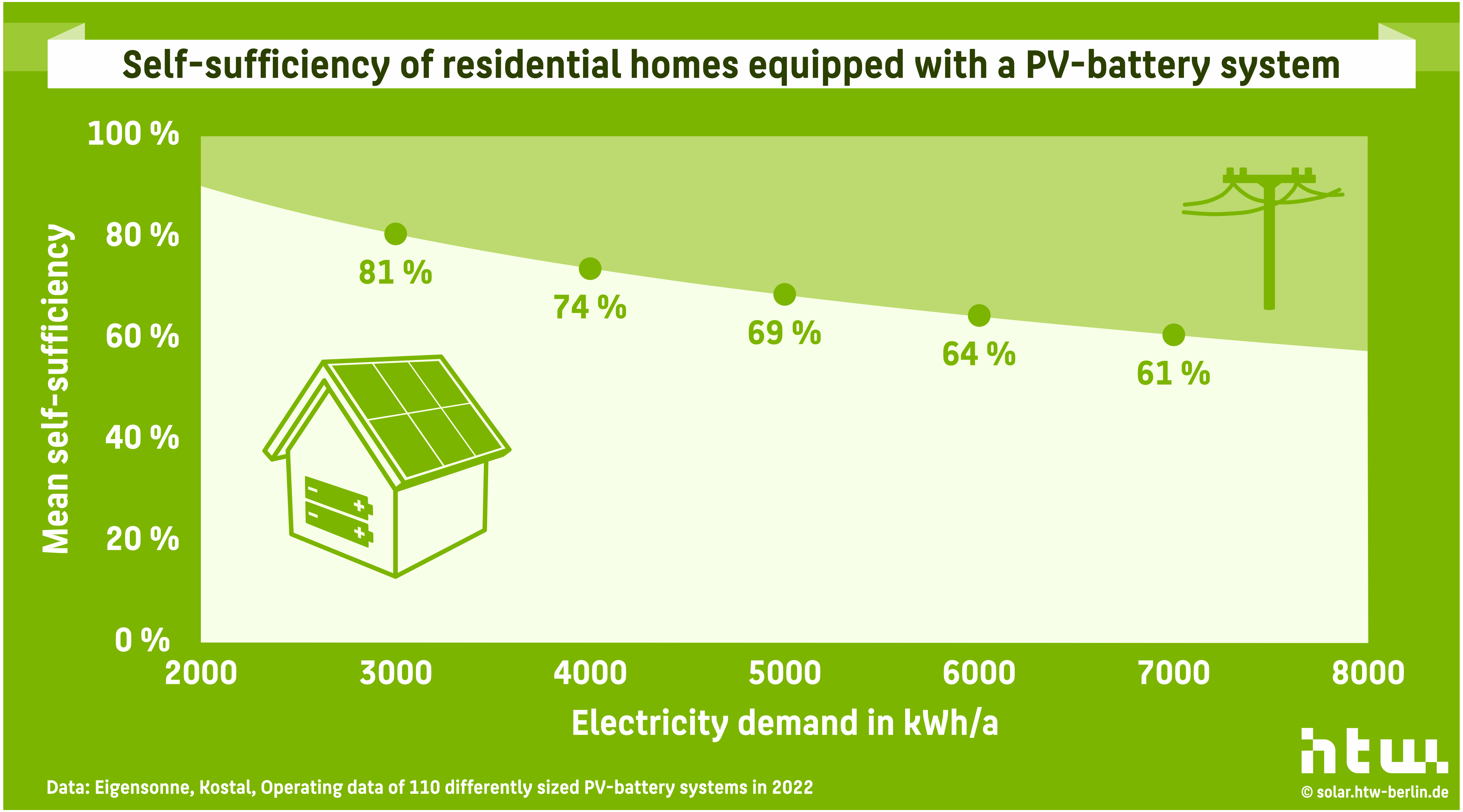
Why a high inverter efficiency at partial load matters

	Efficiency	Battery		Losses		Output
		DC				AC
Highly efficient inverter	92 %	217 W	–	17 W	=	200 W
Less efficient inverter	71 %	282 W	–	82 W	=	200 W

⚠ The lower the efficiency, the shorter the discharge time of the battery.

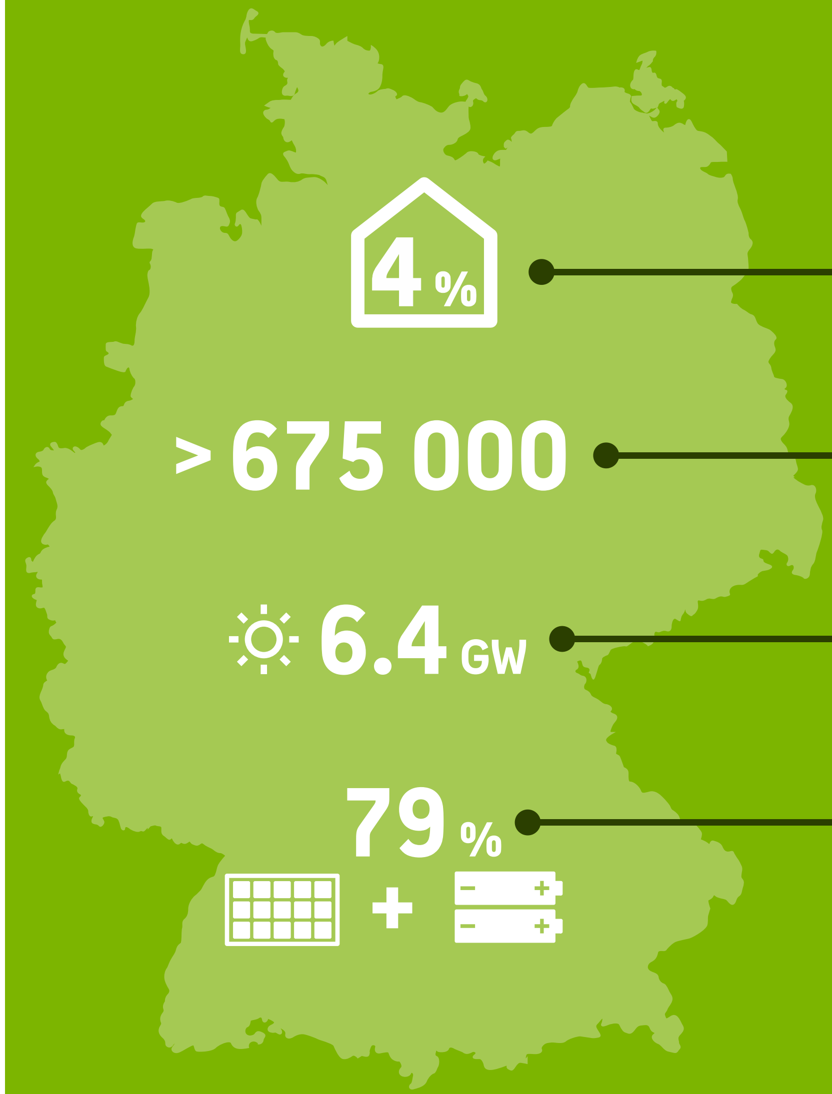
Efficiency of two hybrid inverters in discharge mode with an output power of 200 W. Data: AIT and KIT


Residential homes with a PV-battery system are on average 69 % self-sufficient
Self-sufficiency
Electricity drawn from the grid
Without
PV system
0%
4900 kWh/a
With
PV system
40%
2900 kWh/a
With PV-battery
system
70%
1500 kWh/a
Data: Eigensonne, Kostal, median values: Operating data of 110 PV-battery systems in 2022, rated PV power 8.4 kW and battery capacity 7.3 kWh
© solar.htw-berlin.de



The depicted graph is based on the results of a regression analysis based on the operating data of 110 PV-battery systems.

The Residential PV Market 2023
in Germany



In 2023, 4 % of all single- and two-family homes had a new PV system installed in 2023.

More than 675 000 new PV installations had a rated power between 2 kW and 20 kW.

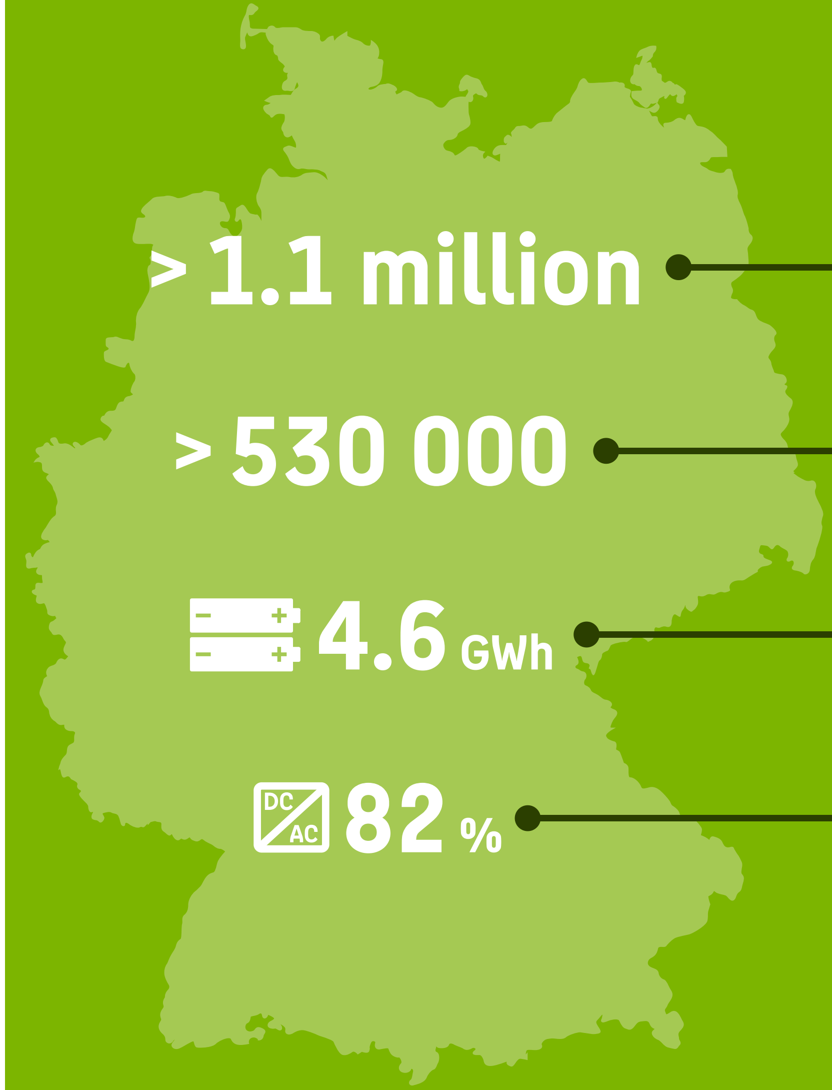
Newly installed PV capacity in the residential segment totaled 6.4 GW.

Approximately 79 % of all new PV installations were combined with a battery storage system.

Data: German Federal Network Agency (PV systems with a rated power between 2 kW and 20 kW), as of January 26th, 2024

The Home Storage Market 2023

in Germany



By the end of 2023, more than 1.1 million battery systems had been deployed in German homes.

More than 530 000 battery systems were installed in 2023: a 153 % increase compared to 2022.

The cumulative storage capacity of the newly installed battery storage systems was 4.6 GWh.

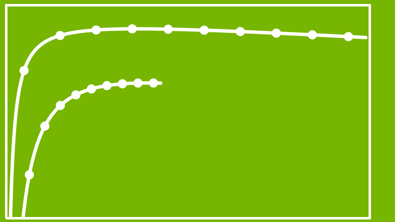
82 % of the newly installed batteries were paired with a hybrid inverter.

Data: German Federal Network Agency (battery systems with a capacity under 20 kWh and a power of up to 20 kW), as of January 26th, 2024

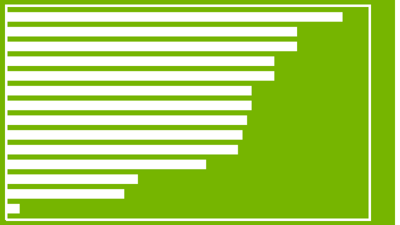
Main topics of the Energy Storage Inspection 2024

1. Analysis of the German market for residential PV-battery systems

2. Comparison of the system properties based on the test reports according to the Efficiency Guideline



3. Simulation-based assessment of the PV-battery systems with the System Performance Index (SPI)



4. Comparison of the operating data of PV-battery systems

Main topics of the Energy Storage Inspection 2024

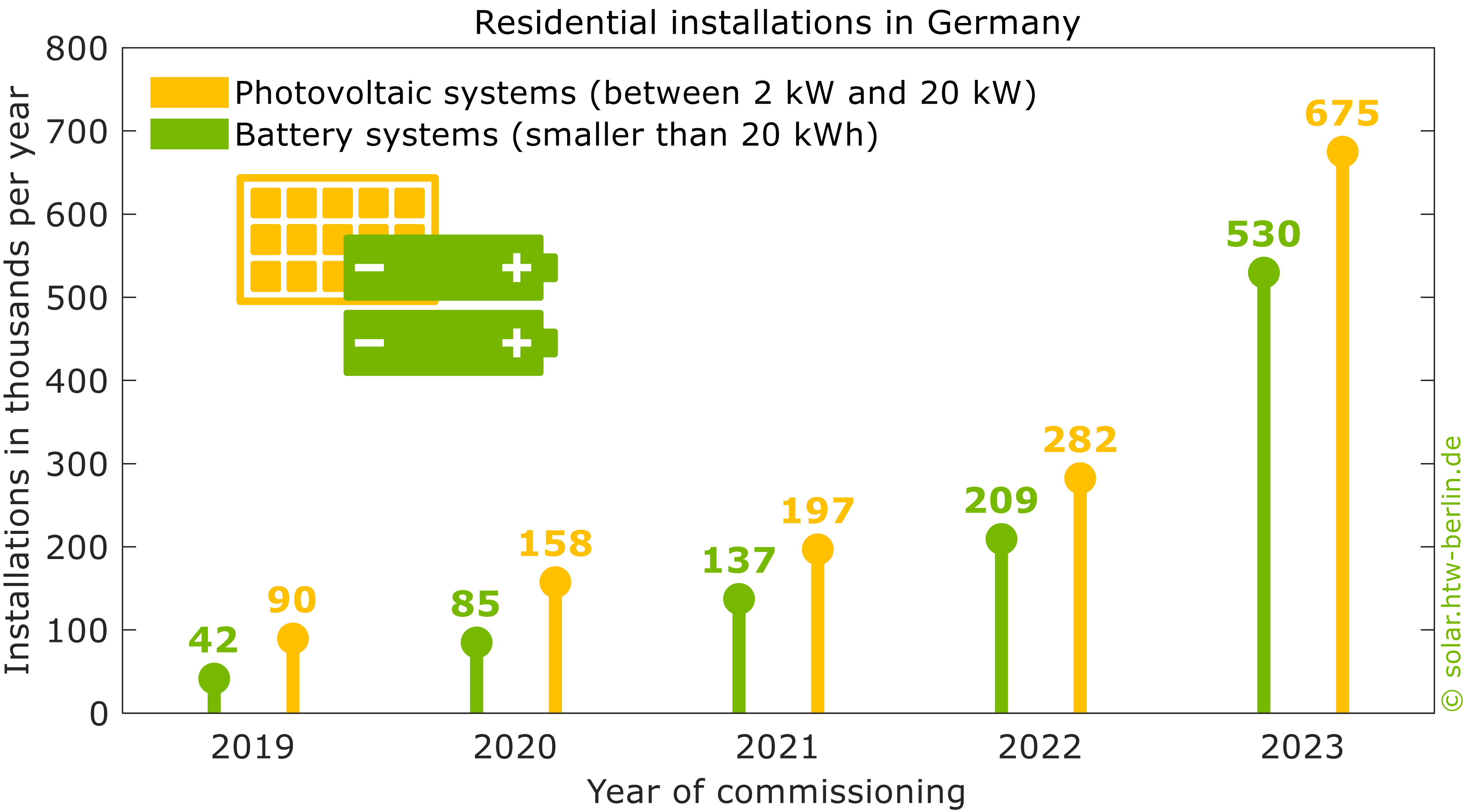
1 Analysis of the German market for residential PV-battery systems

2 Comparison of the system properties based on the test reports according to the Efficiency Guideline

3 Simulation-based assessment of the PV-battery systems with the System Performance Index (SPI)

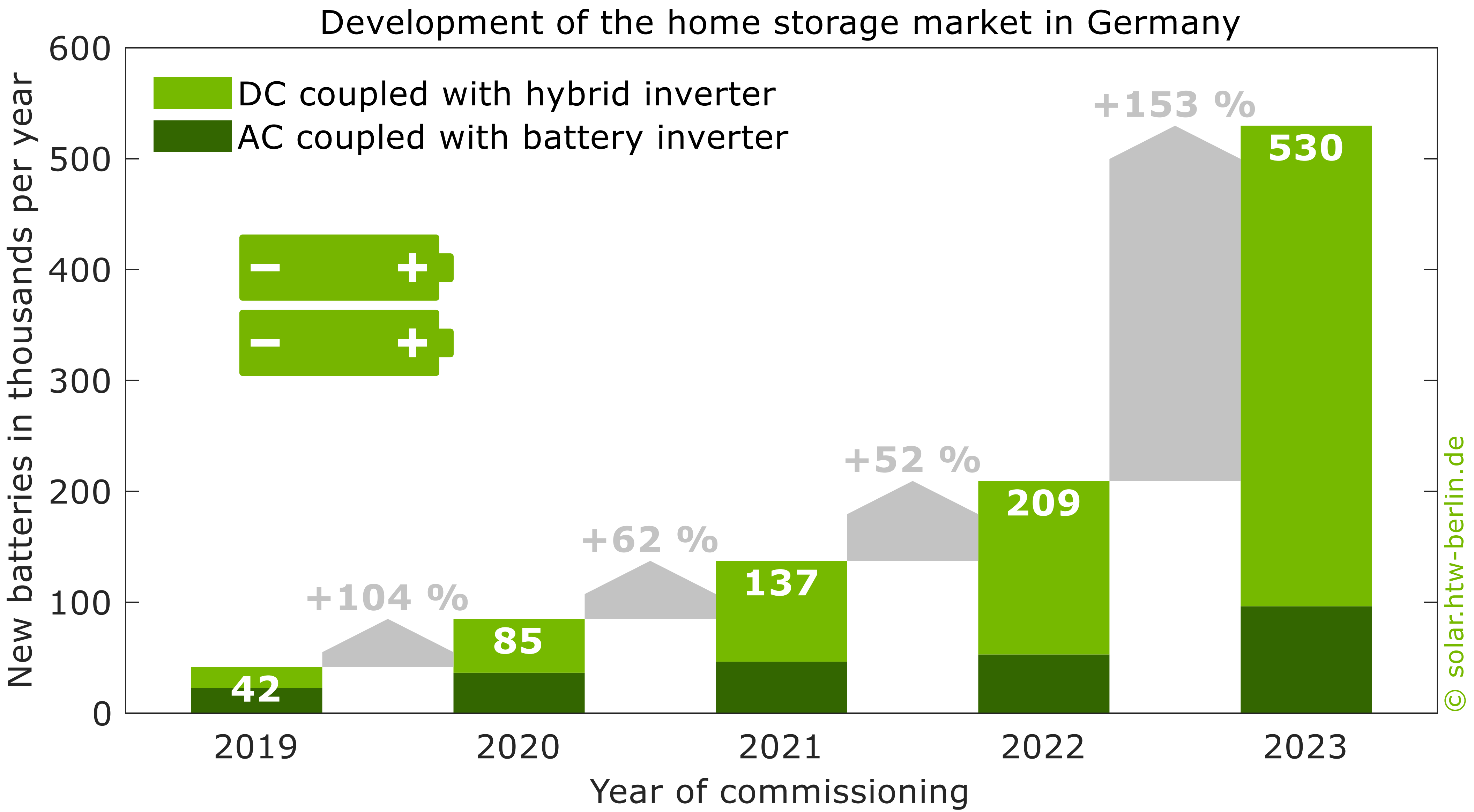
4 Comparison of the operating data of PV-battery systems

Development of the PV-battery market in Germany



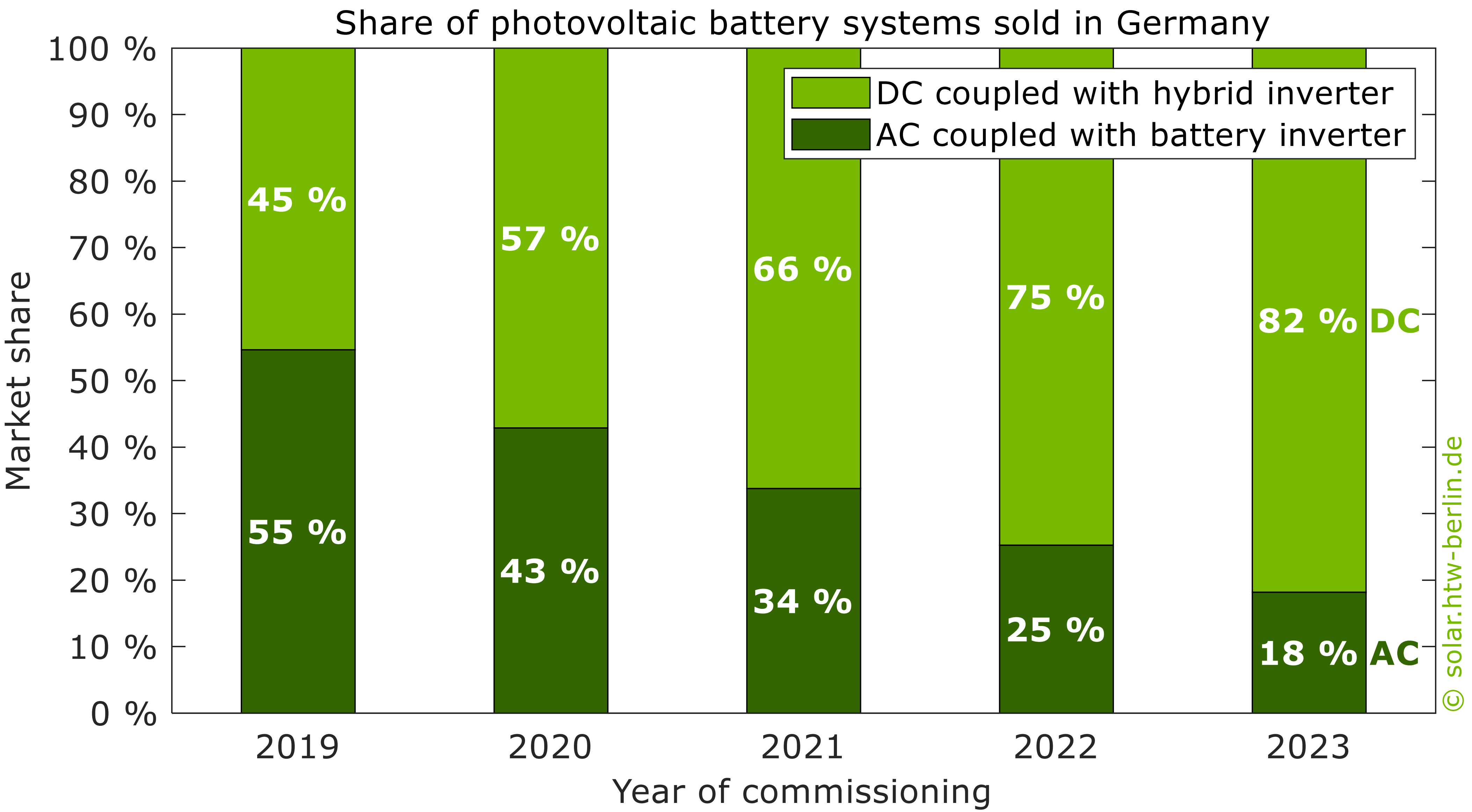
Data: German Federal Network Agency

Rise in the number of annually deployed battery systems



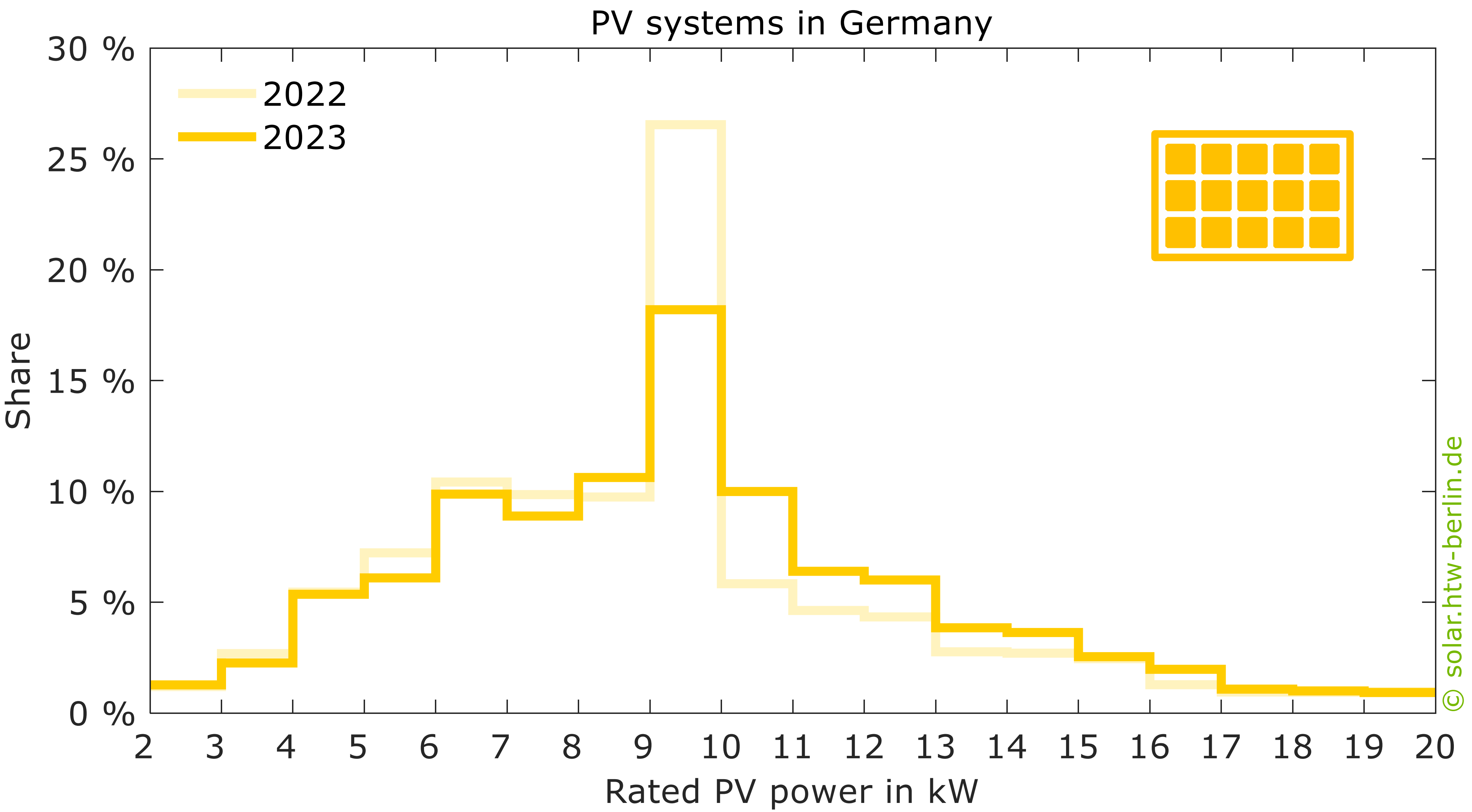
Data: German Federal Network Agency, battery systems smaller than 20 kWh and 20 kW

