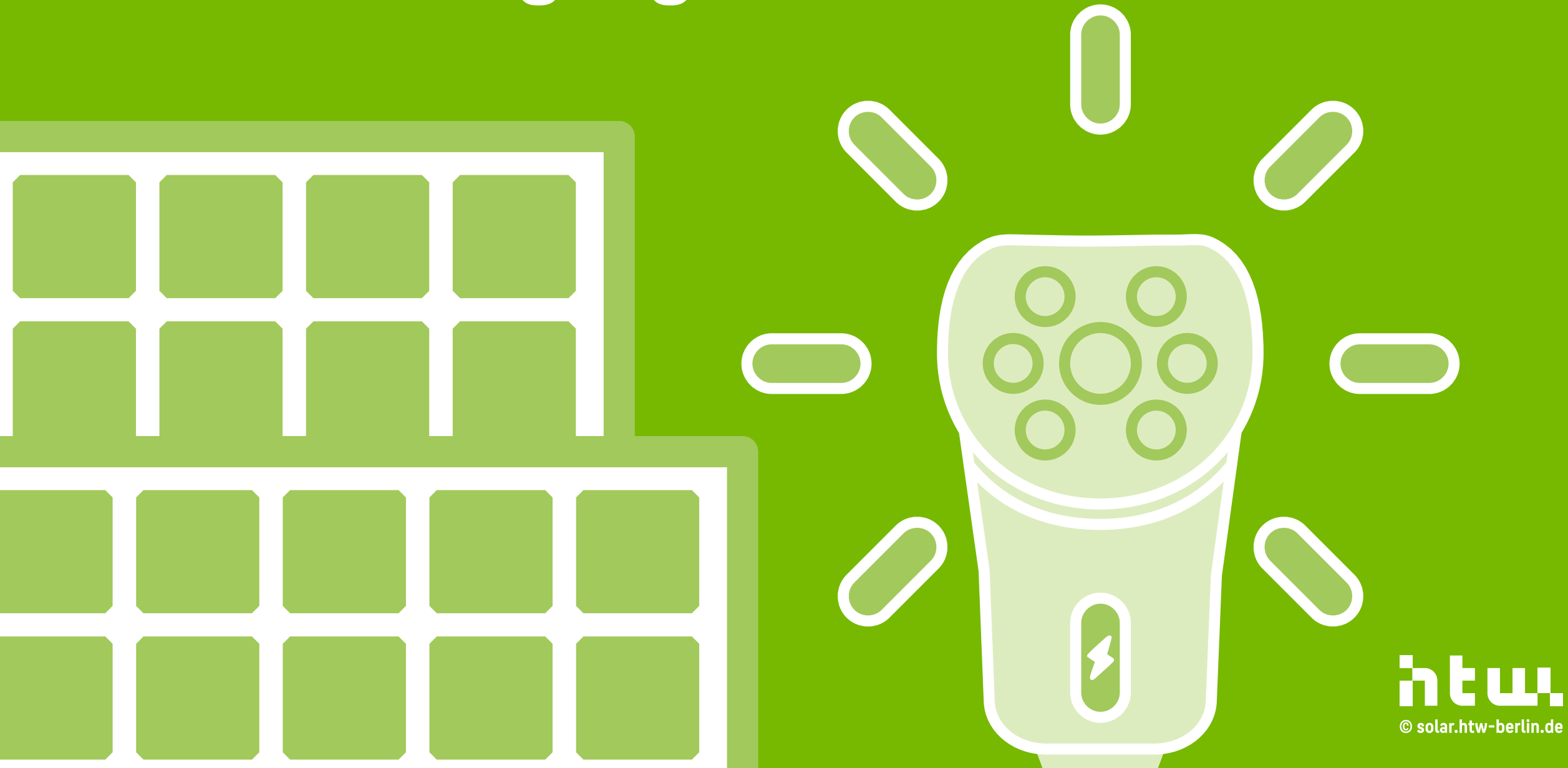


Solar Charging of Electric Vehicles



SOLAR CHARGING of Electric Vehicles



Supported by:



on the basis of a decision
by the German Bundestag

Presentation on the study
Solar Charging of Electric Vehicles

Authors

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Joseph Bergner
Simon Salehi

Research Group – Solar Storage Systems
HTW Berlin – University of Applied Sciences

Version

Version 1.0 (April 2025)

Web

solar.htw-berlin.de/studien/solares-laden-von-elektrofahrzeugen

75 kWh

average usable battery capacity¹

11 kW

standard onboard charger power (AC)