System topologies of the PV-battery systems in Germany



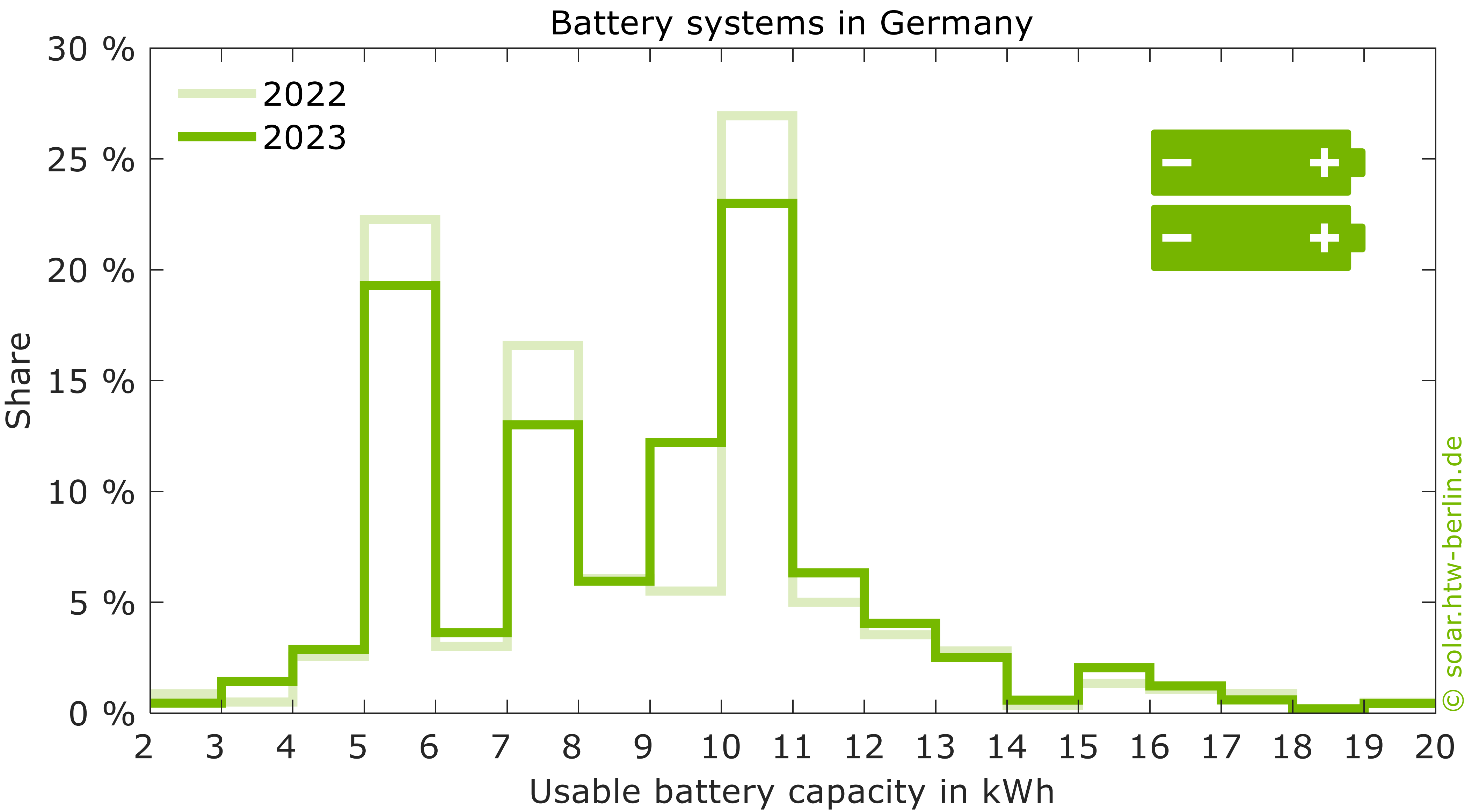
Data: German Federal Network Agency, battery systems smaller than 20 kWh and 20 kW

Rated power of the newly installed PV systems up to 20 kW



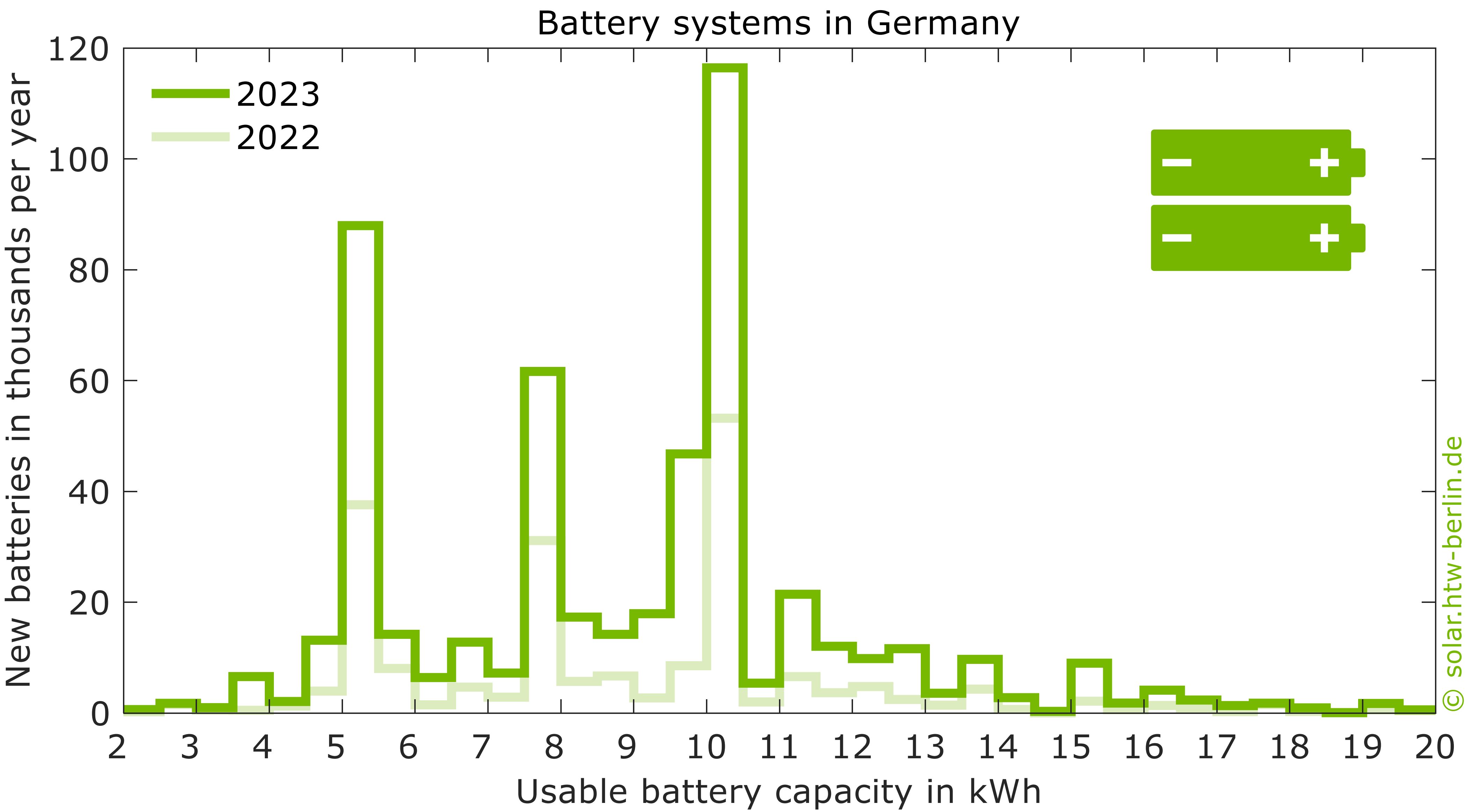
Data: German Federal Network Agency, PV systems between 2 kW and 20 kW, class width: 1 kW

Usable battery capacity of the battery systems up to 20 kWh



Data: German Federal Network Agency, battery systems smaller than 20 kWh and 20 kW, class width: 1 kWh

Distribution of the usable battery capacity up to 20 kWh

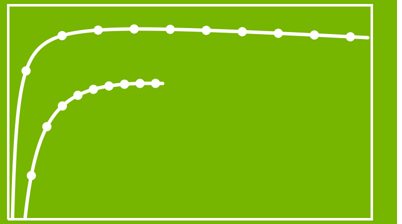


Data: German Federal Network Agency, battery systems smaller than 20 kWh and 20 kW, class width: 0.5 kWh

Main topics of the Energy Storage Inspection 2024

1 Analysis of the German market for residential PV-battery systems

2 Comparison of the system properties based on the test reports according to the Efficiency Guideline



3 Simulation-based assessment of the PV-battery systems with the System Performance Index (SPI)

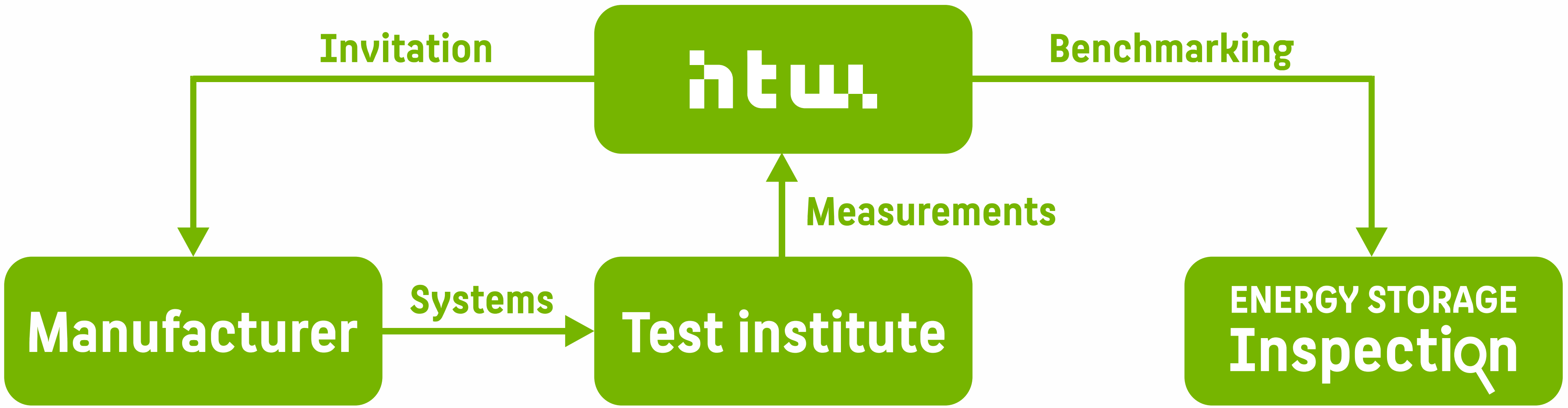
4 Comparison of the operating data of PV-battery systems

Participants of the Energy Storage Inspection 2024

- For the 7th time in a row, all manufacturers of systems or components for storing solar electricity in residential buildings were invited to take part in the **Energy Storage Inspection 2024**.
- **12 manufacturers** took part in the Energy Storage Inspection 2024 with laboratory measurements from a total of **18 systems**.
- One manufacturer decided to **participate anonymously**.
- Two PV-battery systems were purchased **independently** and evaluated also.

Analysis of system properties according to the Efficiency Guideline

- Laboratory tests were conducted by independent testing institutes in accordance with the "Efficiency Guideline for PV Storage Systems”.
- To each analyzed system a **system abbreviation** (e.g. A1) was assigned
- The batteries of the **AC-coupled systems** A1 to B1 are equipped with battery inverters. The **DC-coupled systems** B2 to K1 have so called hybrid inverters.
- Details about the **methodology** can be found in the Energy Storage Inspections 2018 and 2023.



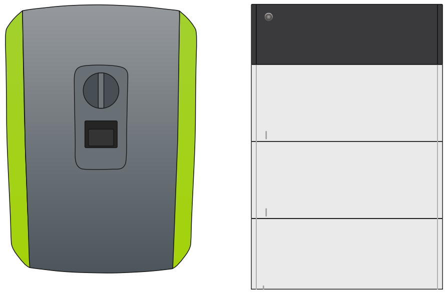
Analyzed systems in the Energy Storage Inspection 2024

A1 ENERGY STORAGE Inspection 2024

VARTA pulse neo 6

Battery connection	AC
Battery capacity	5.8 kWh
Discharge power	2.3 kW
PV output power	-
Efficiency class	B

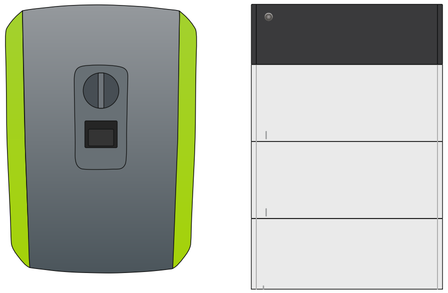
B1 ENERGY STORAGE Inspection 2024



KOSTAL PLENTICORE BI G2 10/26 and BYD Battery-Box Premium HVS 12.8

Battery connection	AC
Battery capacity	12.0 kWh
Discharge power	10.1 kW
PV output power	-
Efficiency class	B

B2 ENERGY STORAGE Inspection 2024

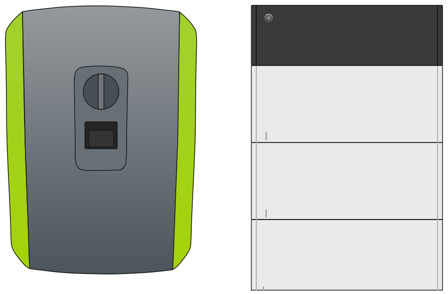


KOSTAL PLENTICORE plus G2 5.5 and BYD Battery-Box Premium HVS 7.7

Battery connection	DC
Battery capacity	7.1 kWh
Discharge power	3.8 kW
PV output power	5.5 kW
Efficiency class	B

Analyzed systems in the Energy Storage Inspection 2024

B3 ENERGY STORAGE Inspection 2024



KOSTAL PLENTICORE plus G2 10 and BYD Battery-Box Premium HVS 12.8

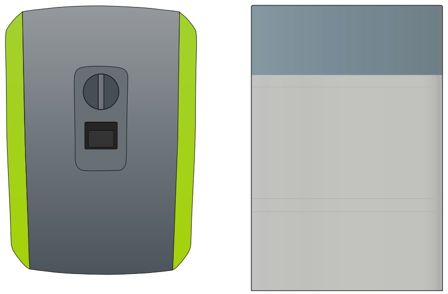
Battery connection	DC
Battery capacity	11.9 kWh
Discharge power	6.3 kW
PV output power	10.0 kW
Efficiency class	A

B4 ENERGY STORAGE Inspection 2024

KOSTAL PLENTICORE plus G2 10 and DYNESS Tower T14

Battery connection	DC
Battery capacity	13.5 kWh
Discharge power	4.8 kW
PV output power	10.0 kW
Efficiency class	B

B5 ENERGY STORAGE Inspection 2024

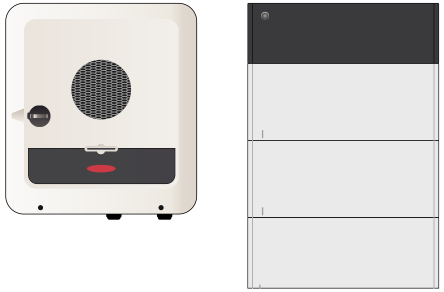


KOSTAL PLENTICORE plus G2 10 and PYLONTECH Force H2

Battery connection	DC
Battery capacity	13.6 kWh
Discharge power	4.8 kW
PV output power	10.0 kW
Efficiency class	B

Analyzed systems in the Energy Storage Inspection 2024

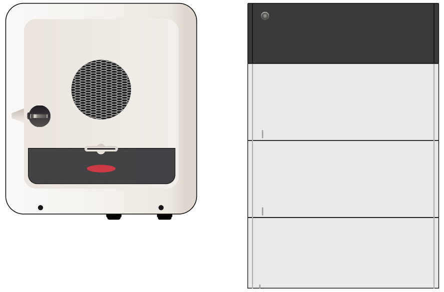
C1 ENERGY STORAGE Inspection 2024



FRONIUS Primo GEN24 6.0 Plus and BYD Battery-Box Premium HVS 7.7

Battery connection	DC
Battery capacity	7.4 kWh
Discharge power	5.8 kW
PV output power	6.1 kW
Efficiency class	A

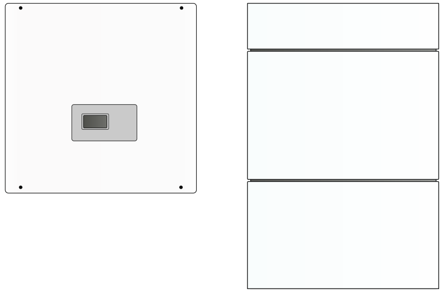
C2 ENERGY STORAGE Inspection 2024



FRONIUS Symo GEN24 10.0 Plus and BYD Battery-Box Premium HVS 10.2

Battery connection	DC
Battery capacity	9.9 kWh
Discharge power	8.9 kW
PV output power	10.2 kW
Efficiency class	A

D1 ENERGY STORAGE Inspection 2024

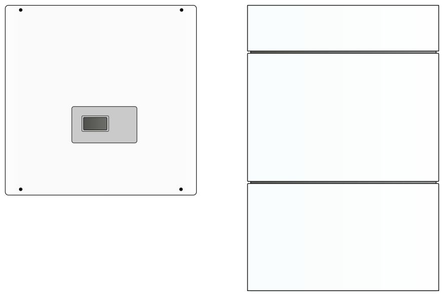


RCT POWER Power Storage DC 6.0 and Power Battery 7.6

Battery connection	DC
Battery capacity	7.0 kWh
Discharge power	5.9 kW
PV output power	5.9 kW
Efficiency class	A

Analyzed systems in the Energy Storage Inspection 2024

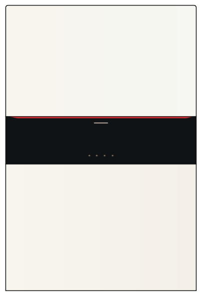
D2 ENERGY STORAGE Inspection 2024



RCT POWER Power Storage DC 10.0 and Power Battery 11.5

Battery connection	DC
Battery capacity	10.6 kWh
Discharge power	9.9 kW
PV output power	10.0 kW
Efficiency class	A

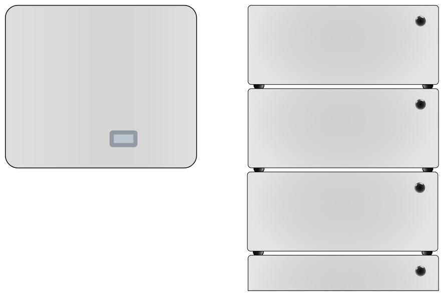
E1 ENERGY STORAGE Inspection 2024



VIESSMANN Vitocharge VX3 Typ 4.6A8

Battery connection	DC
Battery capacity	7.9 kWh
Discharge power	3.6 kW
PV output power	4.5 kW
Efficiency class	B

F1 ENERGY STORAGE Inspection 2024

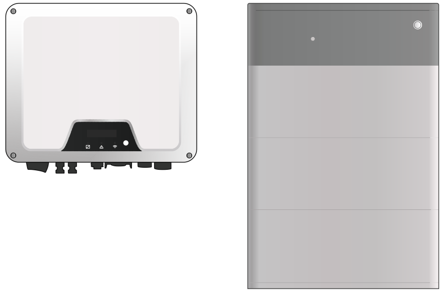


ENERGY DEPOT Centurio 10 und DOMUS 2.5

Battery connection	DC
Battery capacity	15.1 kWh
Discharge power	7.5 kW
PV output power	10.3 kW
Efficiency class	A

Analyzed systems in the Energy Storage Inspection 2024

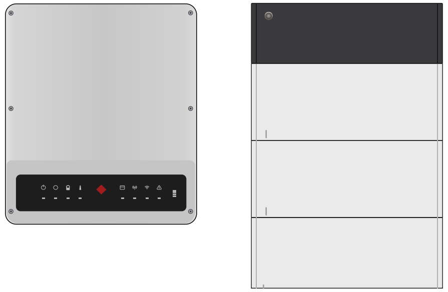
G1 ENERGY STORAGE Inspection 2024



HYPONTECH HHT-12000 und HBP-H15

Battery connection	DC
Battery capacity	13.3 kWh
Discharge power	11.9 kW
PV output power	11.7 kW
Efficiency class	B

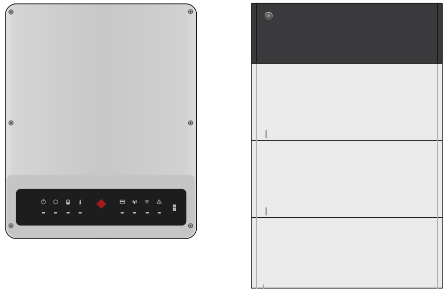
H1 ENERGY STORAGE Inspection 2024



GOODWE GW5000-EH and BYD Battery-Box Premium HVS 7.7

Battery connection	DC
Battery capacity	7.3 kWh
Discharge power	4.9 kW
PV output power	5.0 kW
Efficiency class	B

H2 ENERGY STORAGE Inspection 2024

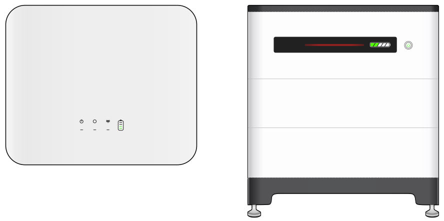


GOODWE GW10K-ET and BYD Battery-Box Premium HVS 12.8

Battery connection	DC
Battery capacity	12.2 kWh
Discharge power	10.0 kW
PV output power	10.0 kW
Efficiency class	B

Analyzed systems in the Energy Storage Inspection 2024

H3 ENERGY STORAGE Inspection 2024



GOODWE GW6000-ET-20 and LX F6.6-H

Battery connection	DC
Battery capacity	6.5 kWh
Discharge power	4.9 kW
PV output power	6.0 kW
Efficiency class	C

H4 ENERGY STORAGE Inspection 2024

GOODWE GW10K-ET-20 and LX F16.0-H-20

Battery connection	DC
Battery capacity	15.5 kWh
Discharge power	10.0 kW
PV output power	10.0 kW
Efficiency class	A