390 km

average range

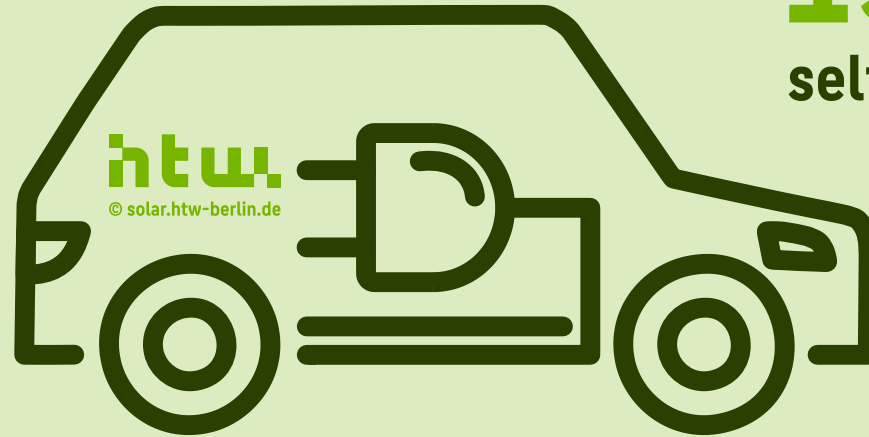
8 years

or 160 000 km driven:
average warranty period
of the battery²

20 kWh per 100 km

average consumption¹

Key Facts on



Electric Vehicles

150 to 350 W

self consumption³

76 %

average efficiency of
the charger at 1,4 kW³

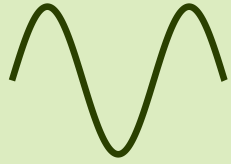
90 %

average efficiency of
the charger at 11 kW³

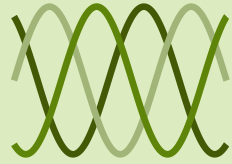
Data: ^{1,2} ADAC, ³ Sevdari et al.

automatic phase switching

51%



single-phase charging



three-phase charging



energy management

for solaroptimized charging (internal):

76%

internet access

WiFi: 61%

cable: 74%

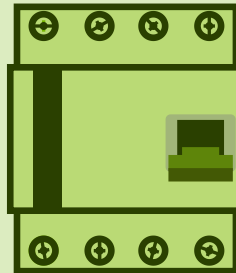


pre-installed current breaker

DC 6 mA: 95%

RCD type A: 28%

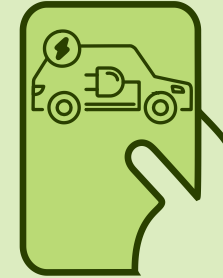
RCD type B: 12%



Equipment



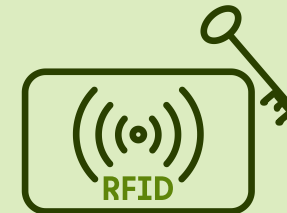
**of home
chargers**



interface

display: 24%

app: 69%



access control

RFID: 80%

**upgradeable for
bidirectional charging**

26%



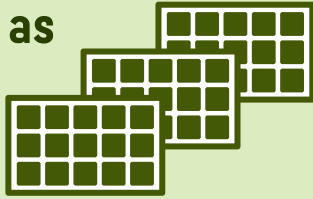
energy meter

MID-meter: 46%

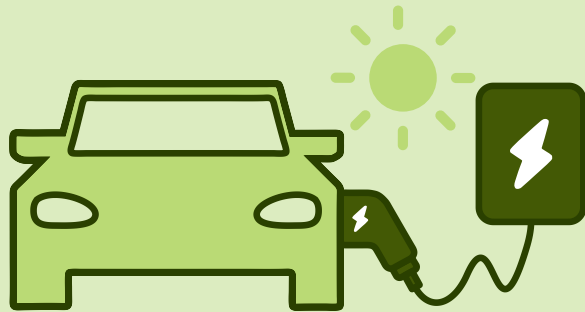
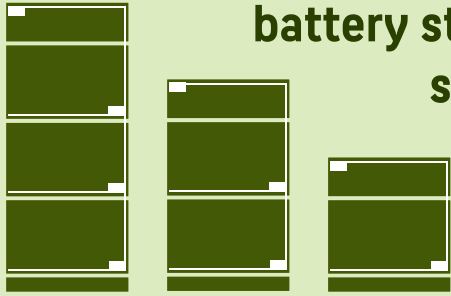
compliant with
calibration law: 14%

Technical equipment of 105 AC home charger with one charging point and power output up to 22 kW. Data: pv magazine wallbox market overview.

install as much
pv power as
possible



consider a reasonably sized
battery storage
system



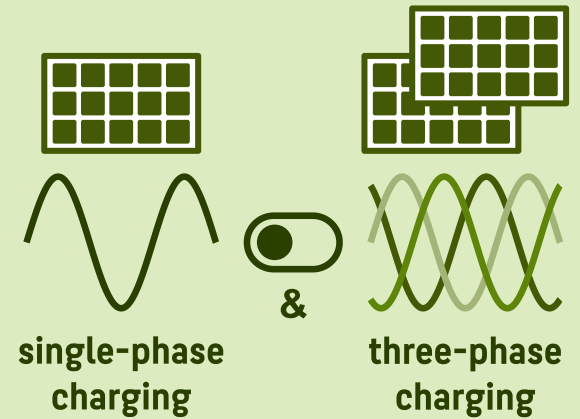
Make it a habit to plug in the vehicle
regularly during the day