I1 ENERGY STORAGE Inspection 2024

DC-coupled system from an anonymous participating manufacturer

Battery connection	DC
Battery capacity	15.5 kWh
Discharge power	8.5 kW
PV output power	10.0 kW
Efficiency class	D

Analyzed systems in the Energy Storage Inspection 2024

J1 ENERGY STORAGE Inspection 2024

DC-coupled system that was purchased independently

Battery connection	DC
Battery capacity	8.9 kWh
Discharge power	4.3 kW
PV output power	9.8 kW
Efficiency class	D

K1 ENERGY STORAGE Inspection 2024

DC-coupled system that was purchased independently

Battery connection	DC
Battery capacity	9.8 kWh
Discharge power	4.8 kW
PV output power	10.0 kW
Efficiency class	G

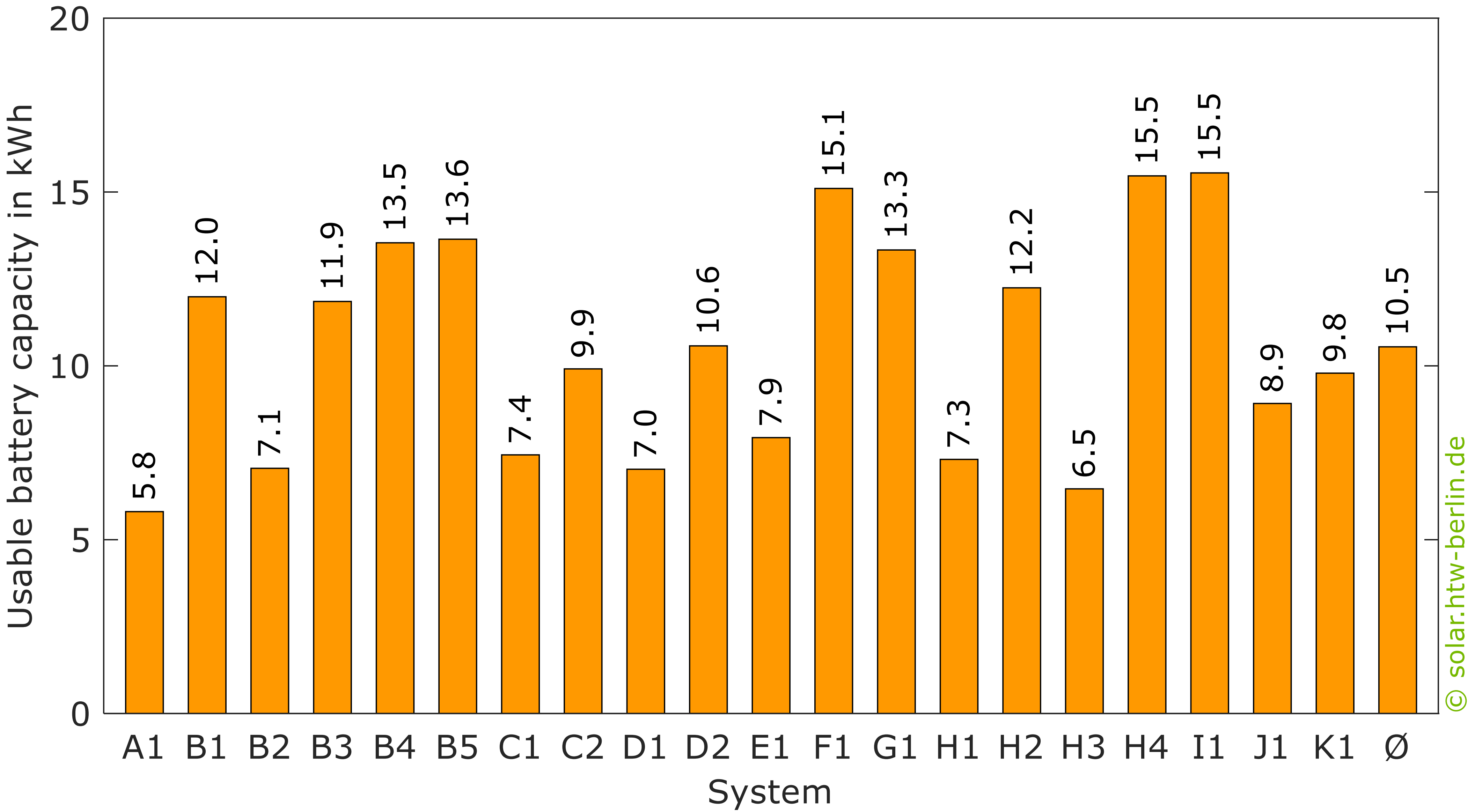
Attribution of the system abbreviations

System	Product name
A1	VARTA pulse neo 6
B1	KOSTAL PLENTICORE BI G2 10/26 and BYD Battery-Box Premium HVS 12.8
B2	KOSTAL PLENTICORE plus G2 5.5 and BYD Battery-Box Premium HVS 7.7
B3	KOSTAL PLENTICORE plus G2 10 and BYD Battery-Box Premium HVS 12.8
B4	KOSTAL PLENTICORE plus G2 10 and DYNESS Tower T14
B5	KOSTAL PLENTICORE plus G2 10 and PYLONTECH Force H2
C1	FRONIUS Primo GEN24 6.0 Plus and BYD Battery-Box Premium HVS 7.7
C2	FRONIUS Symo GEN24 10.0 Plus and BYD Battery-Box Premium HVS 10.2
D1	RCT POWER Power Storage DC 6.0 and Power Battery 7.6
D2	RCT POWER Power Storage DC 10.0 and Power Battery 11.5

Attribution of the system abbreviations

System	Product name
E1	VIESSMANN Vitocharge VX3 Typ 4.6A8
F1	ENERGY DEPOT Centurio 10 and DOMUS 2.5
G1	HYPONTECH HHT-12000 and HBP-H15
H1	GOODWE GW5000-EH and BYD Battery-Box Premium HVS 7.7
H2	GOODWE GW10K-ET and BYD Battery-Box Premium HVS 12.8
H3	GOODWE GW6000-ET-20 and LX F6.6-H
H4	GOODWE GW10K-ET-20 and LX F16.0-H-20
I1	DC-coupled system of an anonymously participating manufacturer
J1	DC-coupled system, independently purchased
K1	DC-coupled system, independently purchased

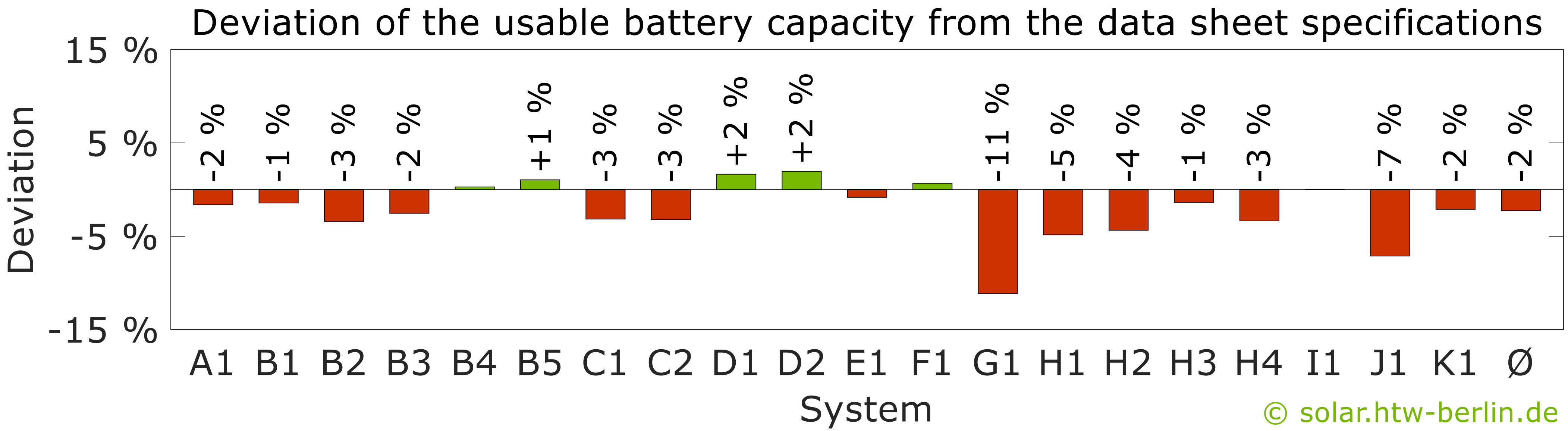
Usable battery capacity of the analyzed systems



Systems D1, D2, H3 and H4: Due to a temperature-induced derating, the test could not be run at 100 % of the nominal power.

Comparison of data sheet specifications to measured values

- For 15 of the 20 systems tested, **lower usable storage capacities** were determined in the laboratory test than were declared on the data sheet.
- The specified **depth of discharge** to protect against deep discharge is often the reason why the measured values are lower than the data sheet values.
- The usable storage capacity of the system G1 is **1.7 kWh (11 %)** lower than the value specified on the data sheet.

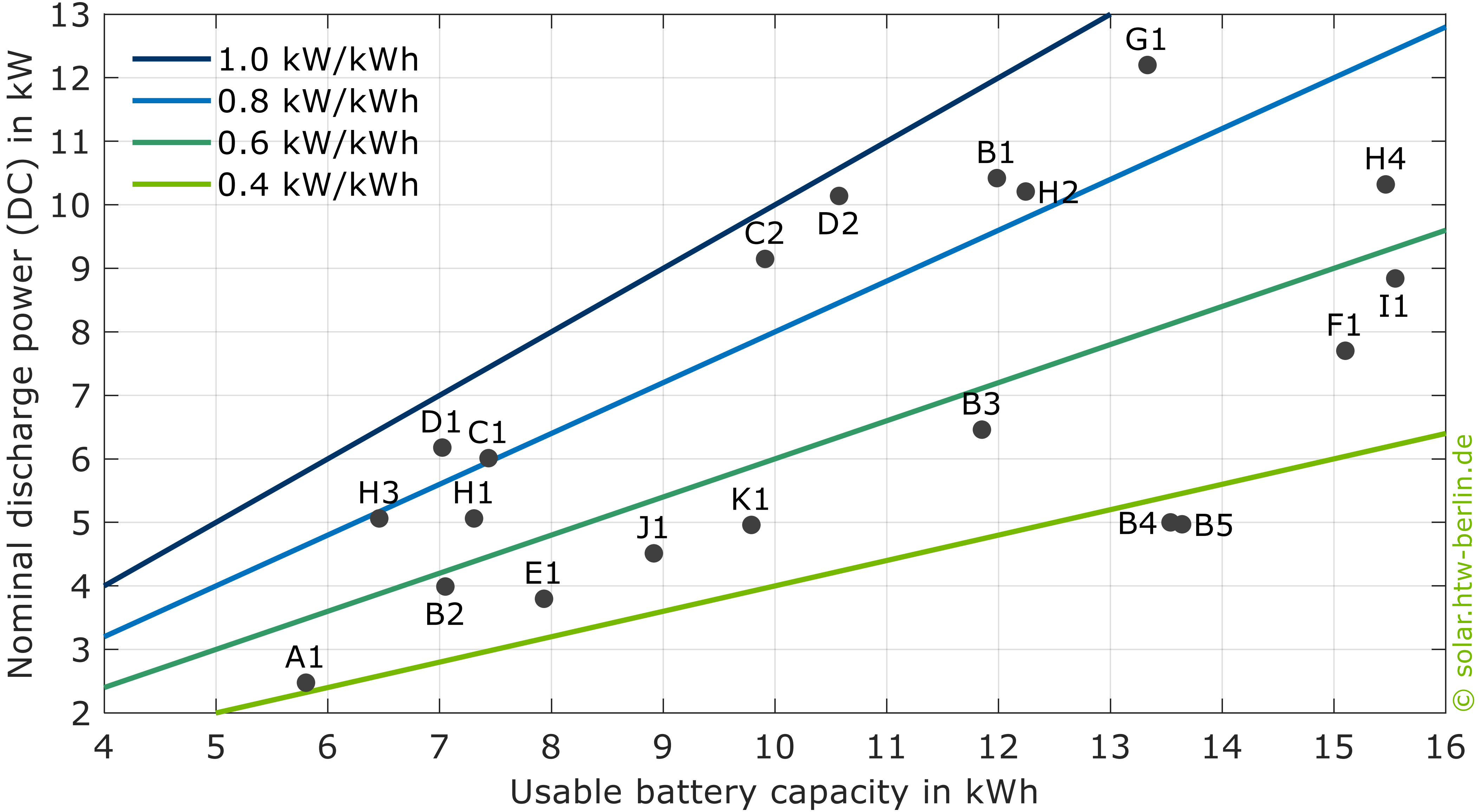


Nominal output power of the DC-coupled systems

- In practice, the ratio of inverter output power to PV generator power is often between 80 % and 90 %.
- In DC-coupled systems, the so-called **PV rated output power** limits the power output of the PV-battery system.
- Of the 18 systems with **hybrid inverters**, 12 can deliver a nominal AC power of between 9.8 kW and 11.7 kW.

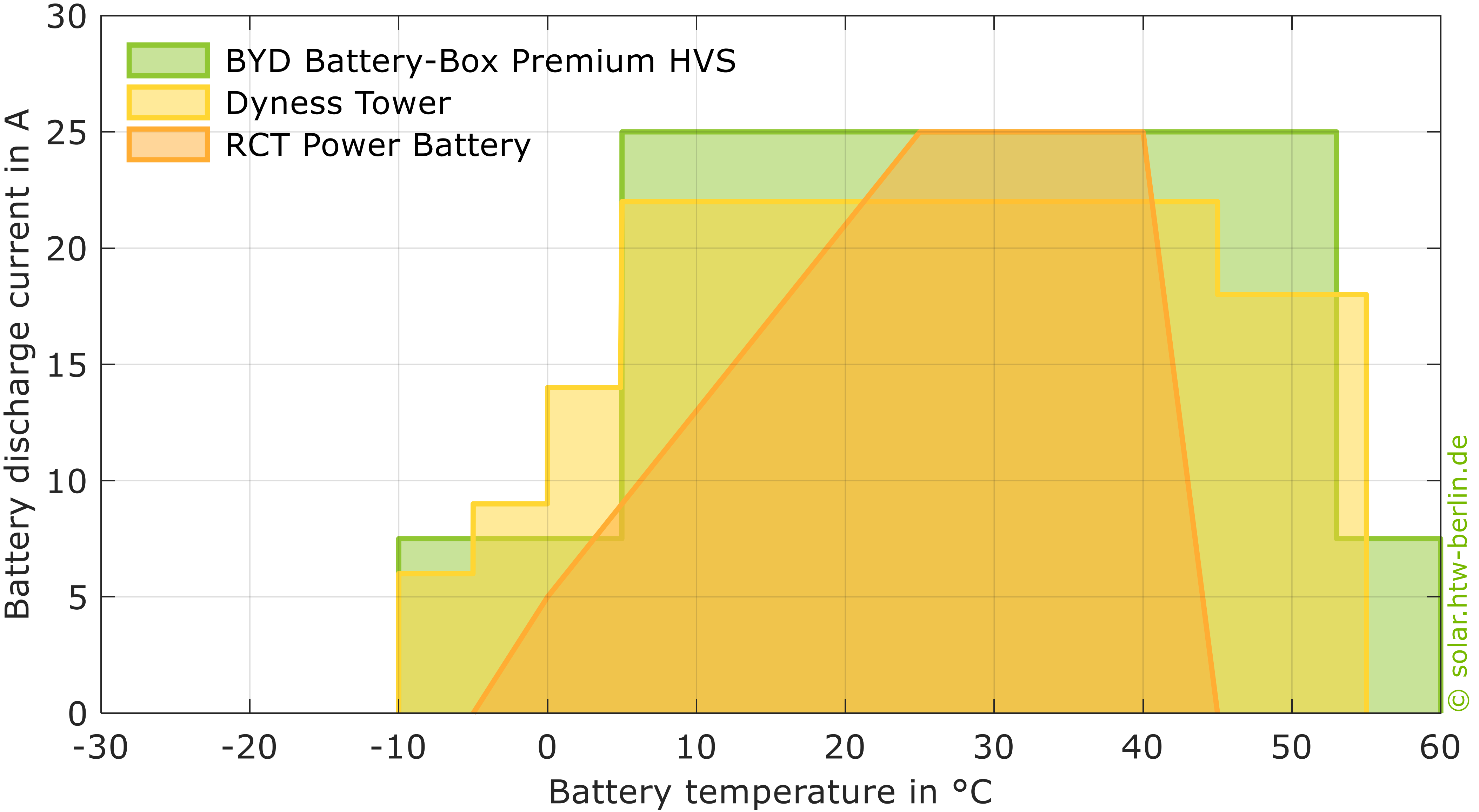
System	B2	B3	B4	B5	C1	C2	D1	D2	E1
Power in kW	5.5	10.0	10.0	10.0	6.1	10.2	5.9	10.0	4.5
System	**F1**	**G1**	**H1**	**H2**	**H3**	**H4**	**I1**	**J1**	**K1**
Power in kW	10.3	11.7	5.0	10.0	6.0	10.0	10.0	9.8	10.0

Nominal discharge power of the analyzed systems



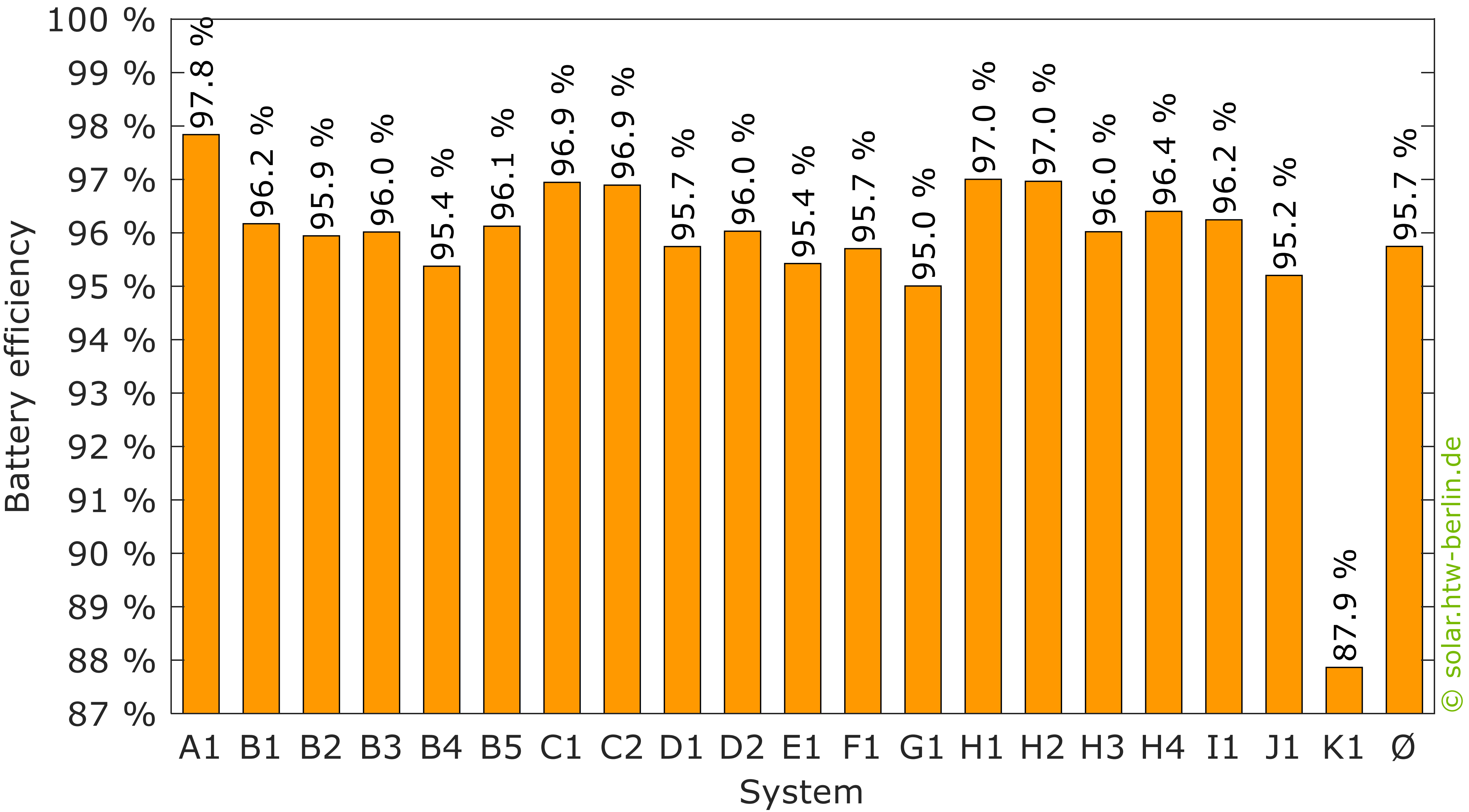
htw.

Maximum battery discharge current depending on its temperature



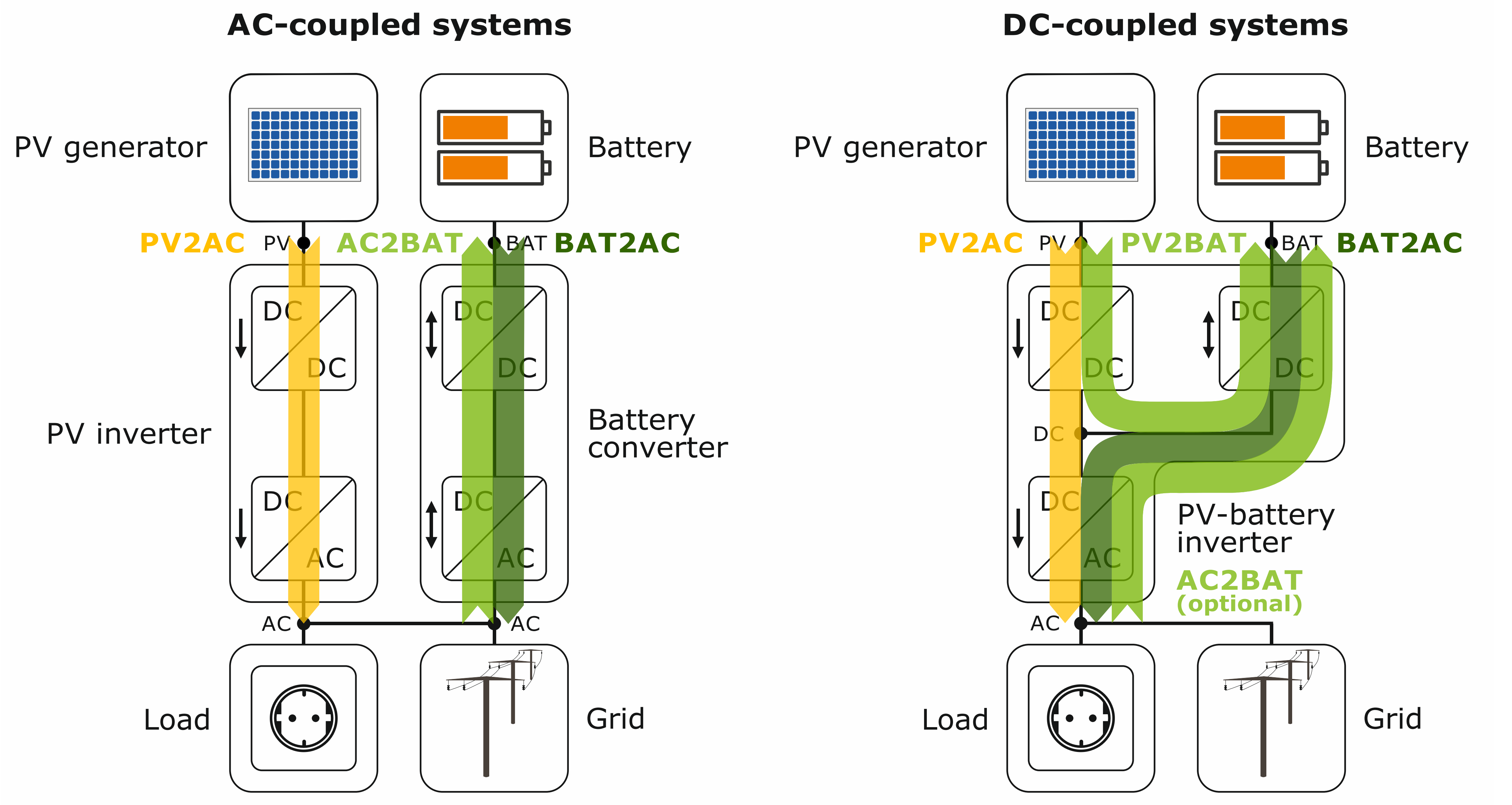
Data: Manufacturer

Average battery efficiency

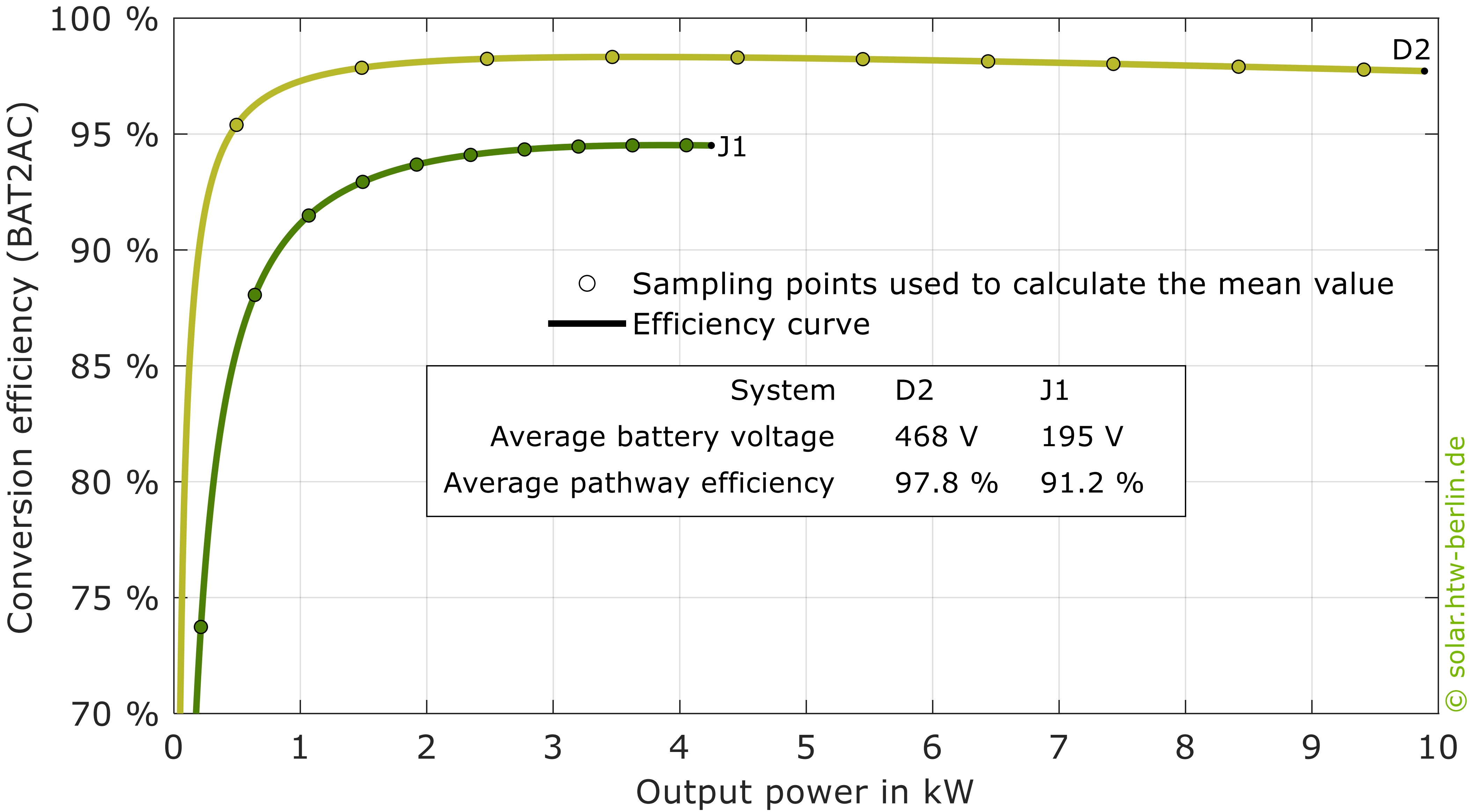


Systems D1, D2, H3 and H4: Due to a temperature-induced derating, the test could not be run at 100 % of the nominal power.