Recommendations for increased solar share on electric vehicle charging

check your mobility
behaviour

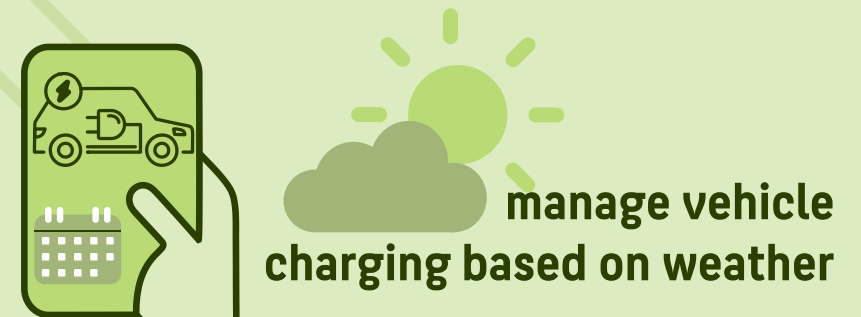


match home chargers output and
solar power



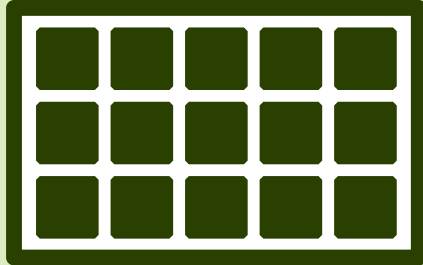
single-phase
charging

three-phase
charging



Statistical description of operational data of home chargers

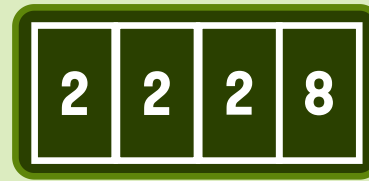
9.9 kW



Median values

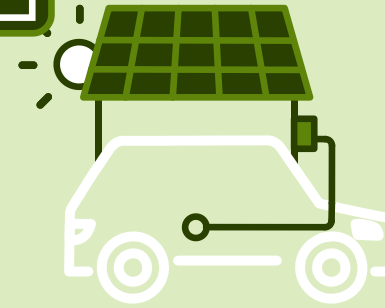


number of days
per week with
charging: 3.9



kWh/a

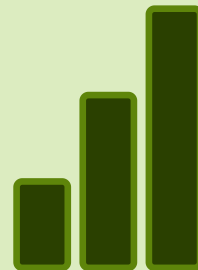
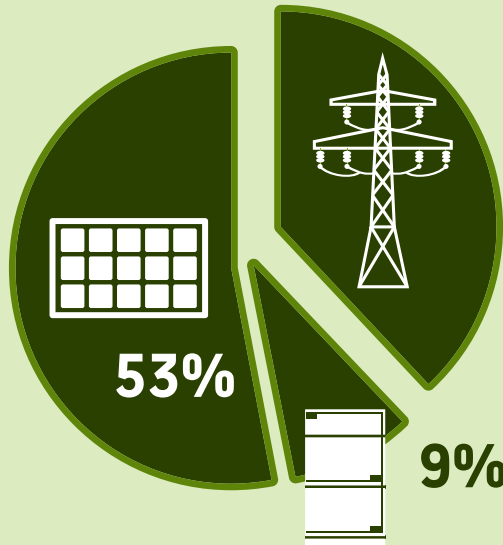
charged
at home



93% in
stand-by
mode



solar
share on
electric vehicle charging



25% increase if charging follows
solar surplus dynamically

Fronius

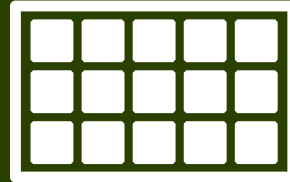
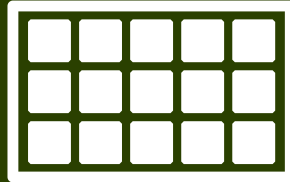
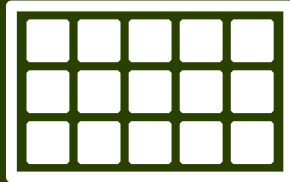
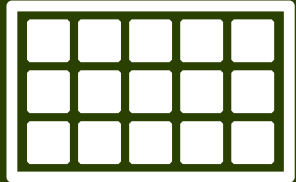
Data:

htw

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Median values of 730 households with a solar system power of up to 30 kW and a home charged energy of the electric vehicle of up to 7000 kWh/a.

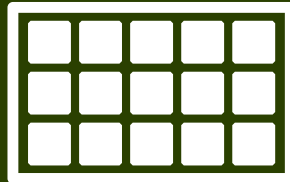
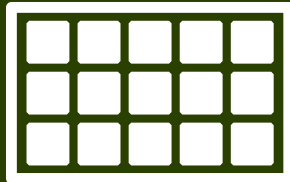
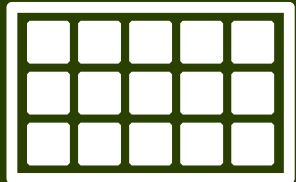
Median solar share for an annual mileage of 10 000 to 15 000 km



15 kW to
20 kW

n = 40

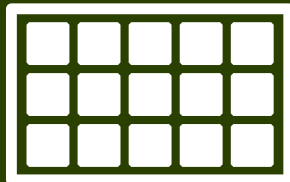
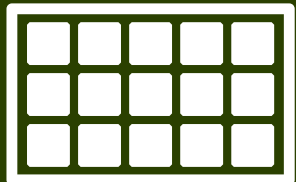
62%



10 kW to
15 kW

n = 58

53%



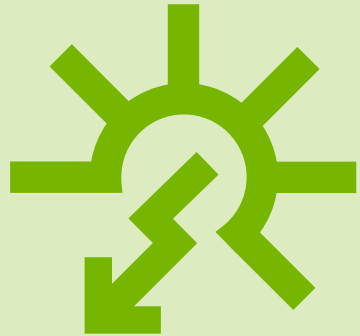
5 kW to
10 kW

n = 112

46%

Median solar share on EV charging of 2000 kWh/a up to 3000 kWh/a. Assumed energy demand: 20 kWh per 100 km.

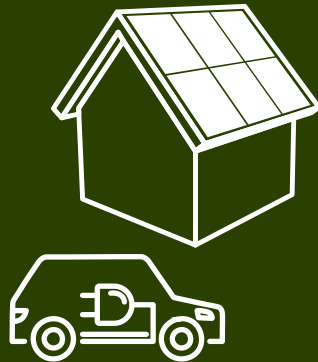
Median degree of self-sufficiency of differently equipped residential buildings



household
equipment
(pv system,
electric vehicle,
battery storage,
heat pump)

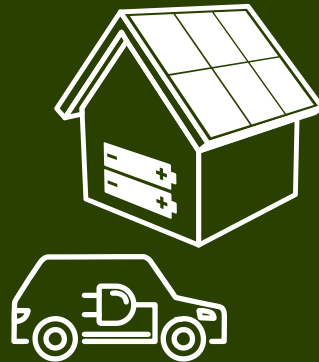
median electricity
consumption in kWh/a

47%



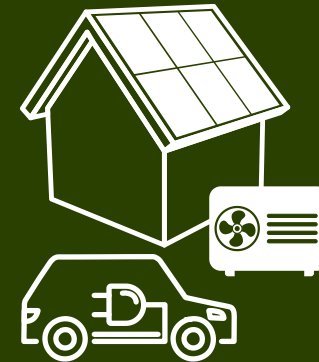
6200

73%



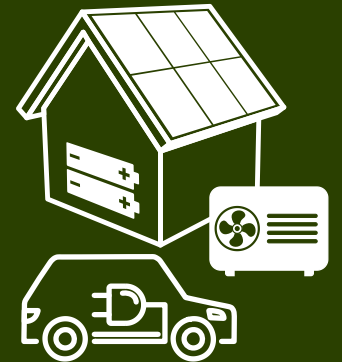
6900

36%



10 100

59%



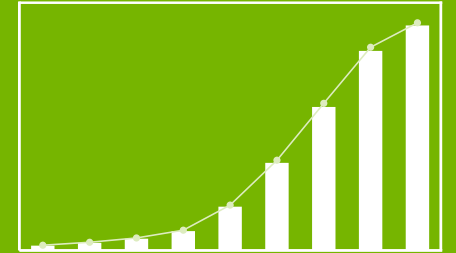
10 500

Median electricity consumption and self-sufficiency levels of 730 households with different equipment and pv system power up to 30 kW. Data: Fronius International.

Scope of the study „Solar Charging of Electric Vehicles“

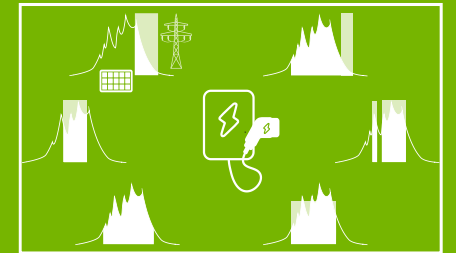
1

German market overview for electric vehicle and home chargers



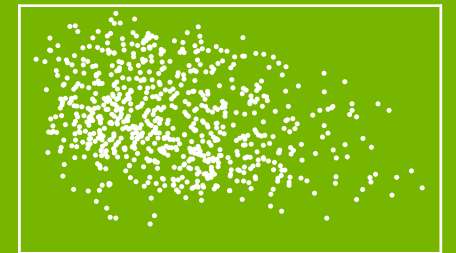
2

Features of smart unidirectional AC-home chargers

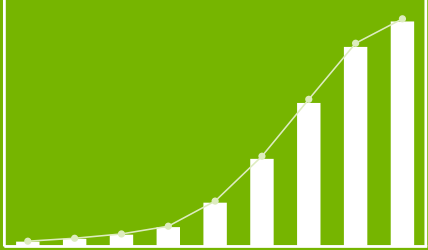
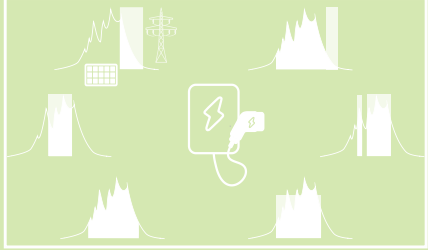