Energy conversion pathways of the different system topologies

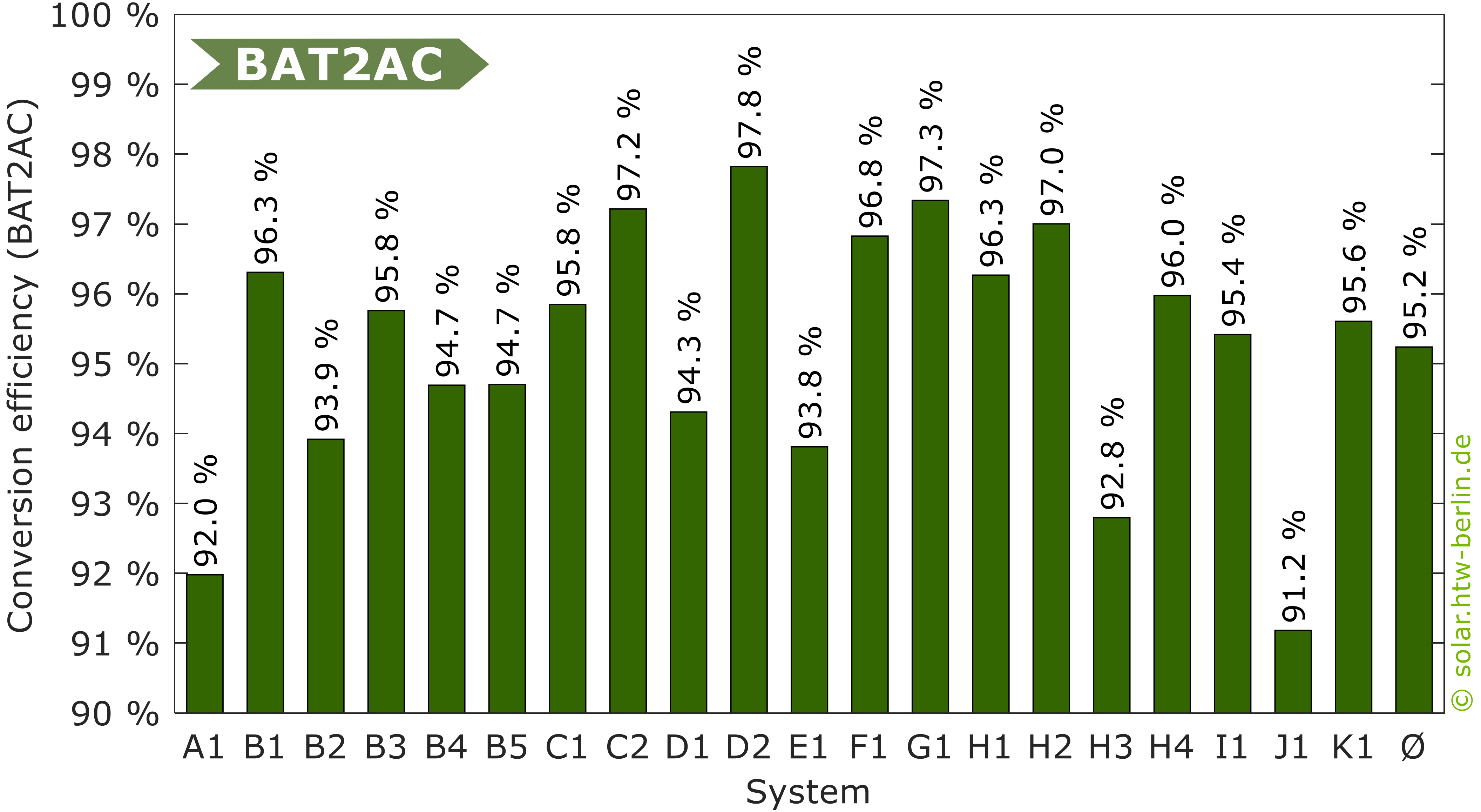


Average path efficiency for comparison of the conversion efficiency



The average pathway efficiency corresponds to the arithmetic mean of the efficiencies at 10 equidistantly distributed sampling points.

Average conversion efficiency of AC battery discharging



Average pathway efficiencies of AC discharging according to the “Efficiency Guideline for PV Storage Systems” 2.0.

Average efficiency of the energy conversion pathways

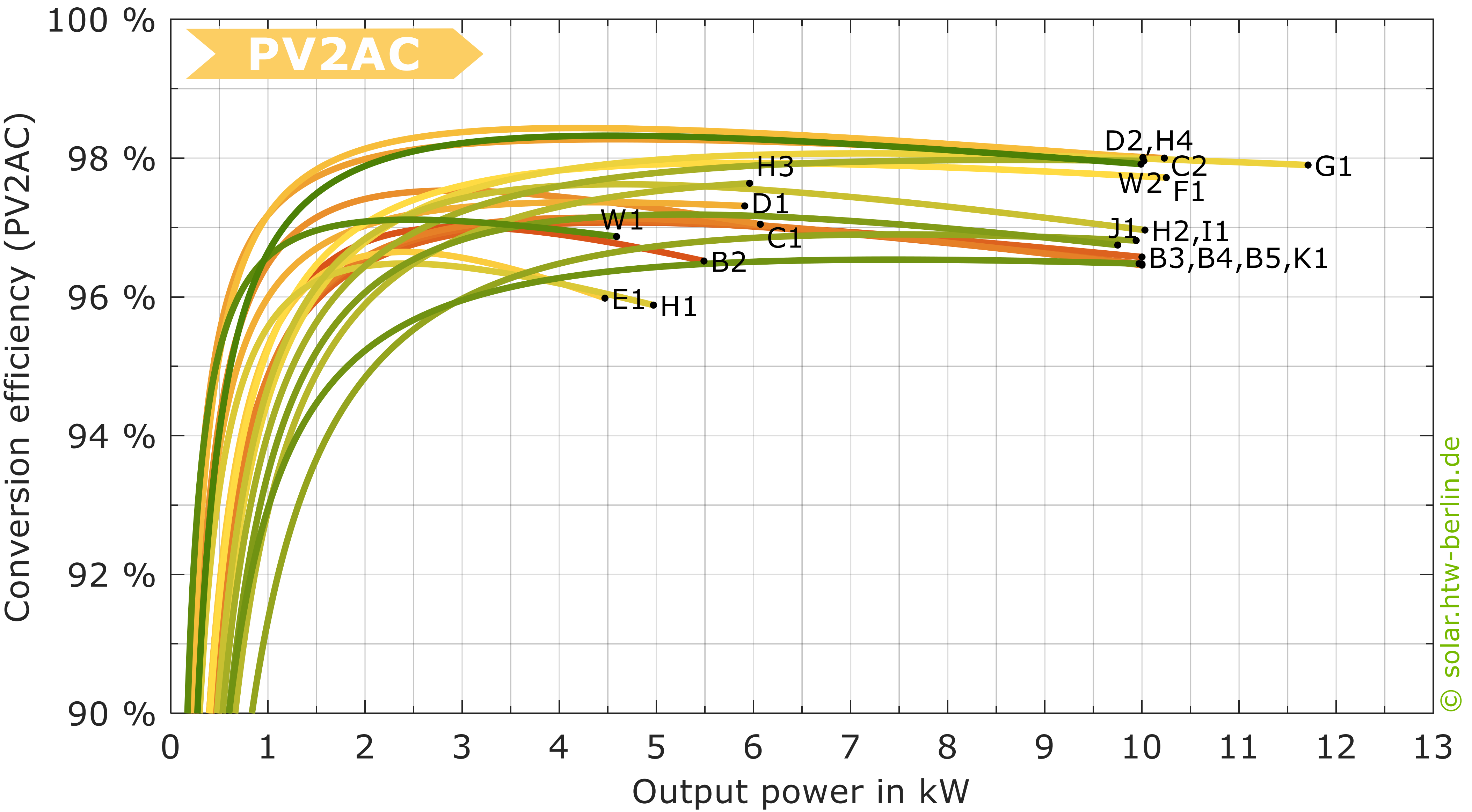
System	PV2AC: PV feed-in	PV2BAT: PV charging	AC2BAT: AC charging	BAT2AC: AC discharging
A1			92.1 %	92.0 %
B1			96.1 %	96.3 %
B2	95.5 %	93.9 %		93.9 %
B3	96.3 %	95.8 %		95.8 %
B4	96.3 %	94.6 %		94.7 %
B5	96.3 %	94.6 %		94.7 %
C1	96.6 %	96.8 %	95.6 %	95.8 %
C2	97.9 %	97.9 %	96.5 %	97.2 %
D1	96.4 %	94.7 %	94.0 %	94.3 %
D2	97.9 %	98.1 %	97.7 %	97.8 %
E1	94.8 %	93.6 %	93.5 %	93.8 %
F1	97.1 %	97.4 %	96.9 %	96.8 %
G1	97.1 %	97.2 %	97.1 %	97.3 %
H1	95.3 %	96.3 %	95.7 %	96.3 %
H2	96.6 %	97.0 %	96.7 %	97.0 %
H3	94.7 %	92.9 %		92.8 %
H4	96.7 %	96.4 %		96.0 %
I1	95.1 %	95.5 %	95.1 %	95.4 %
J1	95.9 %	92.0 %		91.2 %
K1	95.4 %	95.0 %		95.6 %
Ø	96.2 %	95.5 %	95.6 %	95.2 %

Conversion pathway

Average conversion efficiency: 90 % – 98 %

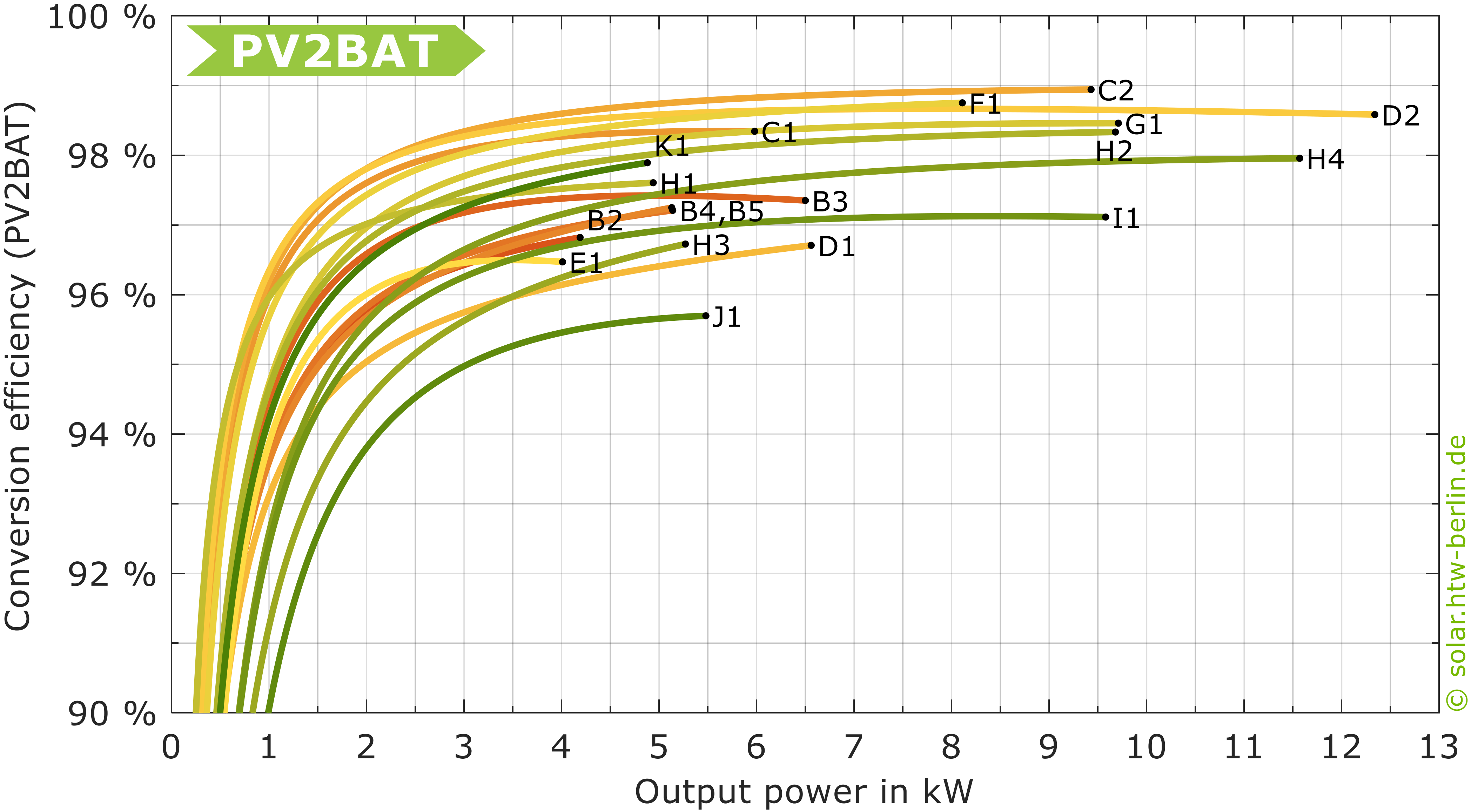
Average pathway efficiencies according to the "Efficiency Guideline for PV Storage Systems" 2.0.

PV feed-in pathway efficiency



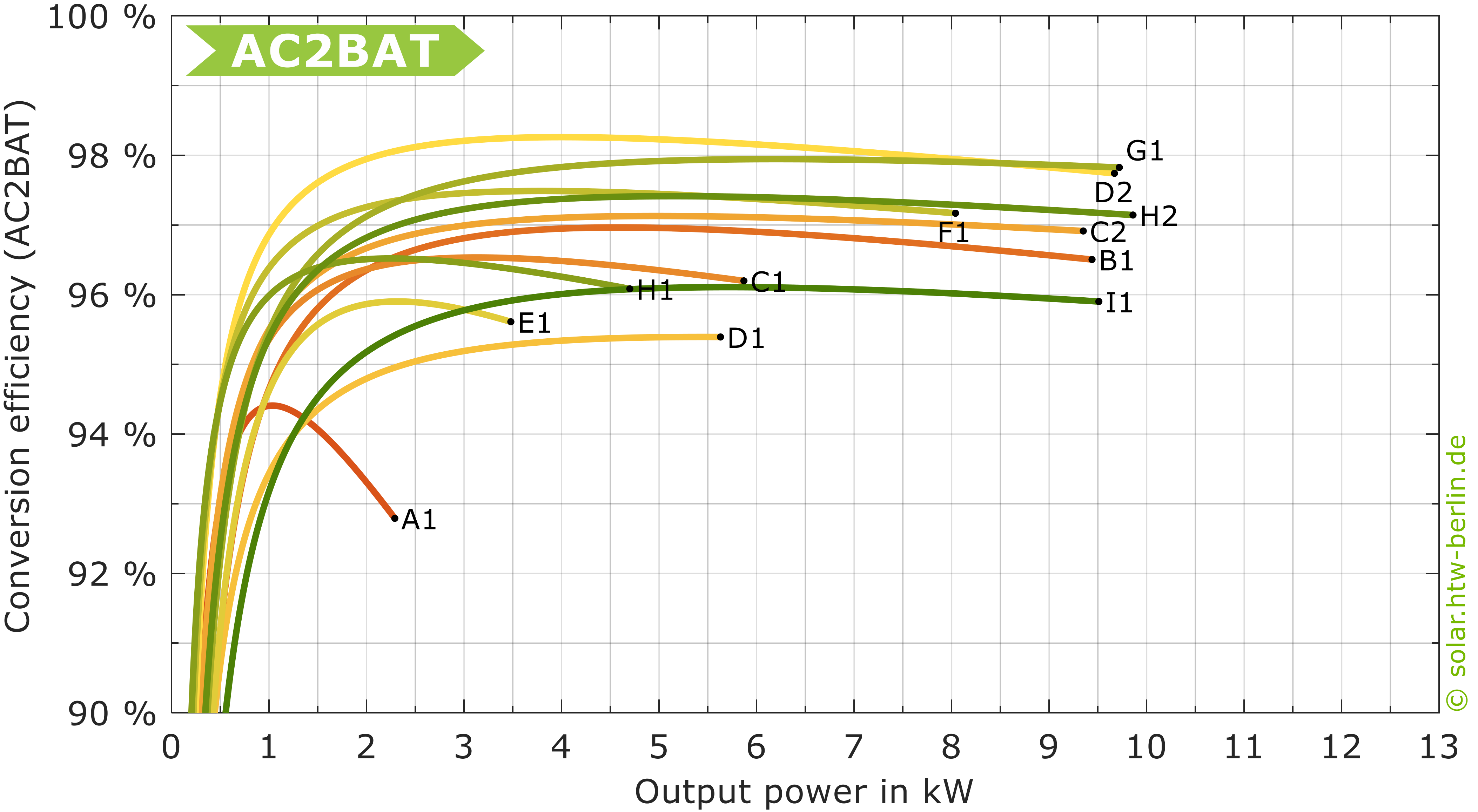
W1 and W2: PV inverter used for assessing the AC-coupled systems with the SPI (5 kW) and SPI (10 kW).

PV battery charging pathway efficiency

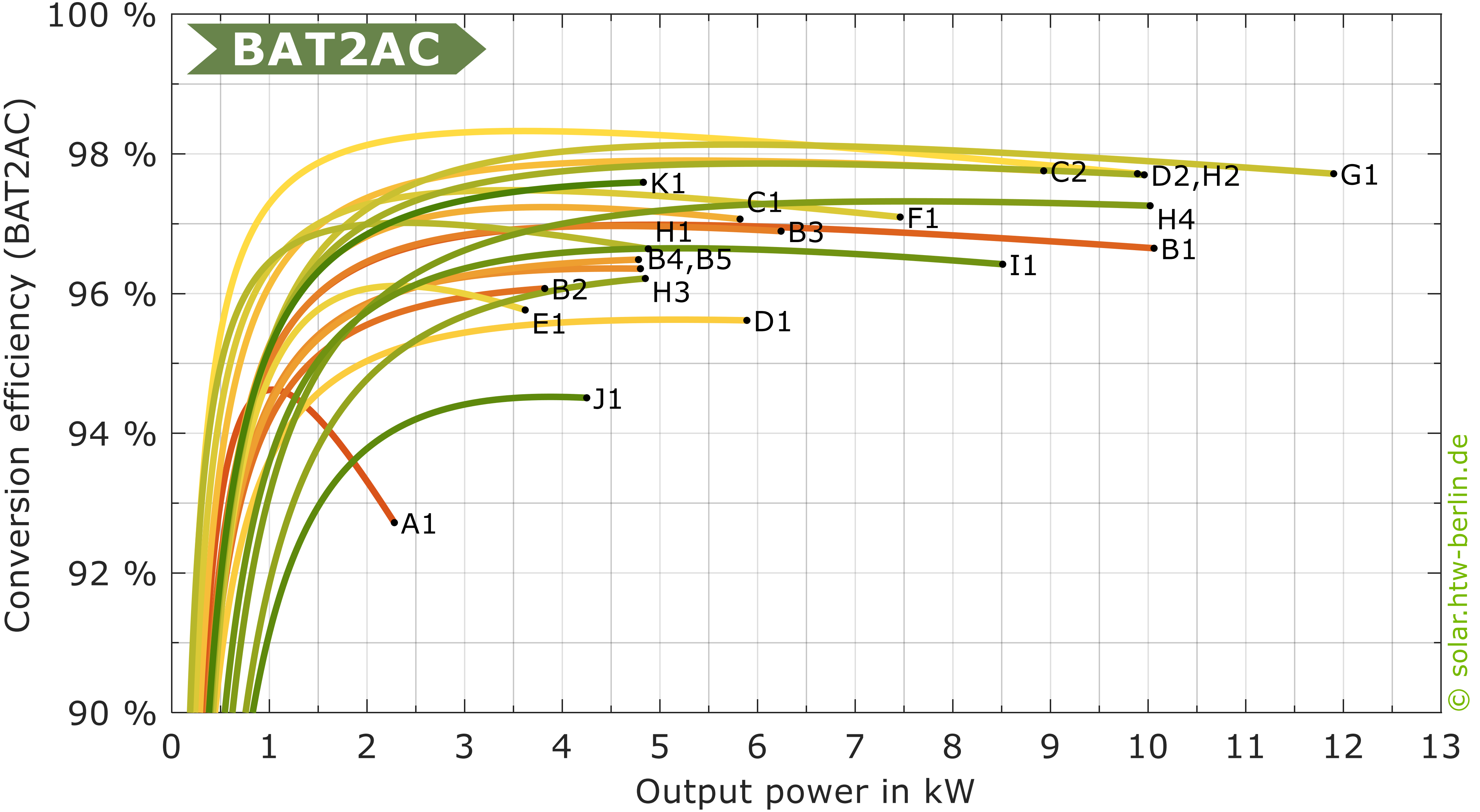


htw.