3

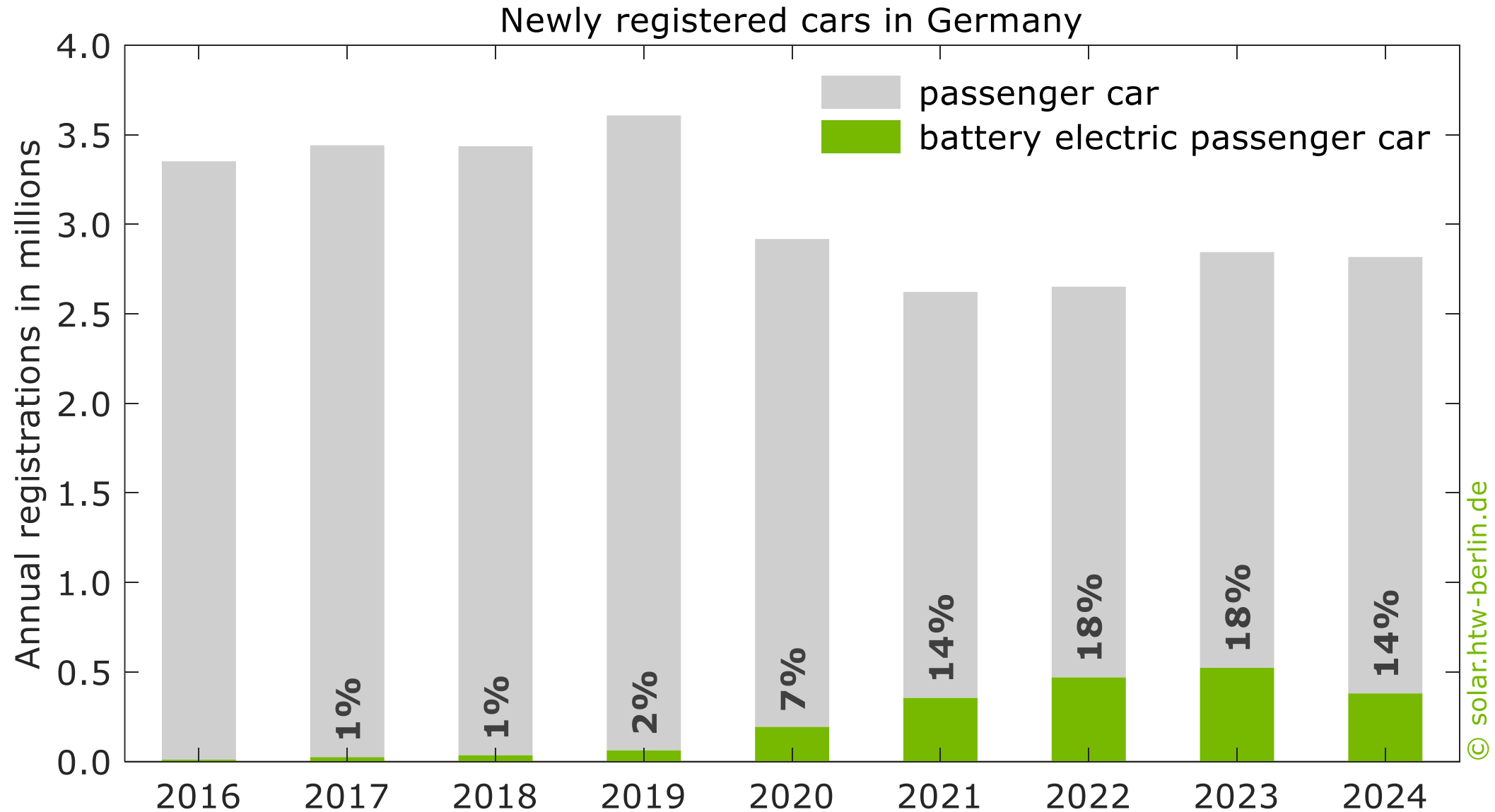
Comparison of energy flows in households with PV systems and electric vehicles



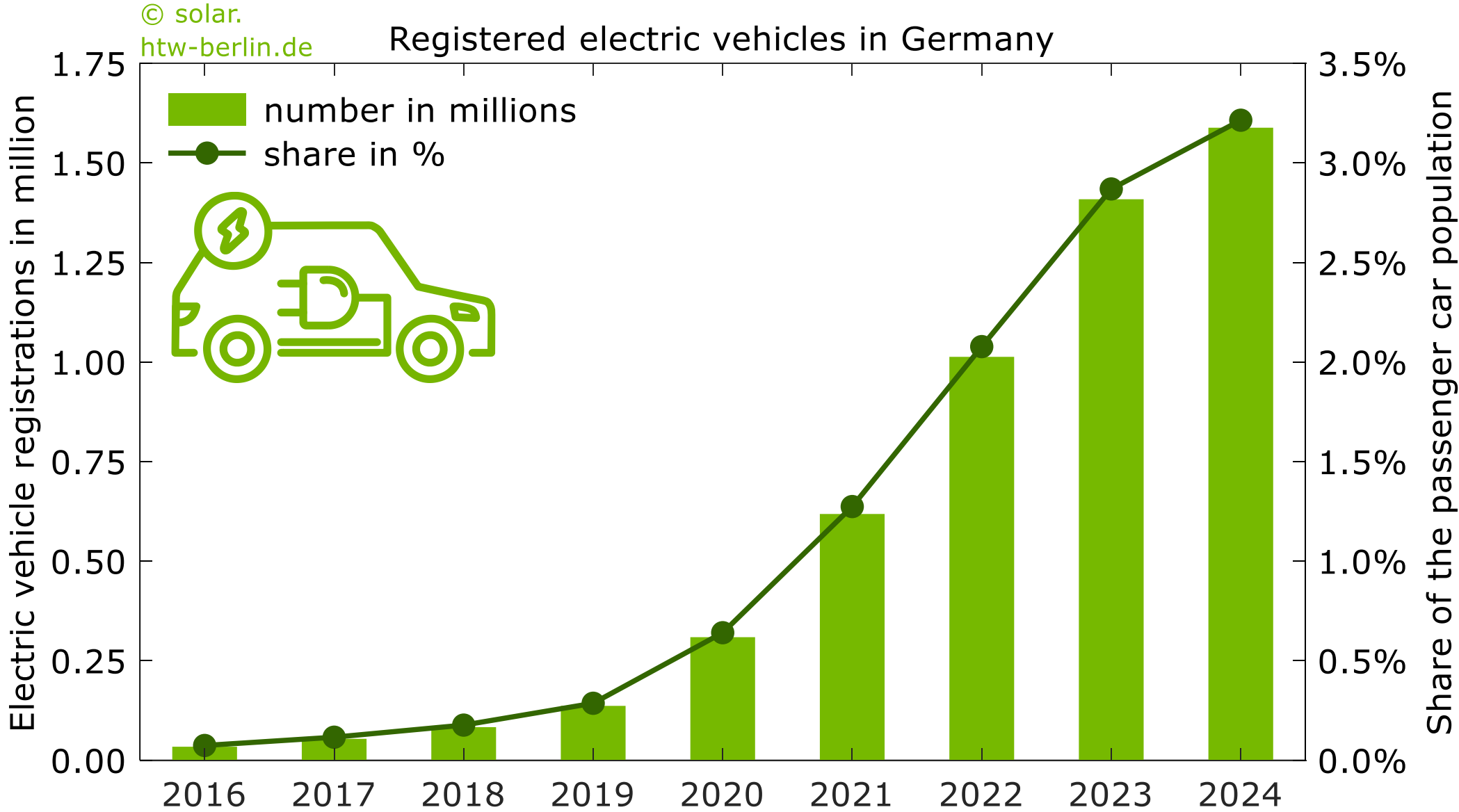
Scope of the study „Solar Charging of Electric Vehicles“

1	German market overview for electric vehicle and home chargers	
2	Features of smart unidirectional AC-home chargers	
3	Comparison of energy flows in households with PV systems and electric vehicles	