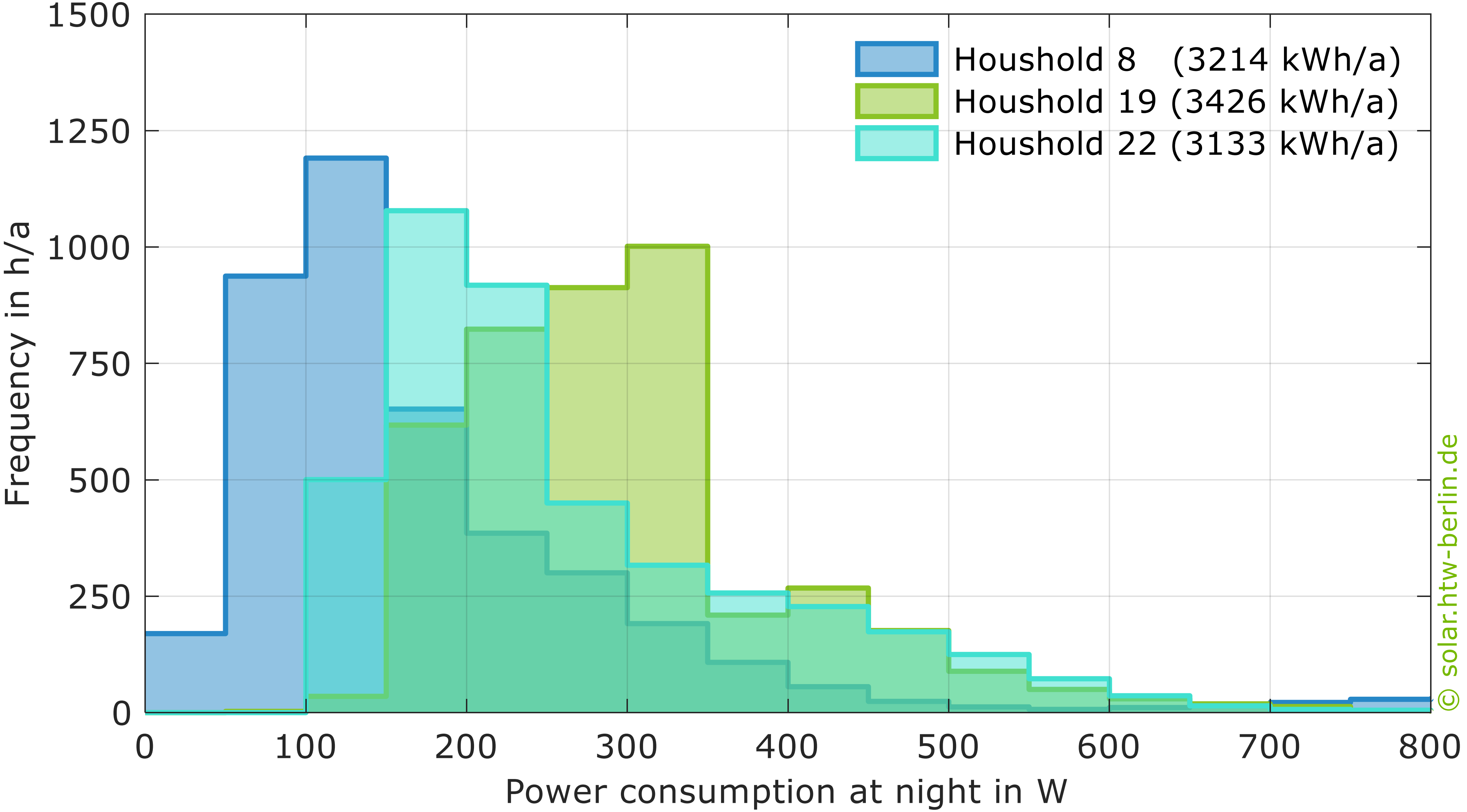
AC battery charging pathway efficiency



AC battery discharging pathway efficiency

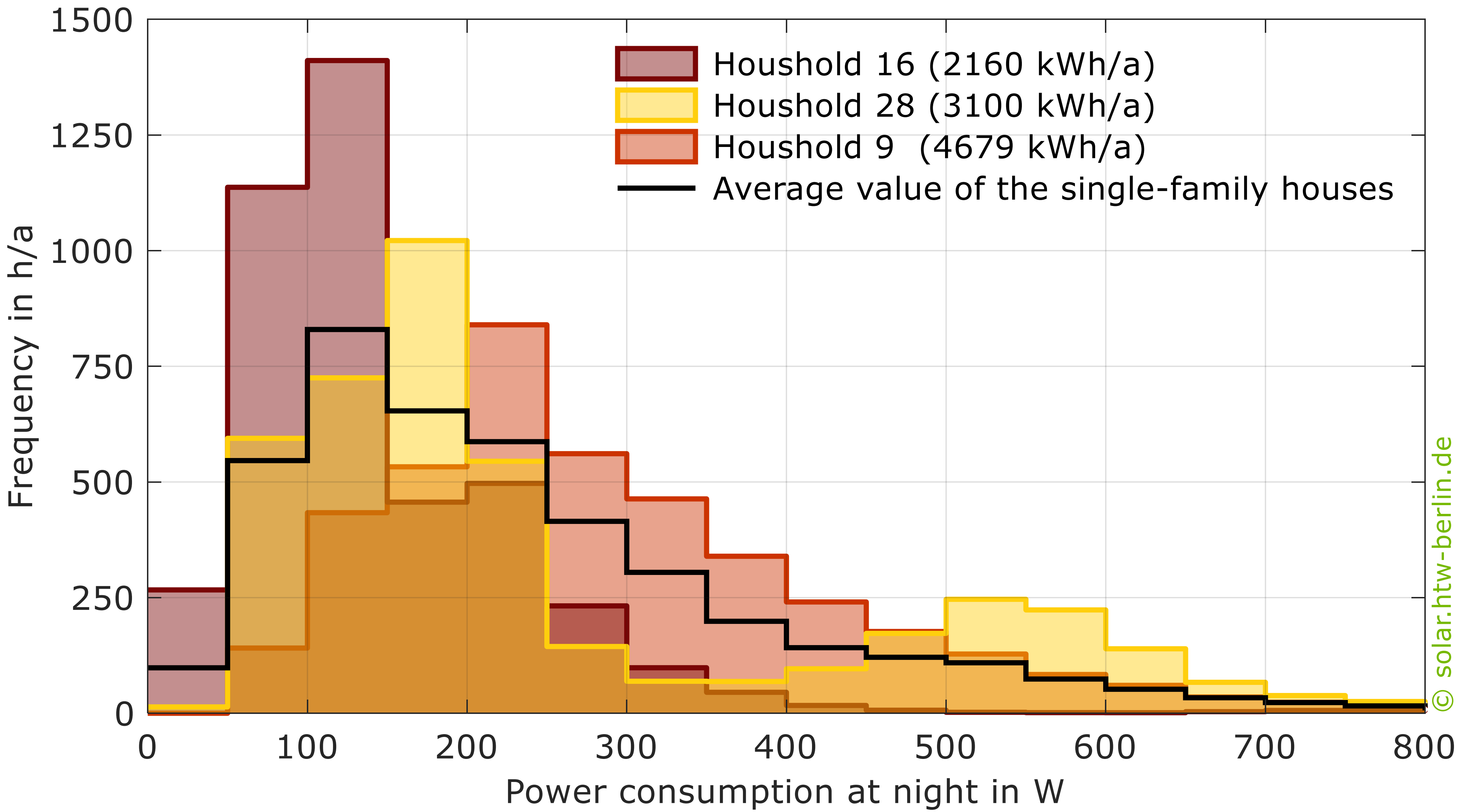


Frequency distribution of nighttime electricity consumption



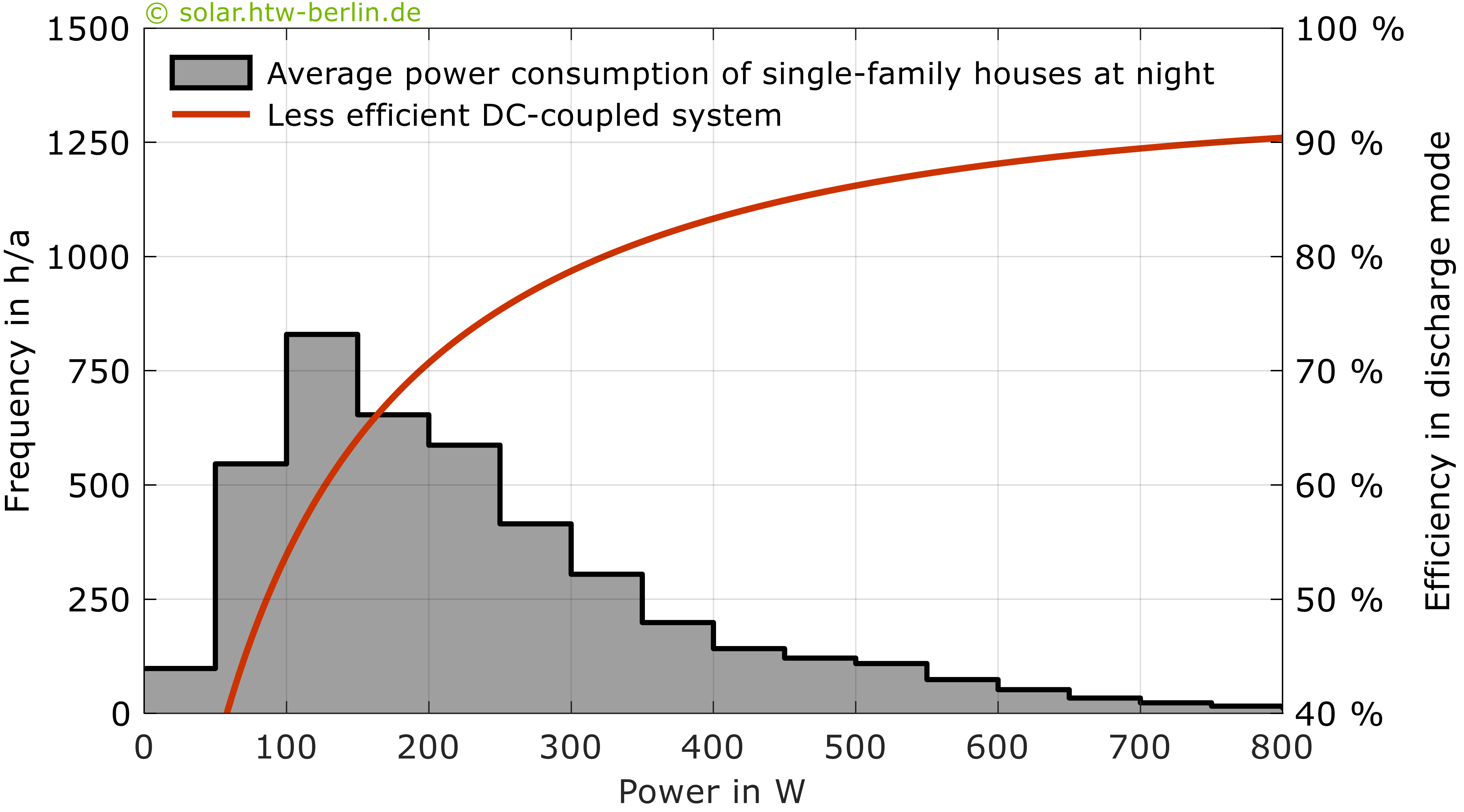
Frequency distribution of the nighttime electricity consumption of different households based on 10 s measurement data. Class width: 50 W, data: Schlemminger et al. - Dataset on electrical single-family houses and heat pump load profiles in Germany.

Frequency distribution of nighttime electricity consumption



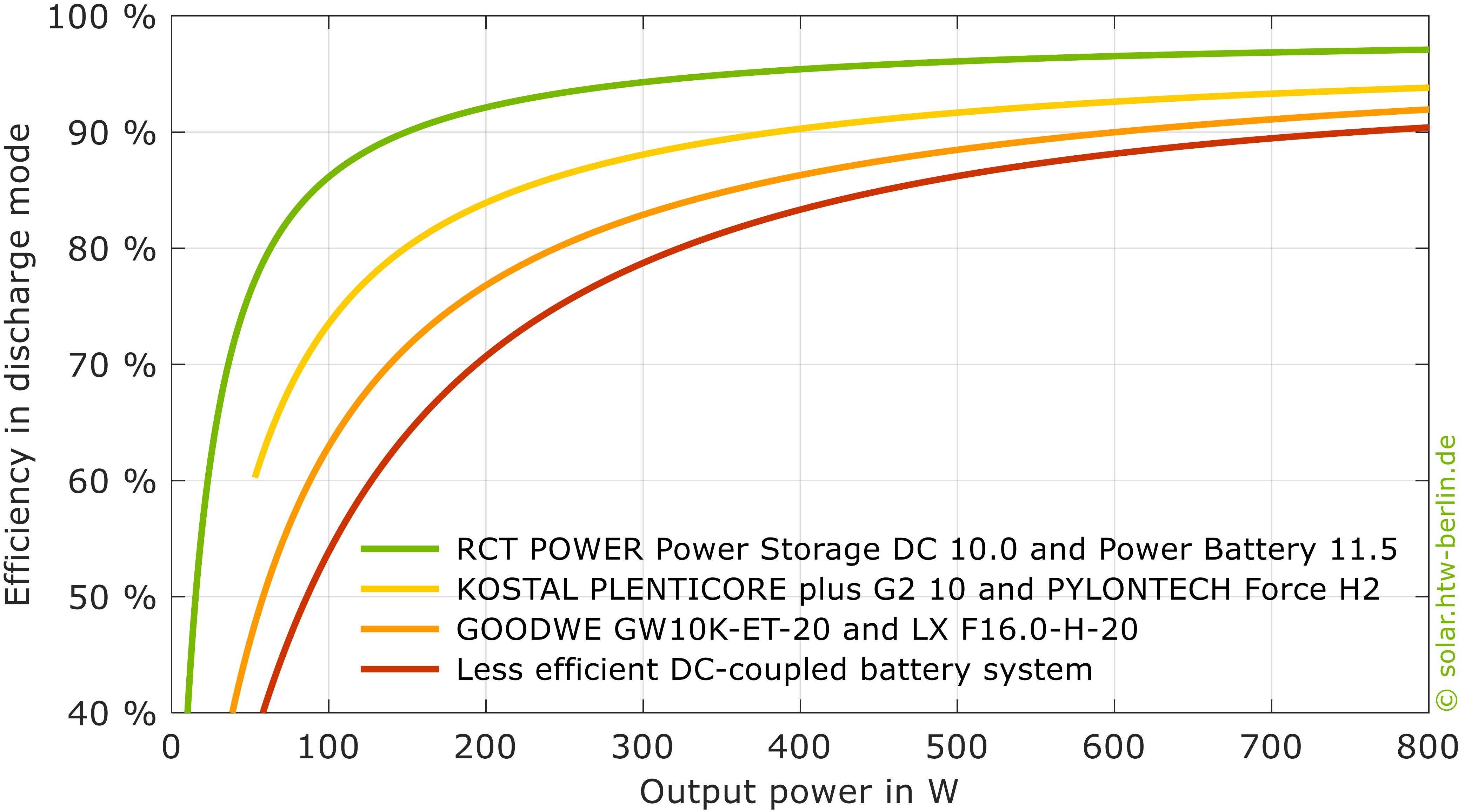
Frequency distribution of the nighttime electricity consumption of different households based on 10 s measurement data. Class width: 50 W, data: Schlemminger et al. - Dataset on electrical single-family houses and heat pump load profiles in Germany.

Partial load efficiencies of an inefficient hybrid inverter



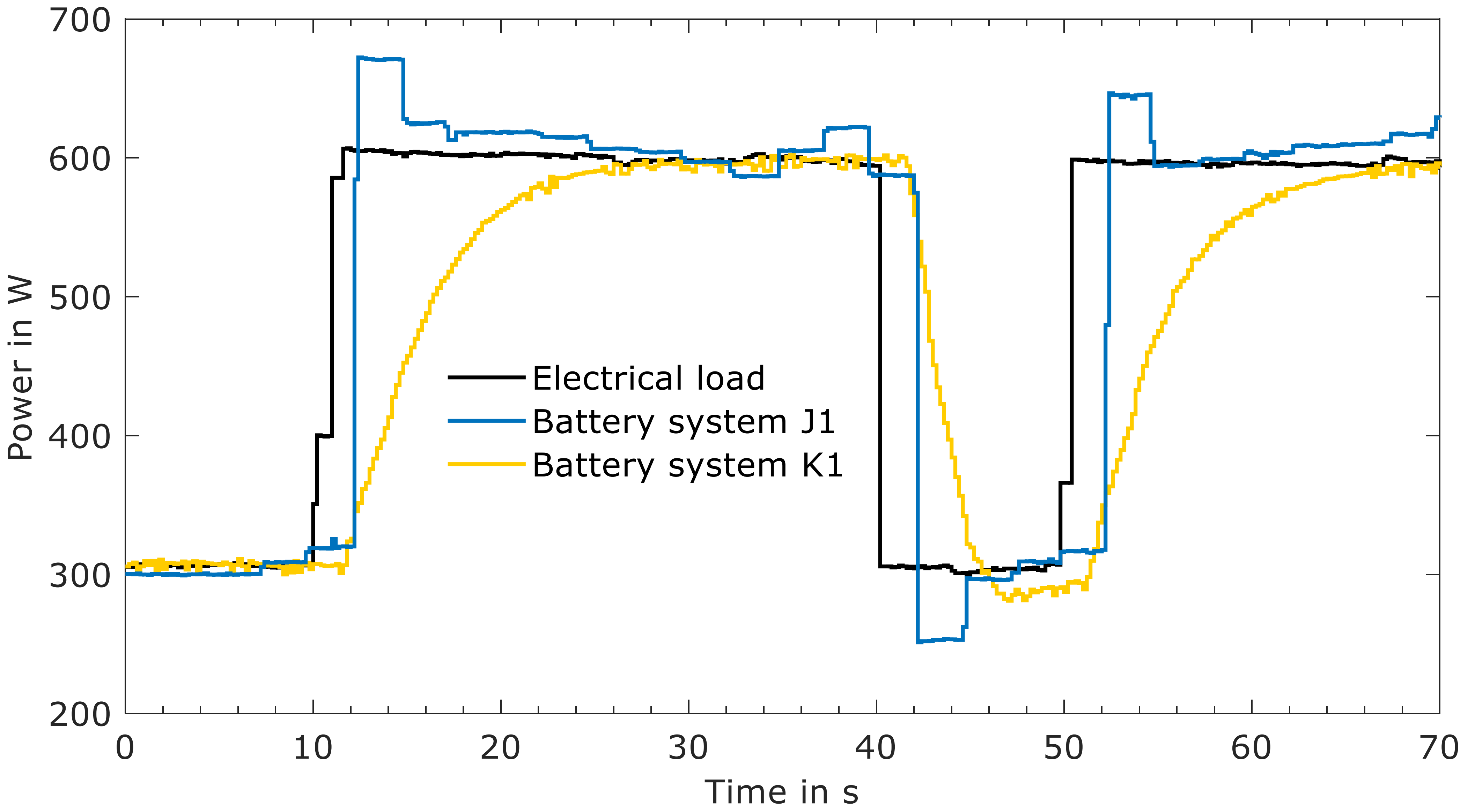
Average frequency distribution of the nighttime electricity consumption of different households based on 10 s measurement data.
Class width: 50 W, data: Schlemminger et al. - Dataset on electrical single-family houses and heat pump load profiles in Germany.

Partial load efficiencies of different hybrid inverters



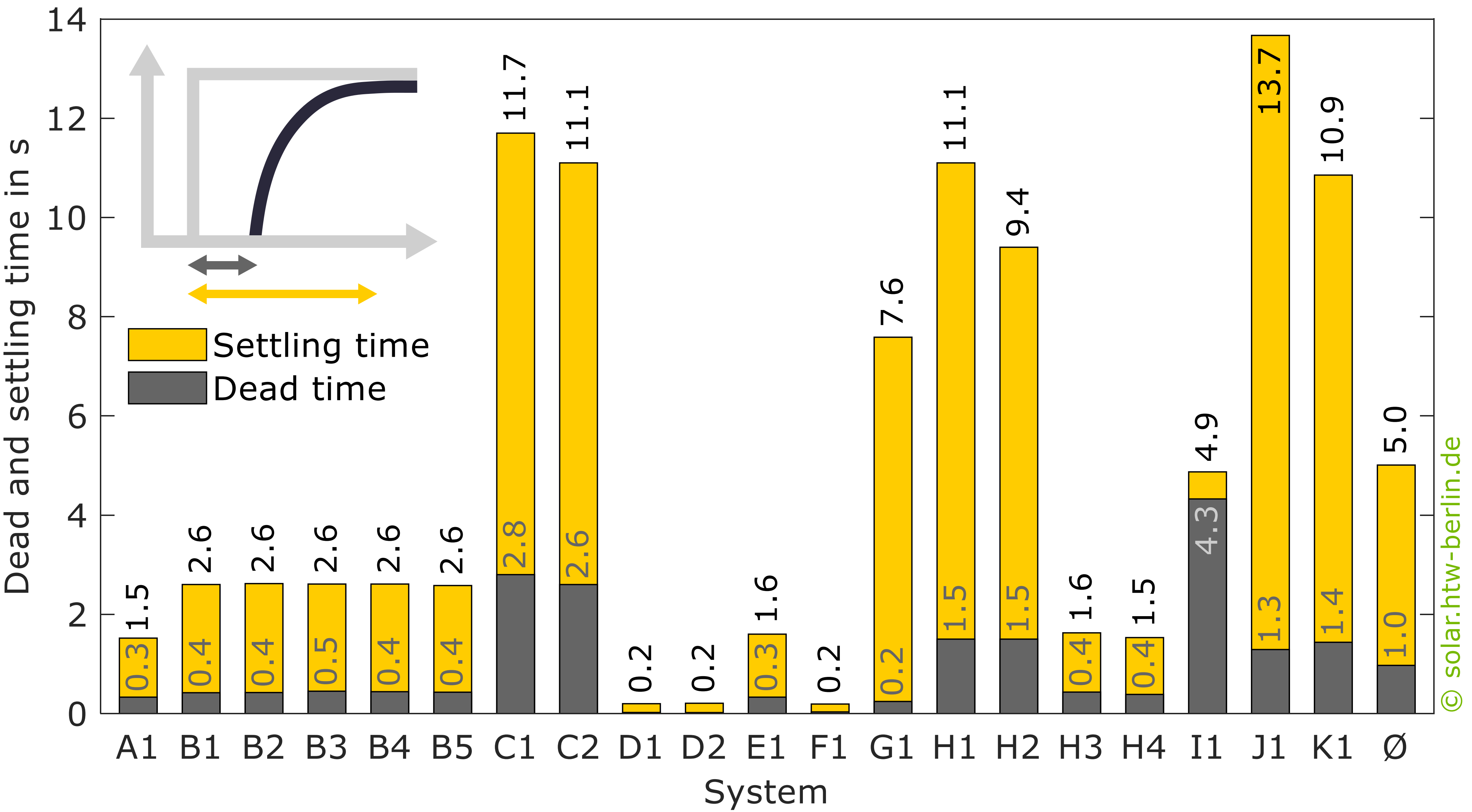
Laboratory measurement data of the hybrid inverters: AIT and KIT, minimum output power of the hybrid inverter from Kostal: 50 W.