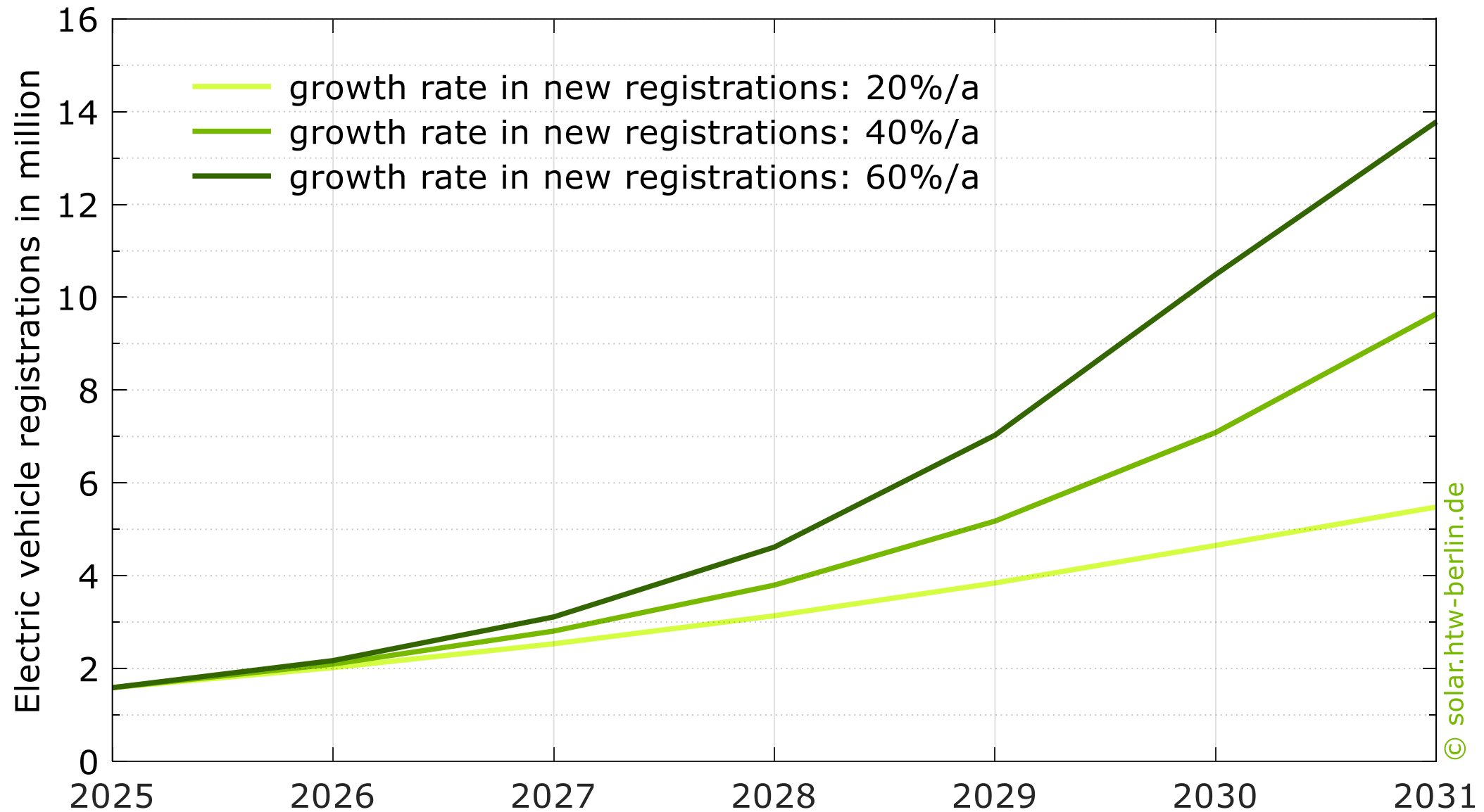
Market development for electric vehicles in Germany



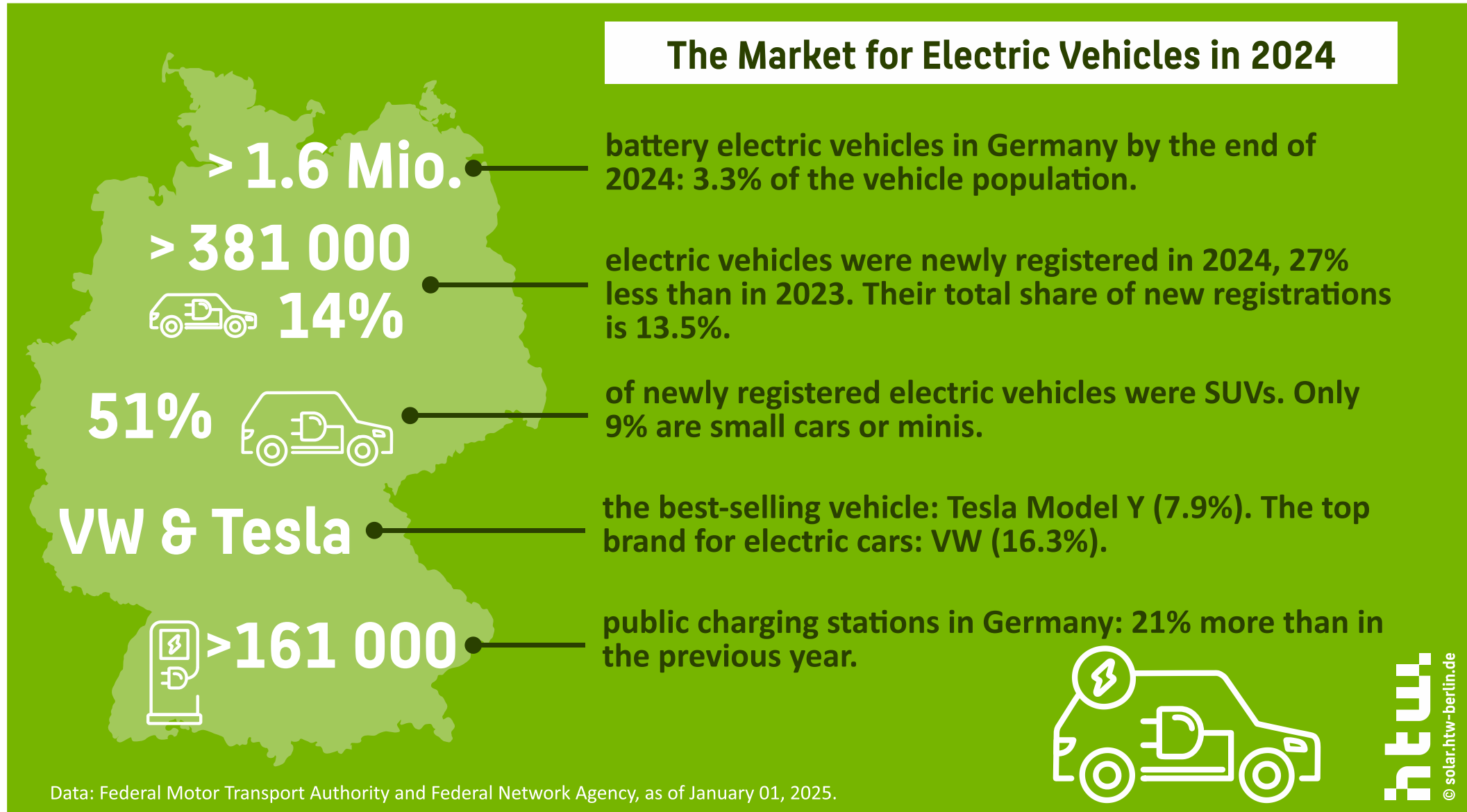
Development of the electric vehicle stock in Germany