Transient response of two storage systems

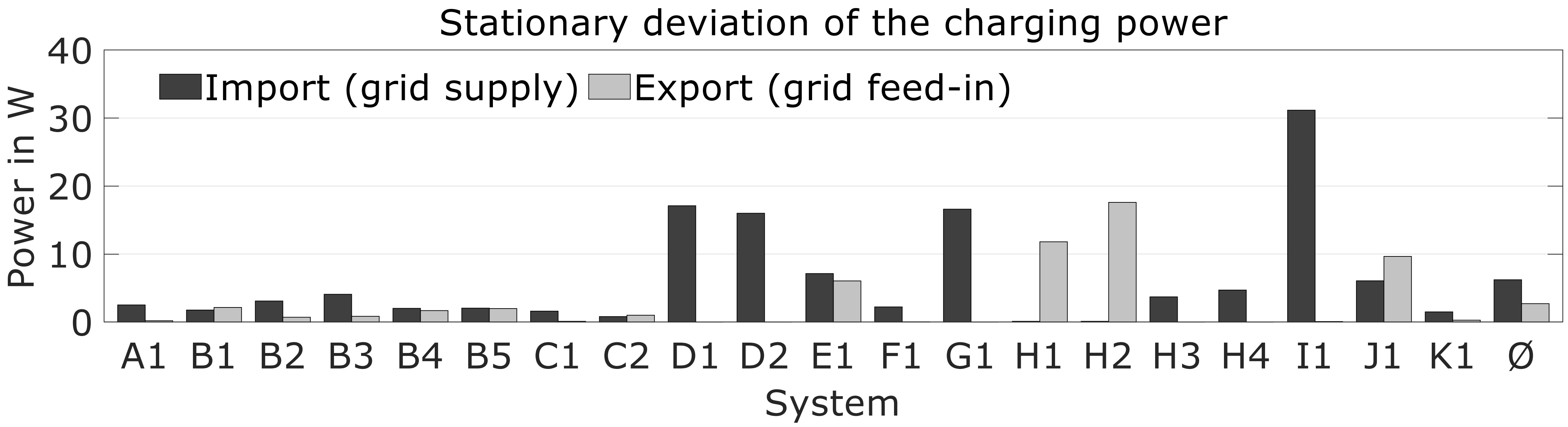


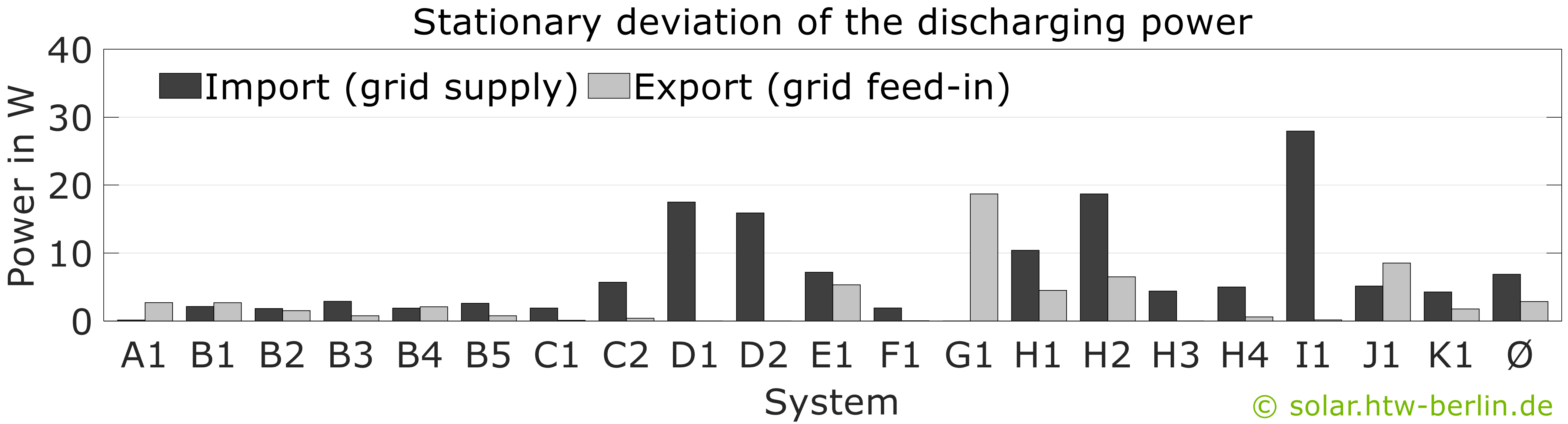
Data: KIT

Dynamic control deviations

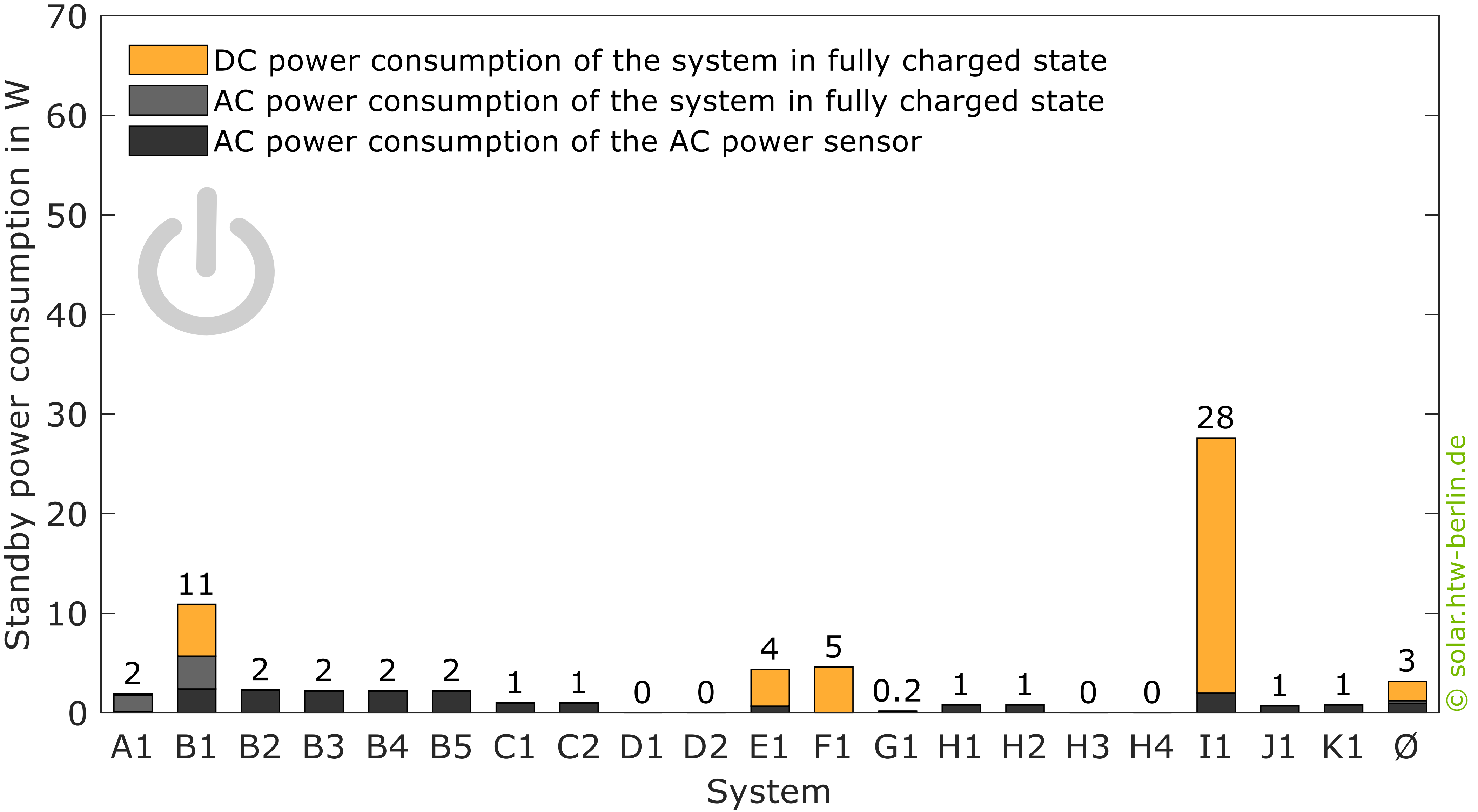


Stationary control deviations



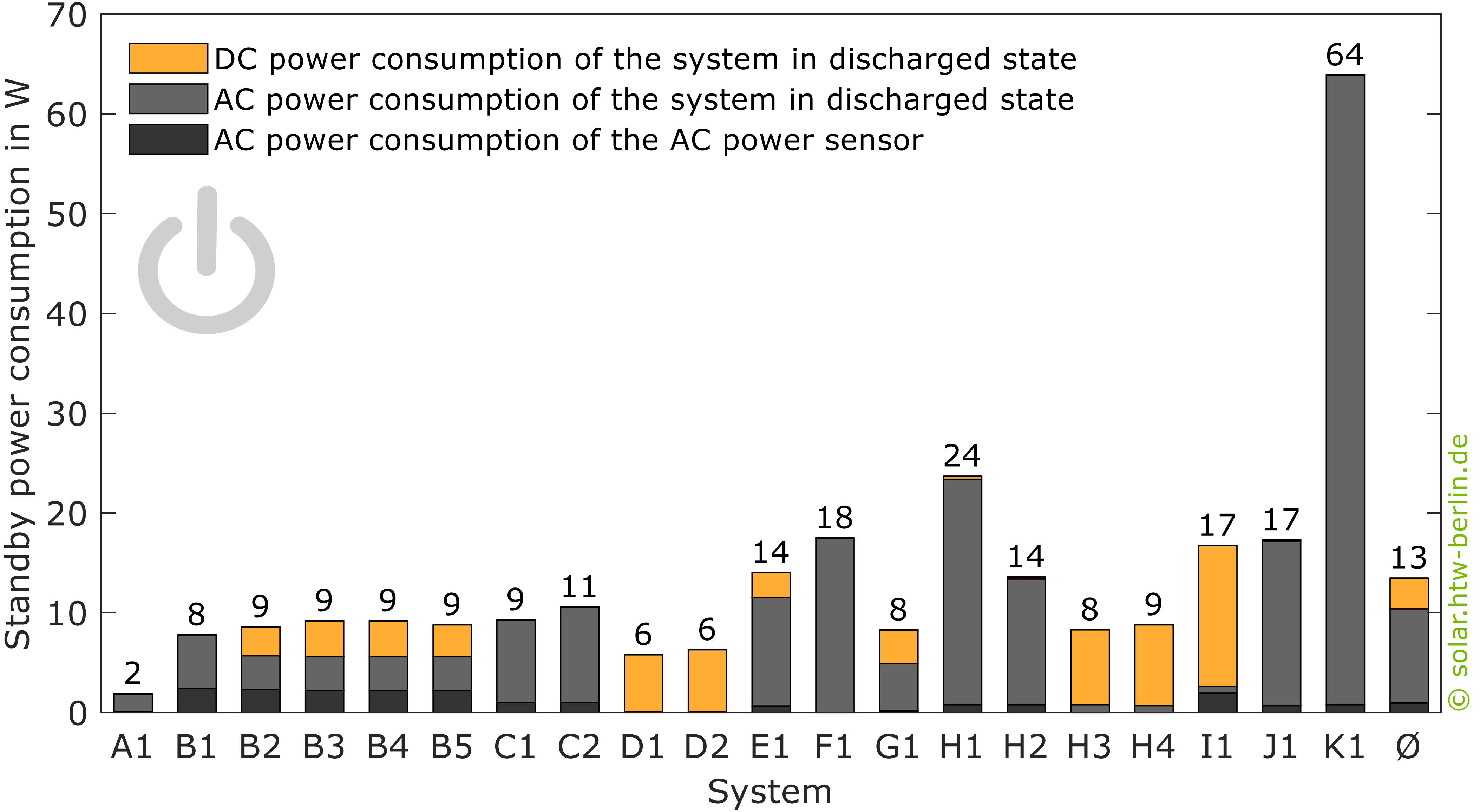


Standby power consumption with fully charged battery



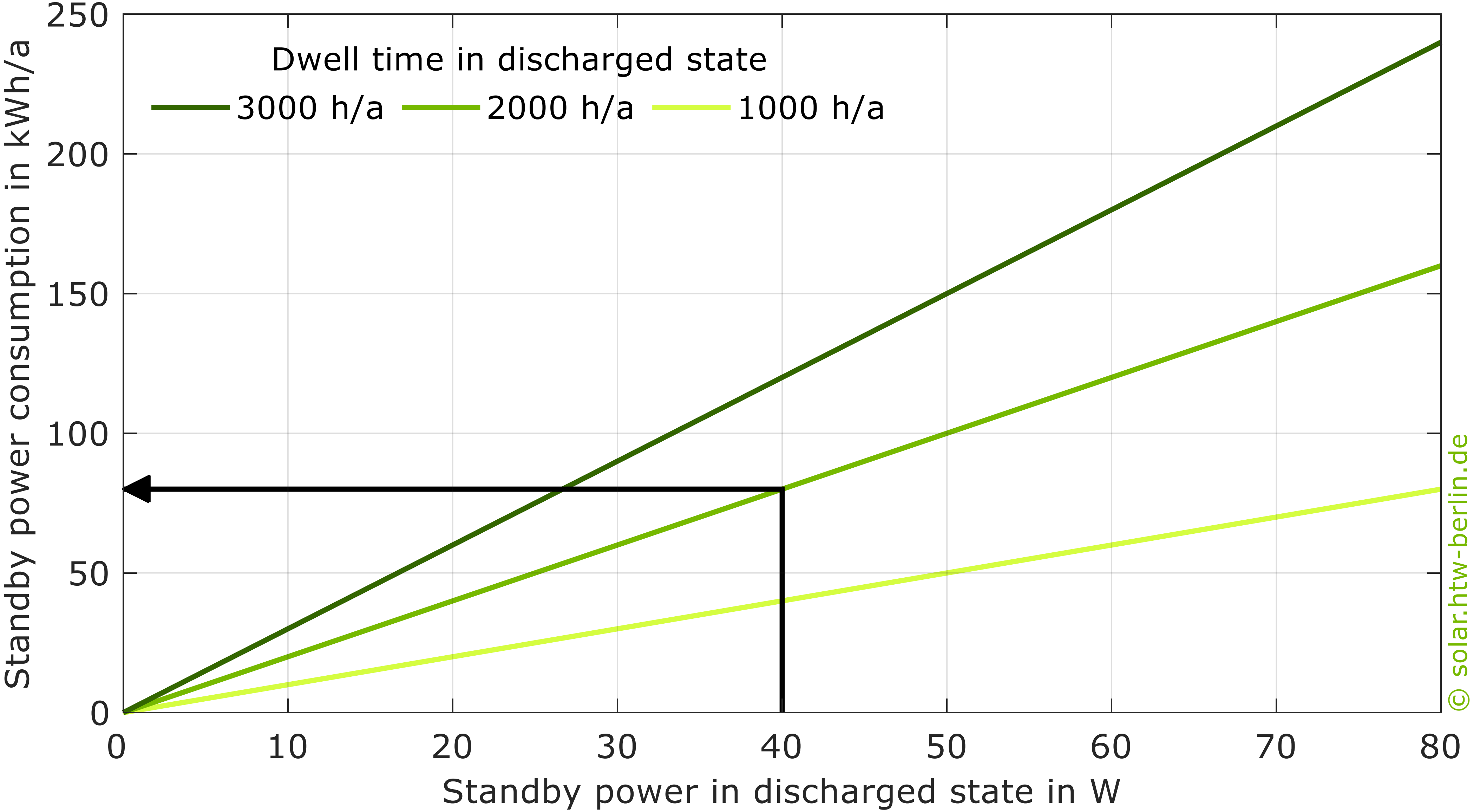
The standby power consumption of the battery management system (BMS) is not included in the values listed.

Standby power consumption with discharged battery



The standby power consumption of the battery management system (BMS) is not included in the values listed.

Different Standby power consumptions at discharged durations



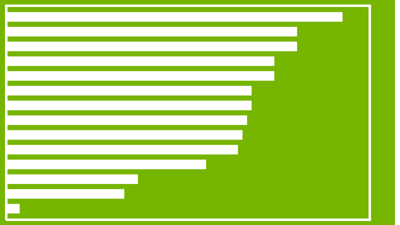
Depending on the system dimensioning, a battery storage system is usually fully discharged between 1250 h/a and 3500 h/a.

Main topics of the Energy Storage Inspection 2024

1 Analysis of the German market for residential PV-battery systems

2 Comparison of the system properties based on the test reports according to the Efficiency Guideline

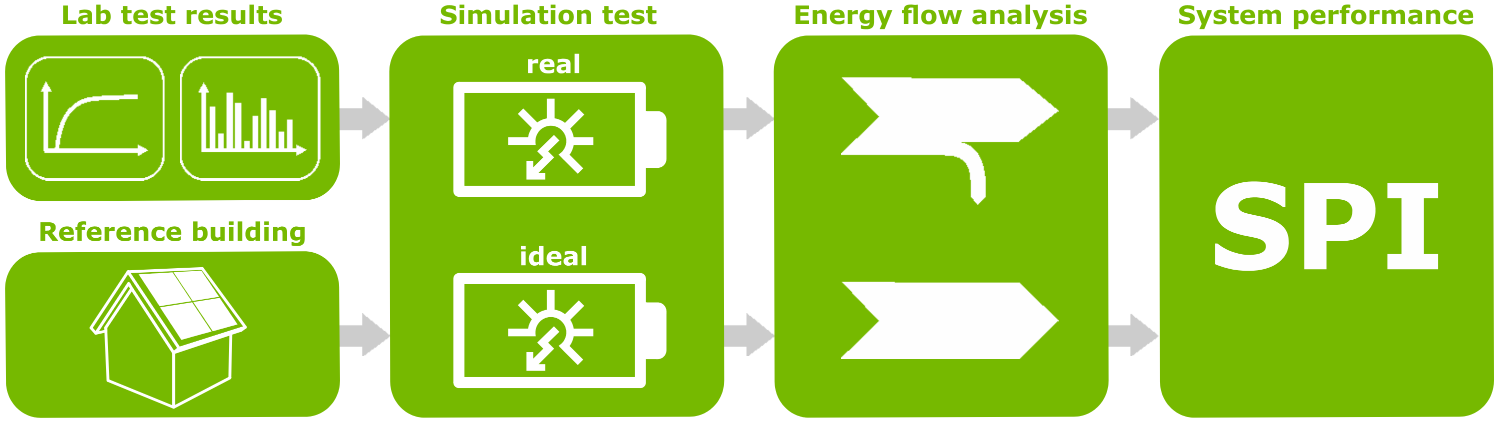
3 Simulation-based assessment of the PV-battery systems with the System Performance Index (SPI)



4 Comparison of the operating data of PV-battery systems

Methodology of the simulation-based system evaluation

- Simulation of the **operating behavior** of tested PV-battery systems over a year.
- The **System Performance Index (SPI)** evaluates the systems based on the energy flows at the grid connection point. It considers the different economic values of the energy fed into the grid at 0.08 €/kWh and the energy drawn from the grid at 0.4 €/kWh.
- Parameterization of the "PerMod" simulation model (version 2.2) based on the laboratory measurement results determined in accordance with the efficiency guideline.
- Including the sizing, conversion, control and standby losses determined in the laboratory.



System Performance Index SPI (5 kW) and SPI (10 kW)

1st reference case for the System Performance Index SPI (5 kW)

PV system (5 kW) + Appliances (5010 kWh/a)

2nd reference case for the System Performance Index SPI (10 kW)

PV system (10 kW) + Appliances (5010 kWh/a) + Heat pump (2664 kWh/a) + Electric vehicle (1690 kWh/a)

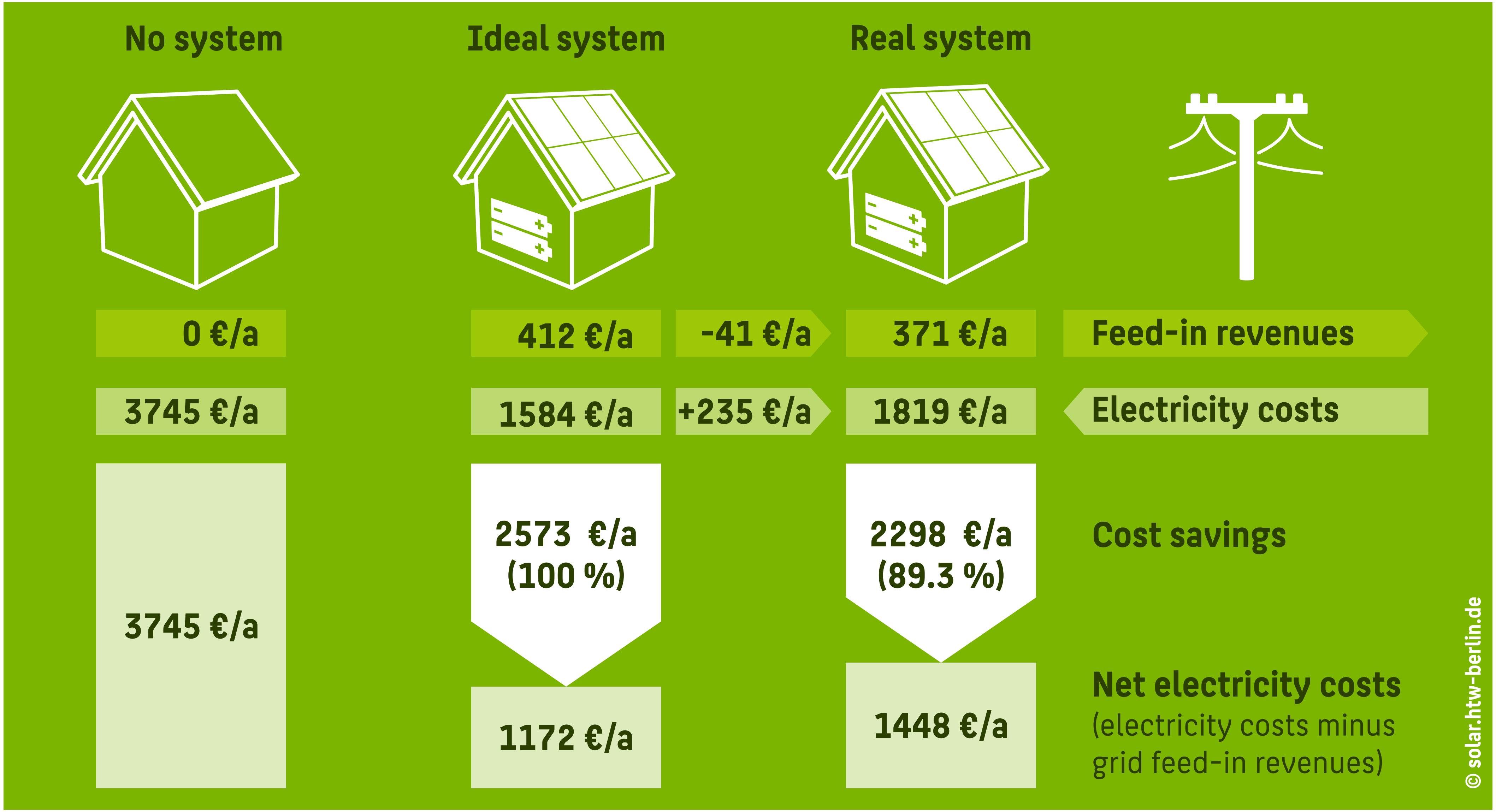
Please note: SPI (5 kW) and SPI (10 kW) are not comparable due to the different characteristics of the two reference cases.

Assignment of the systems to the reference cases

- Depending on the size of the power electronics and battery storage, the efficiency rating with the **SPI (5 kW) or SPI (10 kW)** is appropriate.
- Only systems with usable battery capacities smaller than 8.0 kWh were rated with the **SPI (5 kW)**.
- For a rating with the **SPI (10 kW)** a usable battery capacity smaller than 16.0 kWh was required.
- The classification was based on the usable storage capacity determined in the **laboratory test**.
- 7 systems were rated with the SPI (5 kW) and 14 systems were assessed with the SPI (10 kW). Both metrics were determined for the AC-coupled system A1.

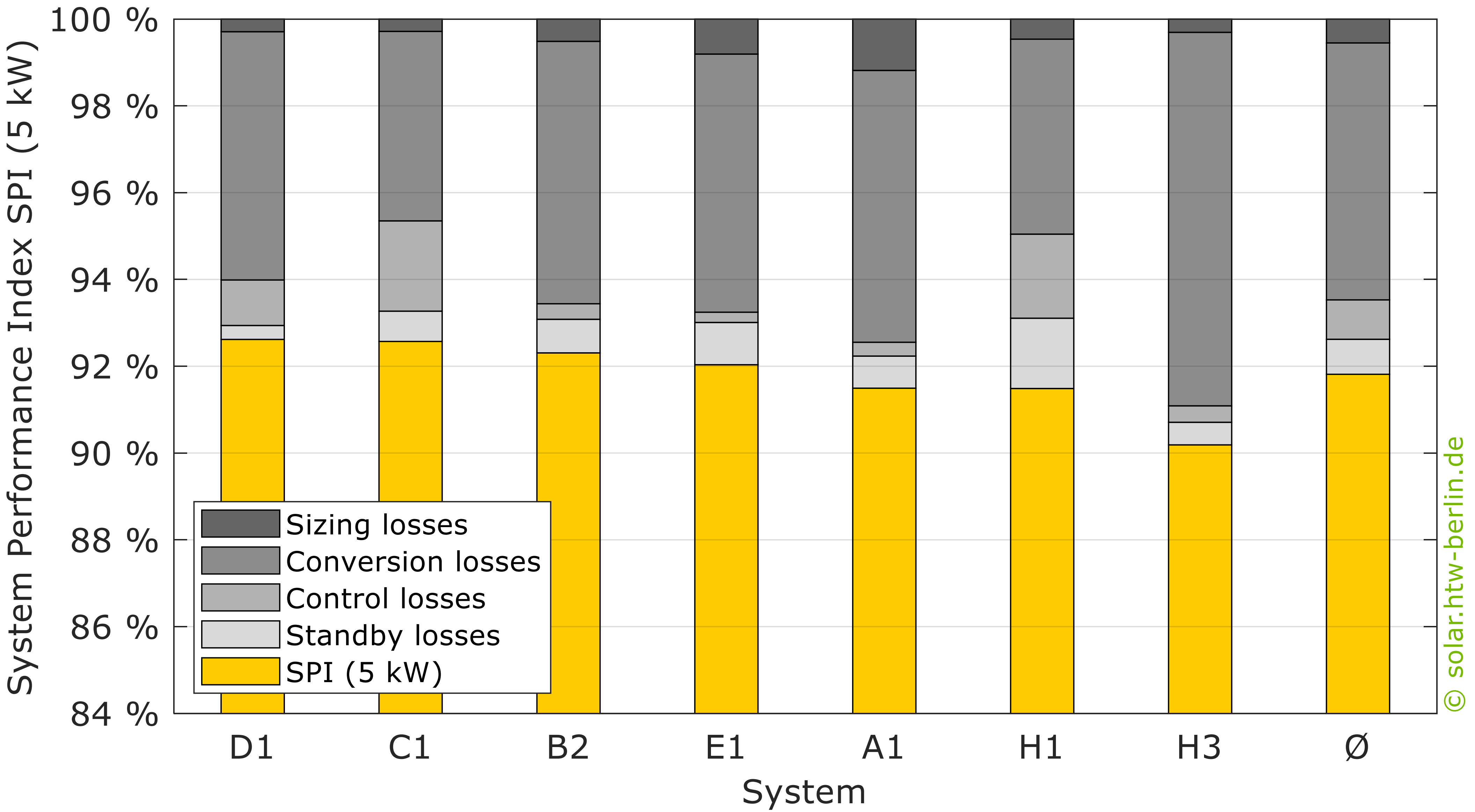
System	A1	B1	B2	B3	B4	B5	C1	C2	D1	D2	E1	F1	G1	H1	H2	H3	H4	I1	J1	K1
SPI (5 kW)	■		■				■		■		■			■		■				
SPI (10 kW)	■	■		■	■	■		■		■		■	■		■		■	■	■	■

Example for determining the System Performance Index (SPI)

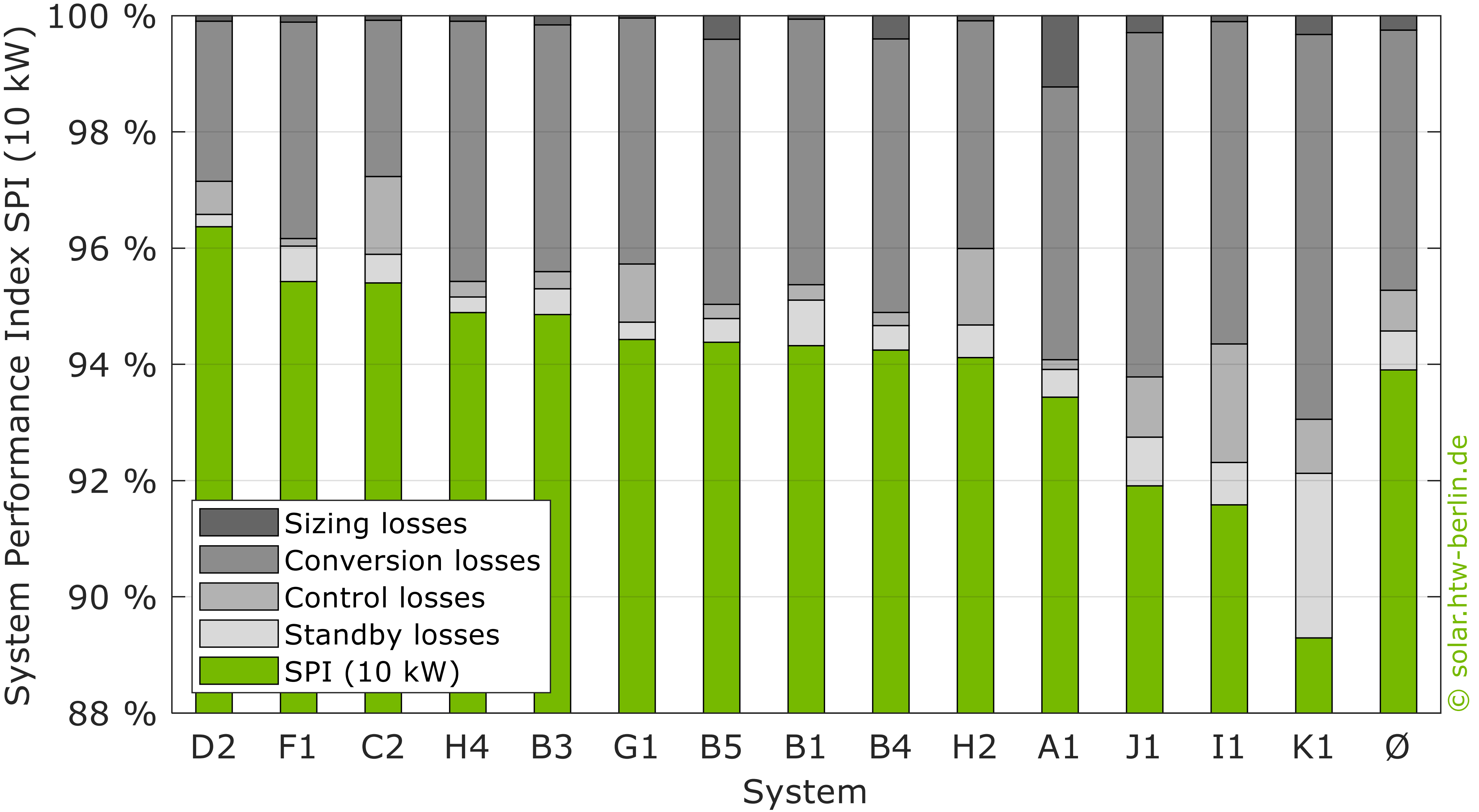


Grid feed-in revenues and grid purchase costs as well as cost savings achieved when using the ideal (loss-free) and real example system K1 (feed-in tariff 0.08 €/kWh, grid purchase price 0.4 €/kWh). Framework conditions according to the 2nd reference case.

Loss analysis of the systems assessed with the SPI (5 kW)



Loss analysis of the systems assessed with the SPI (10 kW)

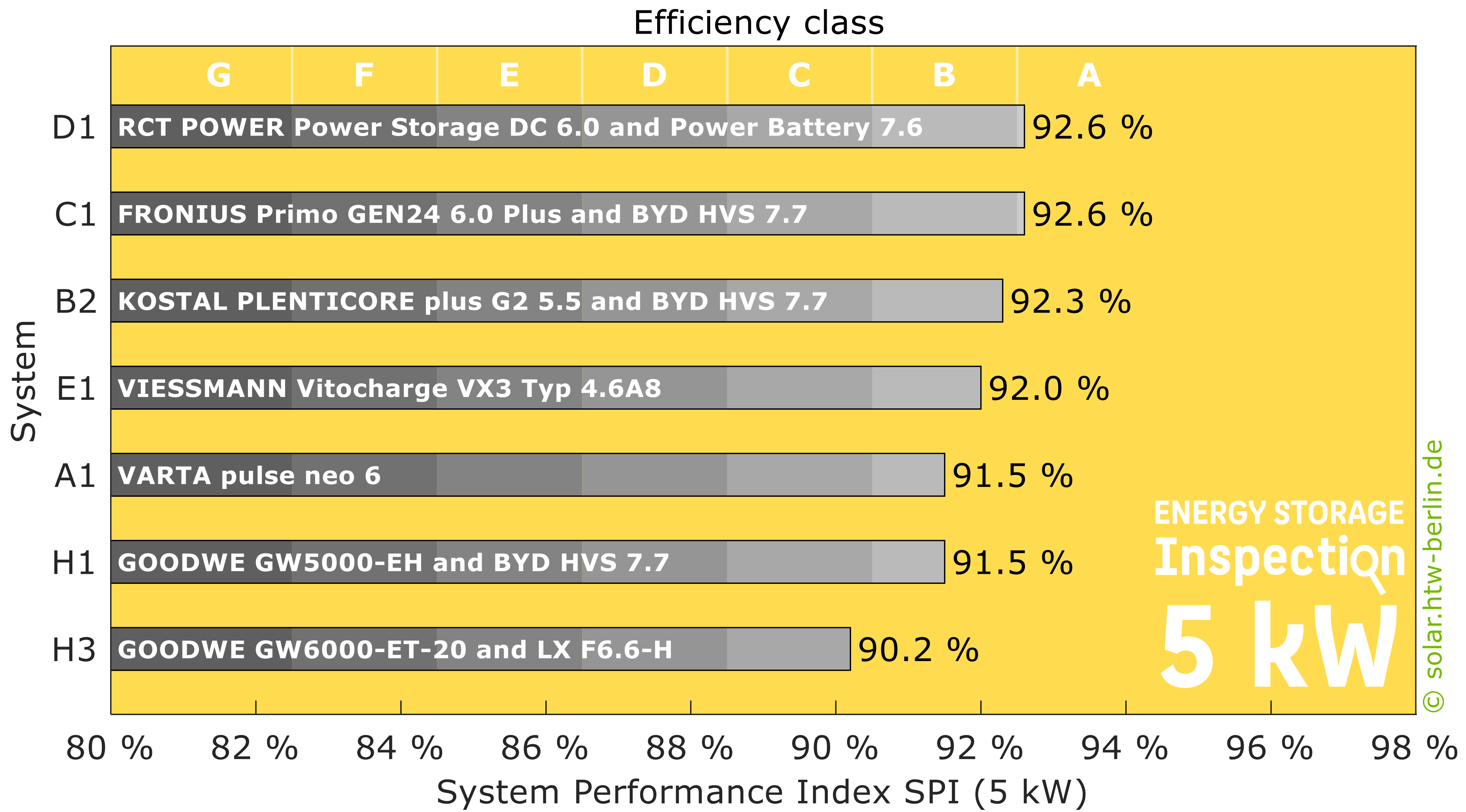


Definition of the efficiency classes for PV-battery systems

- Due to the different SPI values, the threshold values for reaching the individual **efficiency classes** vary.

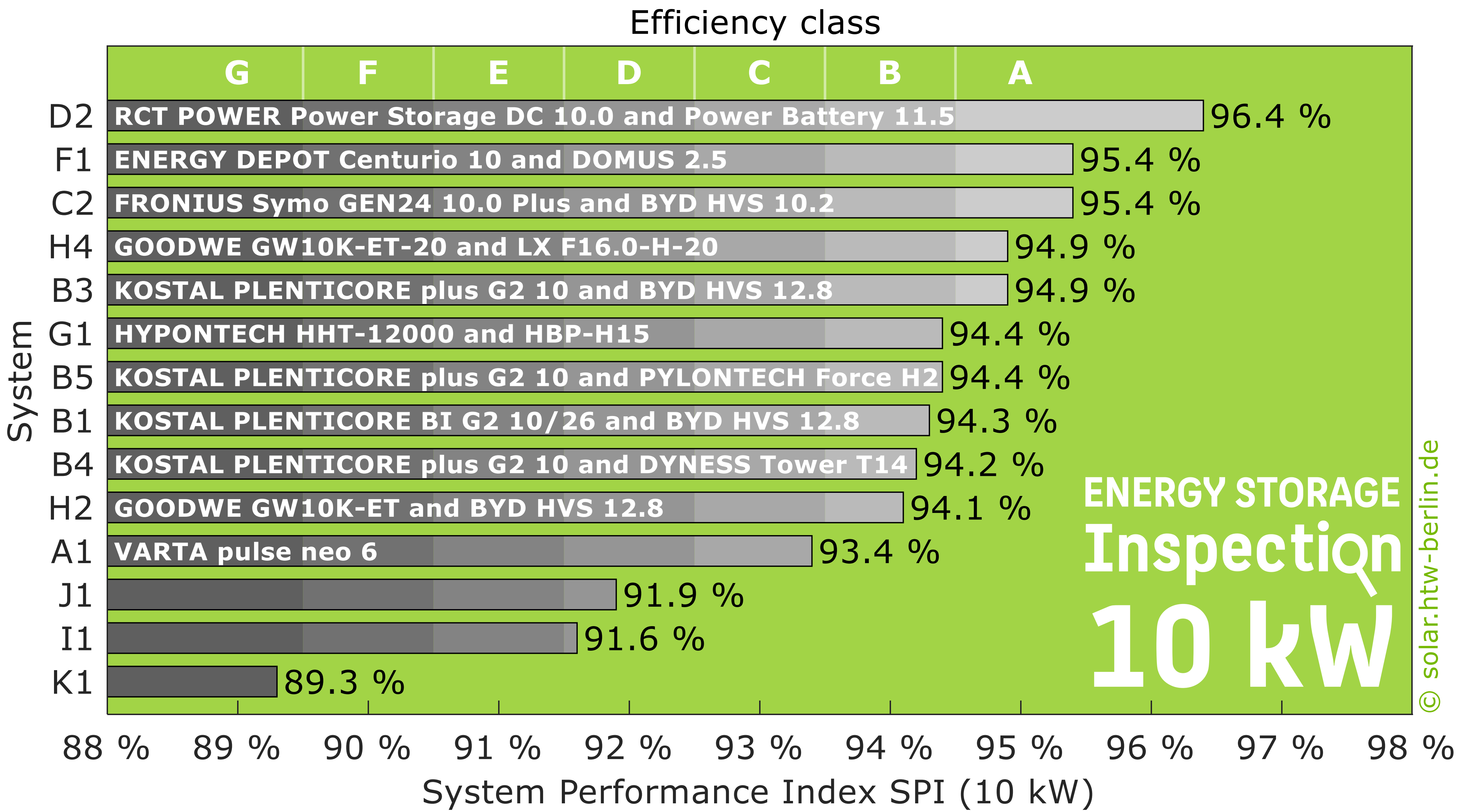
Class	SPI (5 kW)	SPI (10 kW)
A	≥ 92.5 %	≥ 94.5 %
B	≥ 90.5 %	≥ 93.5 %
C	≥ 88.5 %	≥ 92.5 %
D	≥ 86.5 %	≥ 91.5 %
E	≥ 84.5 %	≥ 90.5 %
F	≥ 82.5 %	≥ 89.5 %
G	< 82.5 %	< 89.5 %

SPI (5 kW) and efficiency classes of the analyzed systems



The AC-coupled system A1 was assessed in combination with the PV inverter SMA Sunny Boy 5.0.

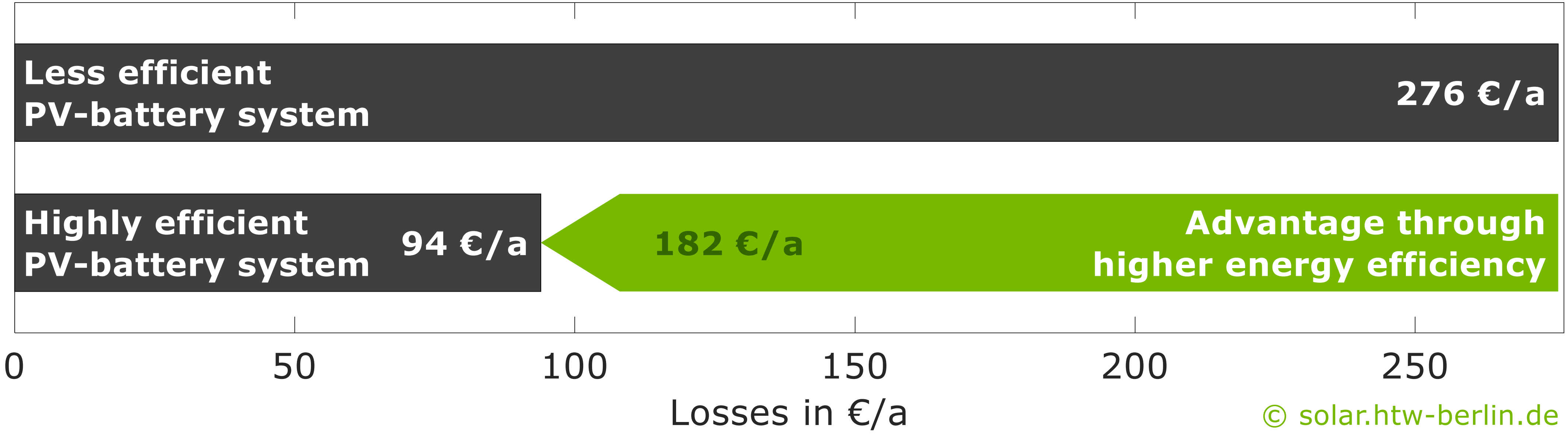
SPI (10 kW) and efficiency classes of the analyzed systems



The AC-coupled systems A1 and B1 were assessed in combination with the PV inverter SMA Tripower 10.0.

Why is a high system efficiency important?

- Efficiency losses reduce the **cost savings potential** of a PV-battery system. The economic losses for the systems evaluated with the SPI (10 kW) lay between 94 €/a and 276 €/a.
- Those who choose a highly efficient PV-battery system can save up to an additional **1820 € within the first ten years** of operation compared to a less efficient system.



Highly efficient system: D2, less efficient system: K1, framework conditions of the 2nd reference case.

Summary of the results of the system evaluation

- The Energy Storage Inspection 2024 analyzed and compared the energy efficiency of **20 battery systems**.
- In the reference case up to 5 kW, a DC-coupled system from RCT POWER came out on top with an **SPI (5 kW) of 92.6%**.
- It was closely followed by the hybrid inverters FRONIUS Symo GEN24 10.0 Plus and KOSTAL PLENTICORE plus G2 5.5, both of which competed in combination with the BYD Battery-Box Premium HVS 7.7.
- The RCT POWER Power Storage DC 10.0 and Power Battery 11.5 system achieved the highest **SPI (10 kW) with a value of 96.4%**.
- 16 of the 20 systems tested scored with very good system efficiency and achieved either the **efficiency classes A or B**.
- However, the range of system efficiency is still very wide – the least efficient system only achieved the **efficiency class G**.

Main topics of the Energy Storage Inspection 2024

1 Analysis of the German market for residential PV-battery systems

2 Comparison of the system properties based on the test reports according to the Efficiency Guideline

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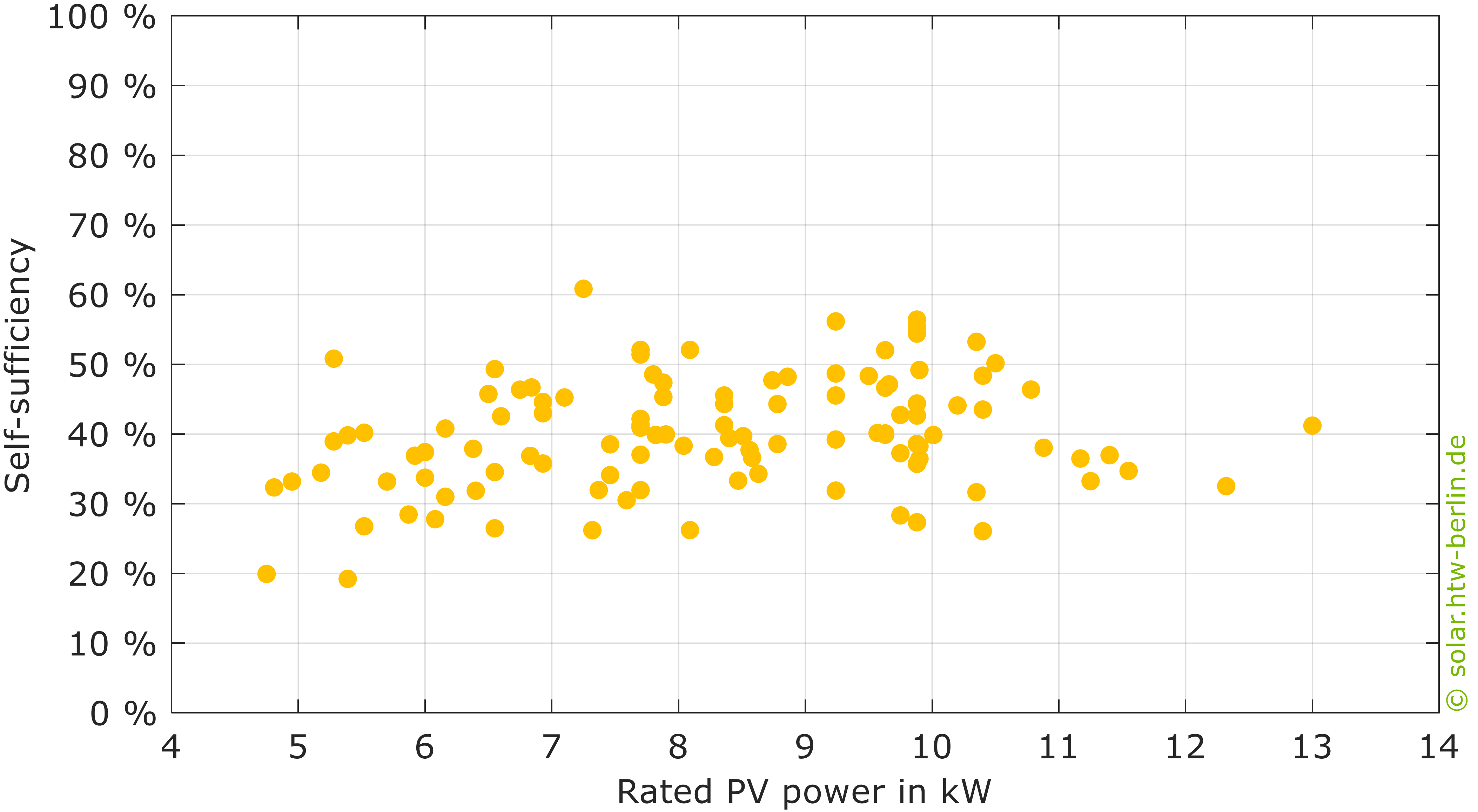
4 Comparison of the operating data of PV-battery systems

Operating data analysis of PV-battery systems

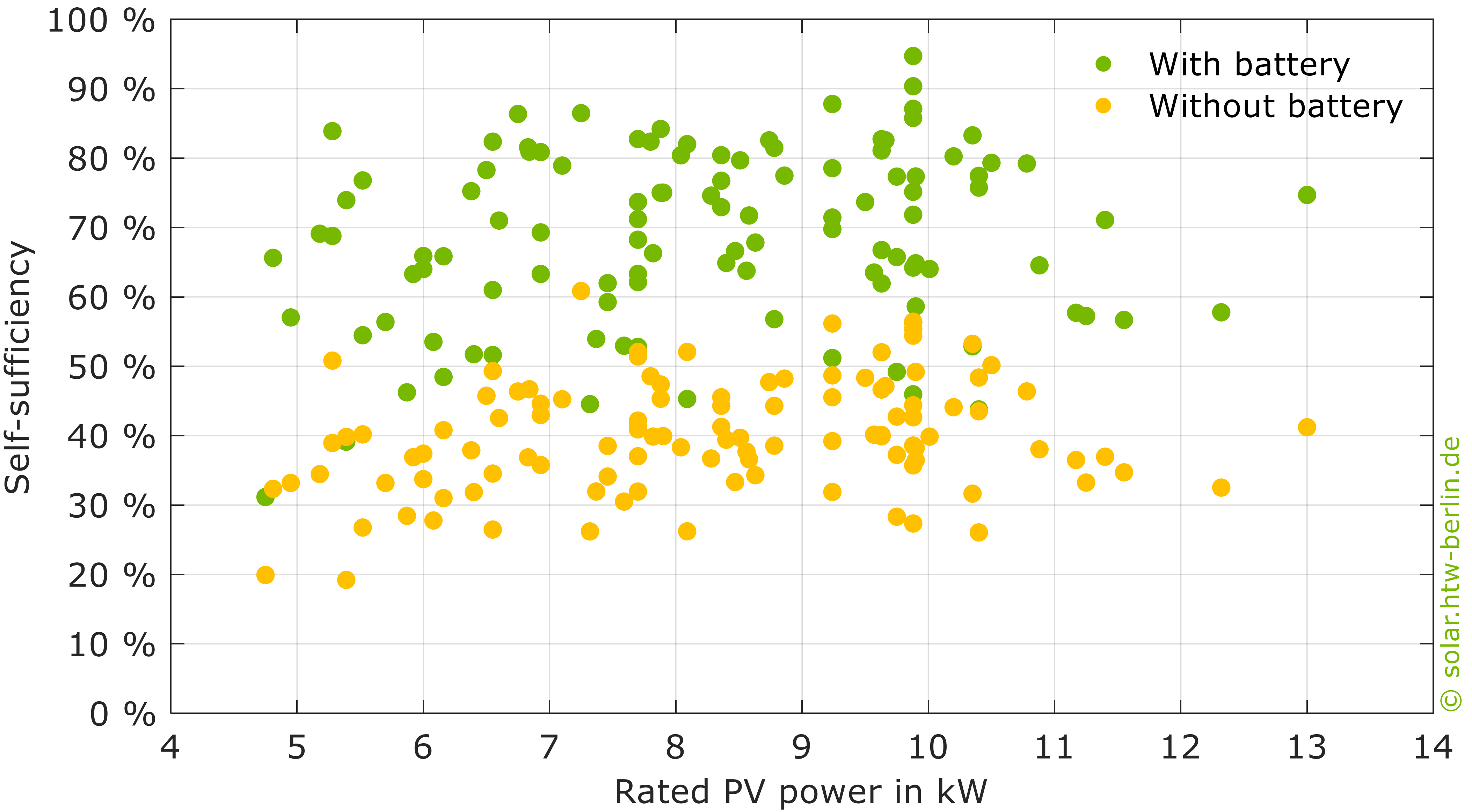
- In the fourth topic of the 2024 energy storage inspection, the operating results of **more than 100 households** with PV systems and battery storage were compared.
- For the analysis, the companies Eigensonne and Kostal provided operating data from several hundred residential homes.
- In addition to the measurement data for the **operating year of 2022**, information on the rated PV power and the usable storage capacity of the installed battery storage system of the 110 compared households is available.
- Among other things, the chapter answers the questions of how much the **degree of self-sufficiency** of different residential buildings with PV systems varies and by how many percentage points a battery storage system increases solar-electric self-sufficiency.
- The following results and graphs are explained in detail in the **Energy Storage Inspection 2024**.

Degrees of self-sufficiency with different PV power outputs



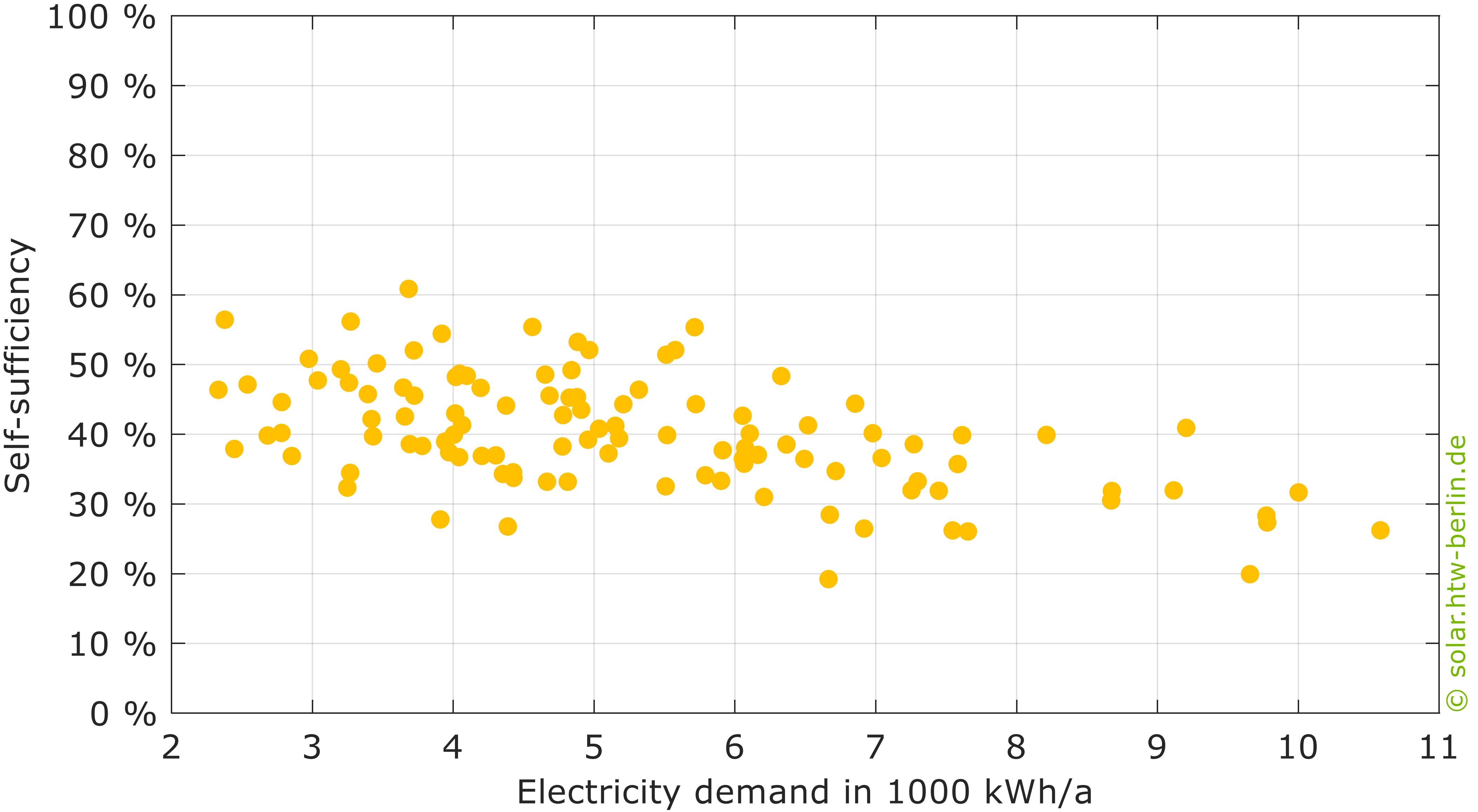
With a PV system, the analyzed households achieve a degree of self-sufficiency between 19 % and 61 %. The average self-sufficiency achieved by households with a PV system is 40 %.

Increase in self-sufficiency by using a battery storage system



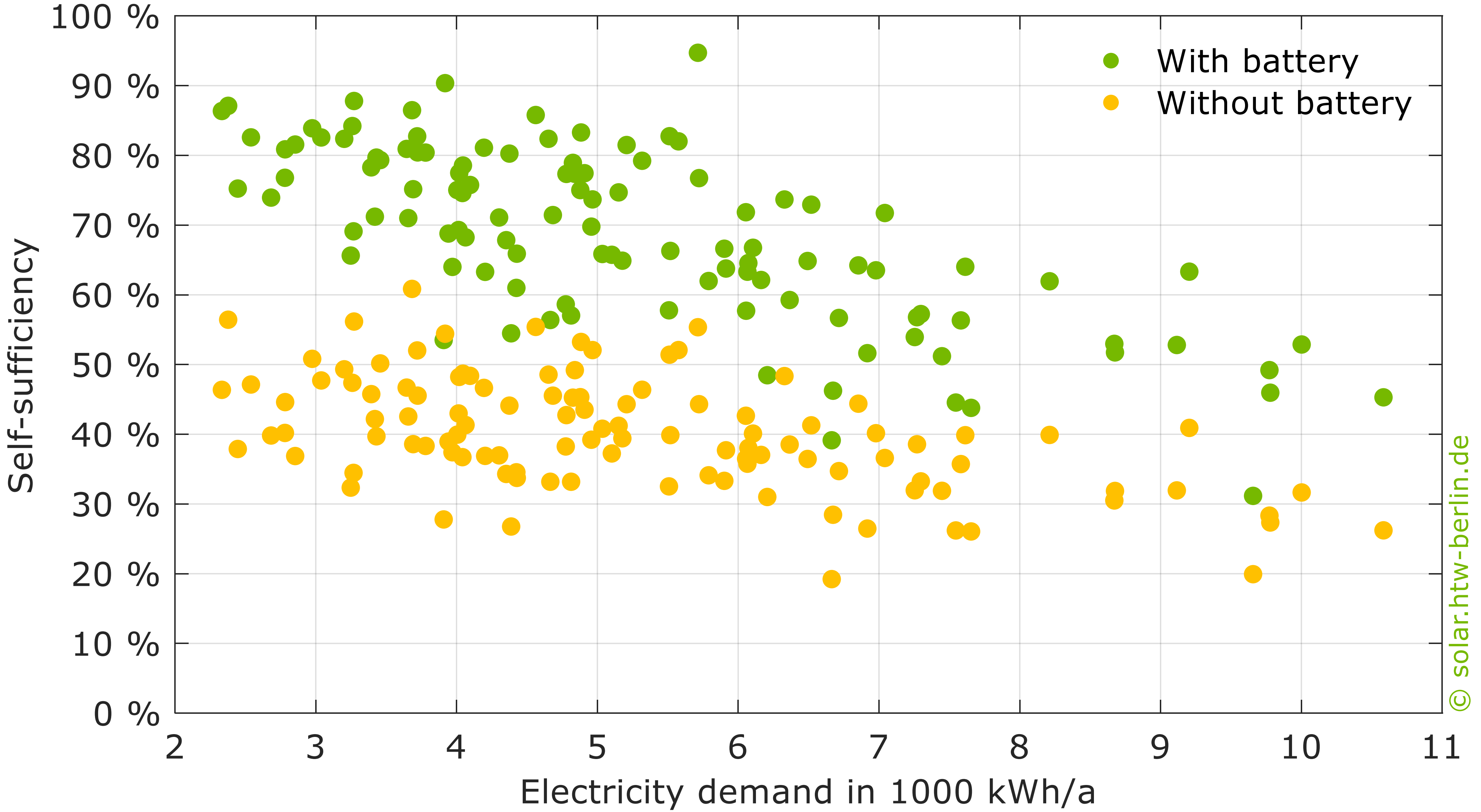
By installing a battery storage system, households achieve self-sufficiency levels between 31 % and 95 %. The median is 70 % - on average, households with a PV-battery system only draw 30 % of their power demand from the public grid.

Self-sufficiency depending on the annual electricity consumption



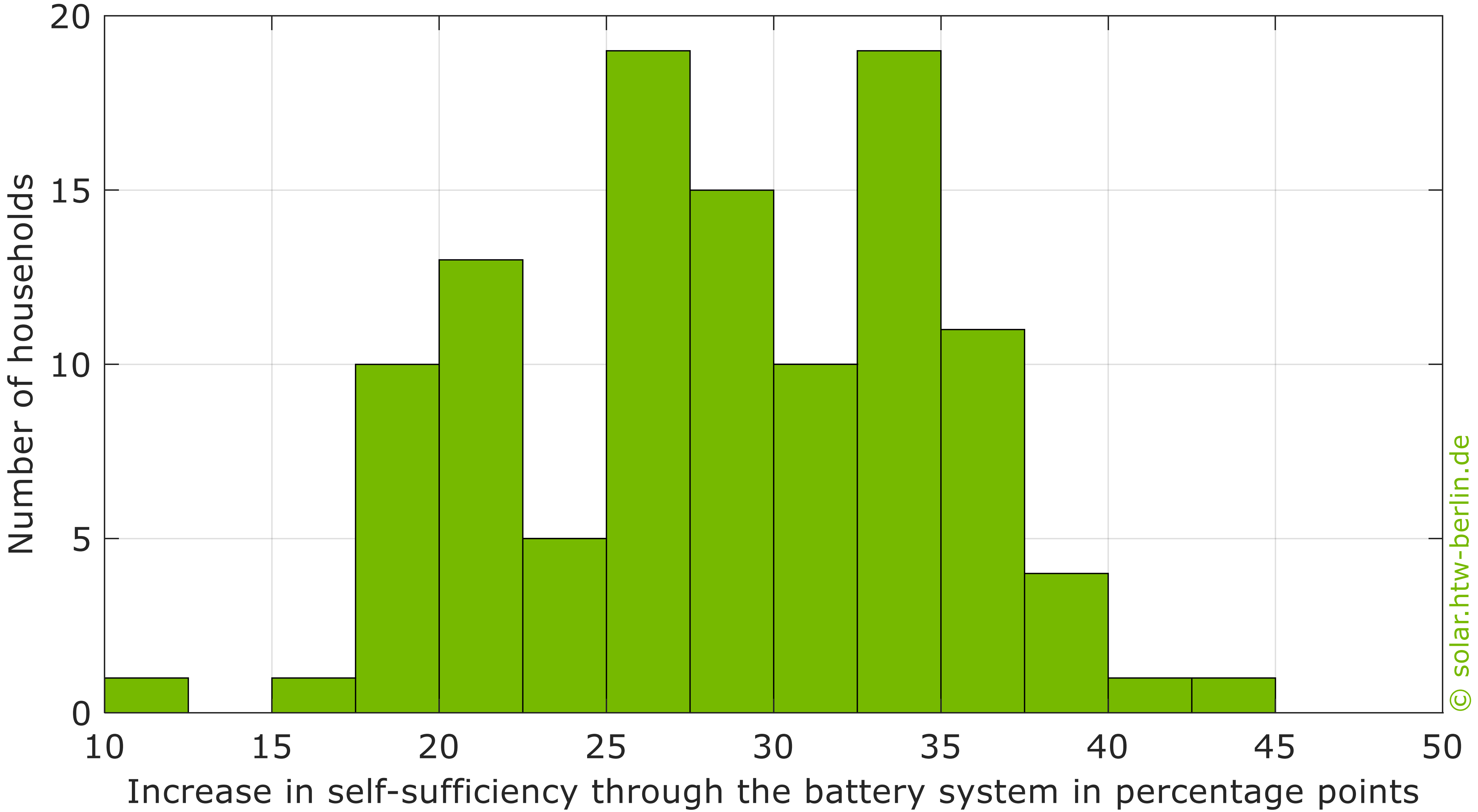
On average, the degree of self-sufficiency of the observed households with a PV system decreases by 2.2 % as the electricity consumption increases by 1000 kWh/a. The degrees of self-sufficiency of the households vary by up to 25 percentage points.

Increase in self-sufficiency by using a battery storage system



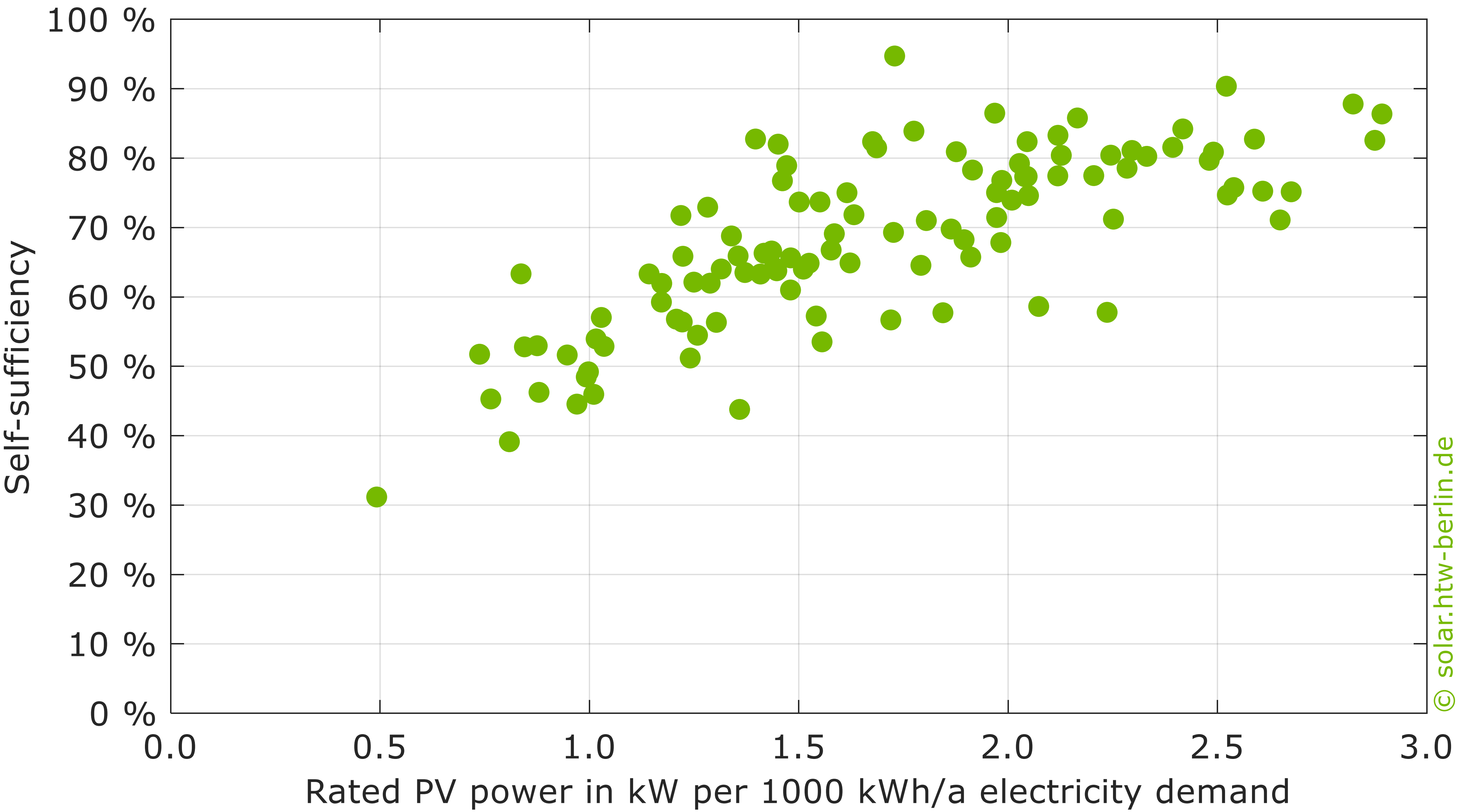
It can be observed that battery storage systems have a greater influence on increasing the degree of self-sufficiency of a household, especially of those with a low annual electricity consumption.

Frequency distribution of the increase in self-sufficiency



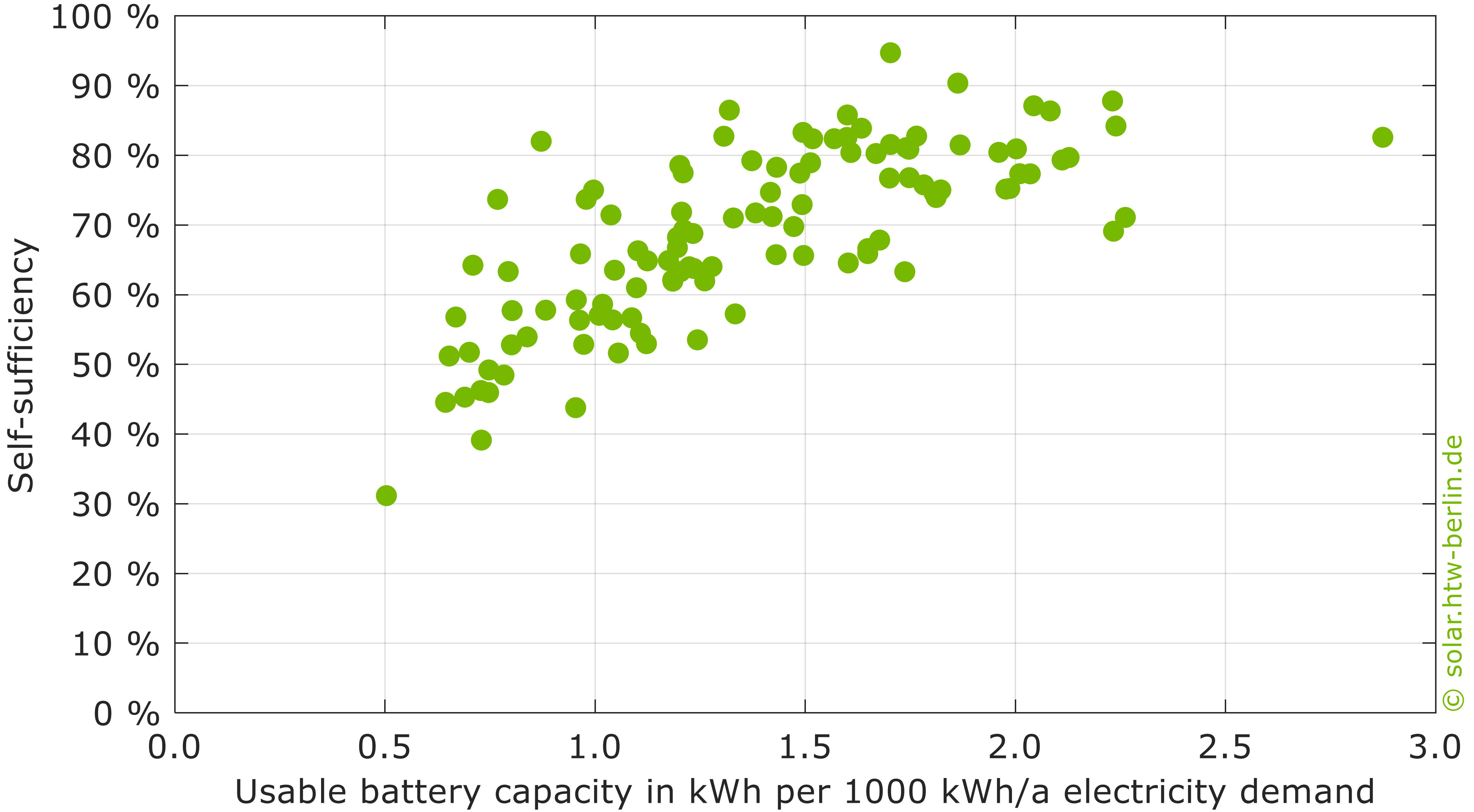
The battery storage systems increase the degree of self-sufficiency of the analyzed households by between 15 percentage points to 45 percentage points. On average, the degree of self-sufficiency can be expected to increase by 30 %, as the median shows.

Degrees of self-sufficiency depending on the normalized PV power



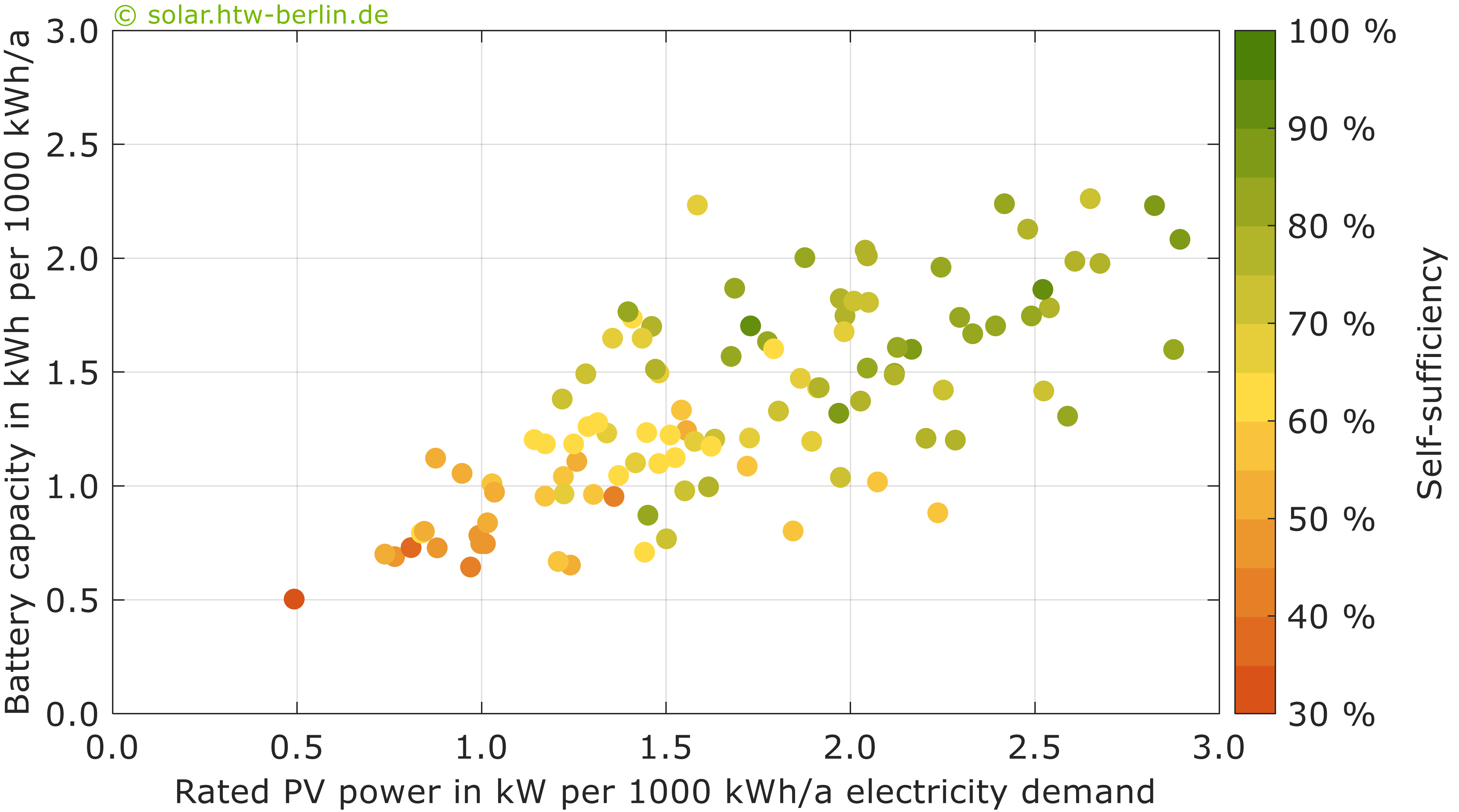
The degree of self-sufficiency of the investigated households with PV-battery system tends to increase with the ratio of PV power to annual electricity demand. From a ratio of 2.0 kW per 1000 kWh/a on, an increasing saturation effect can be observed.

Degrees of self-sufficiency depending on the normalized capacity



The significance of the system dimensioning on the increase in the degree of self-sufficiency becomes particularly clear when considering the normalized battery capacity.

Influence of system dimensioning on the self-sufficiency



While an increase in storage capacity and rated PV power has a positive effect on self-sufficiency, the degree of self-sufficiency achieved differs greatly in some cases despite similar system dimensioning. This is mainly due to differences in the load profiles.

Summary of the results of the operating data analysis

- By installing a PV system with a rated output power between 4.8 kW and 13 kW, the inspected homes achieve an average **degree of self-sufficiency of 40 %**.
- In nine out of ten households, the battery storage system can increase the degree of self-sufficiency by **18 to 38 percentage points**.
- Solar-electric self-sufficiency with a PV system and a battery storage system reduces the amount of electricity drawn from the grid by an **average of 70 %**.
- The benefits of a solar storage system are significantly influenced by demand-based dimensioning, consumption behavior, and the efficiency of the system components.
- For better comparability of the operating results of PV battery systems, it is advisable to **normalize** the rated output power of the PV system and the usable storage capacity **to the annual electricity consumption**.

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ENERGY STORAGE

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