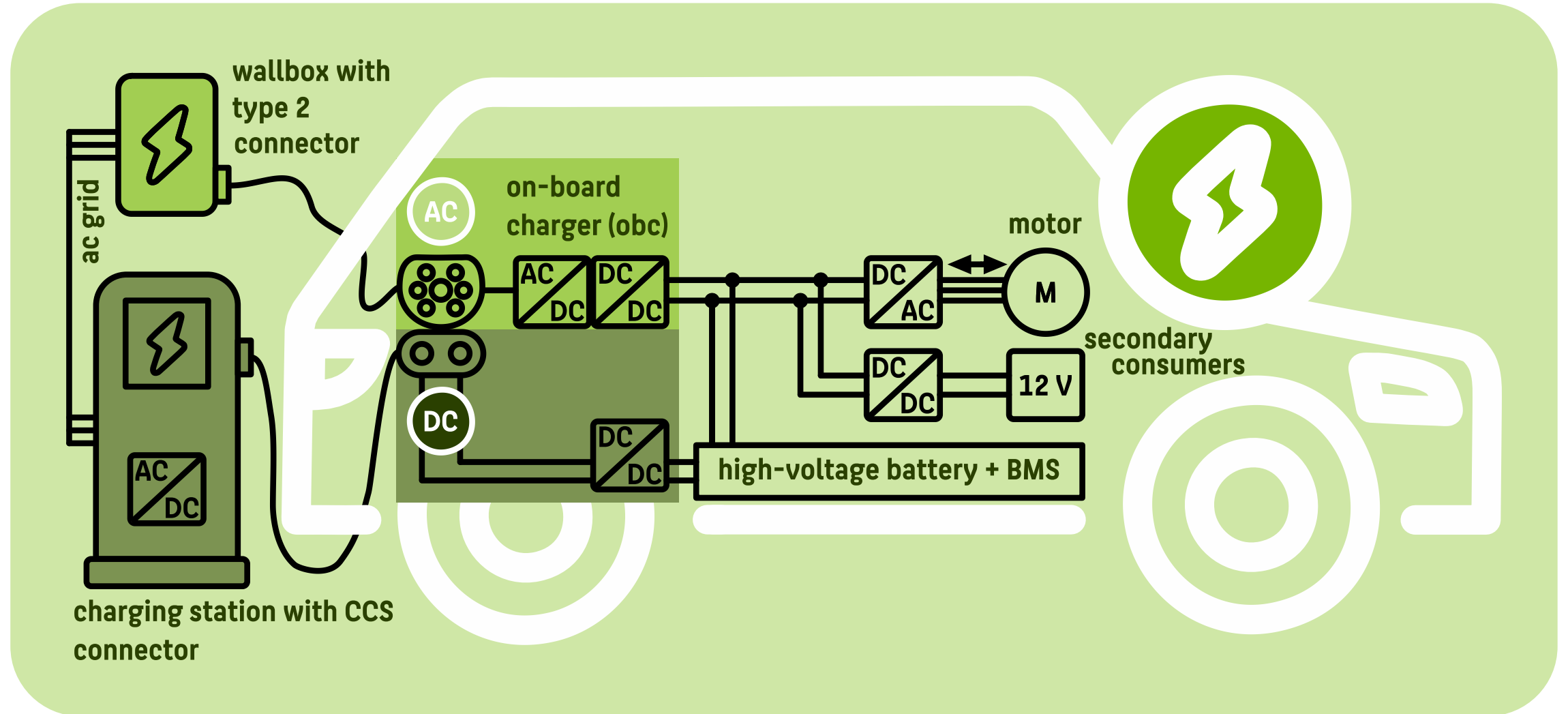
Development of the stock of electric vehicles in Germany until 2031



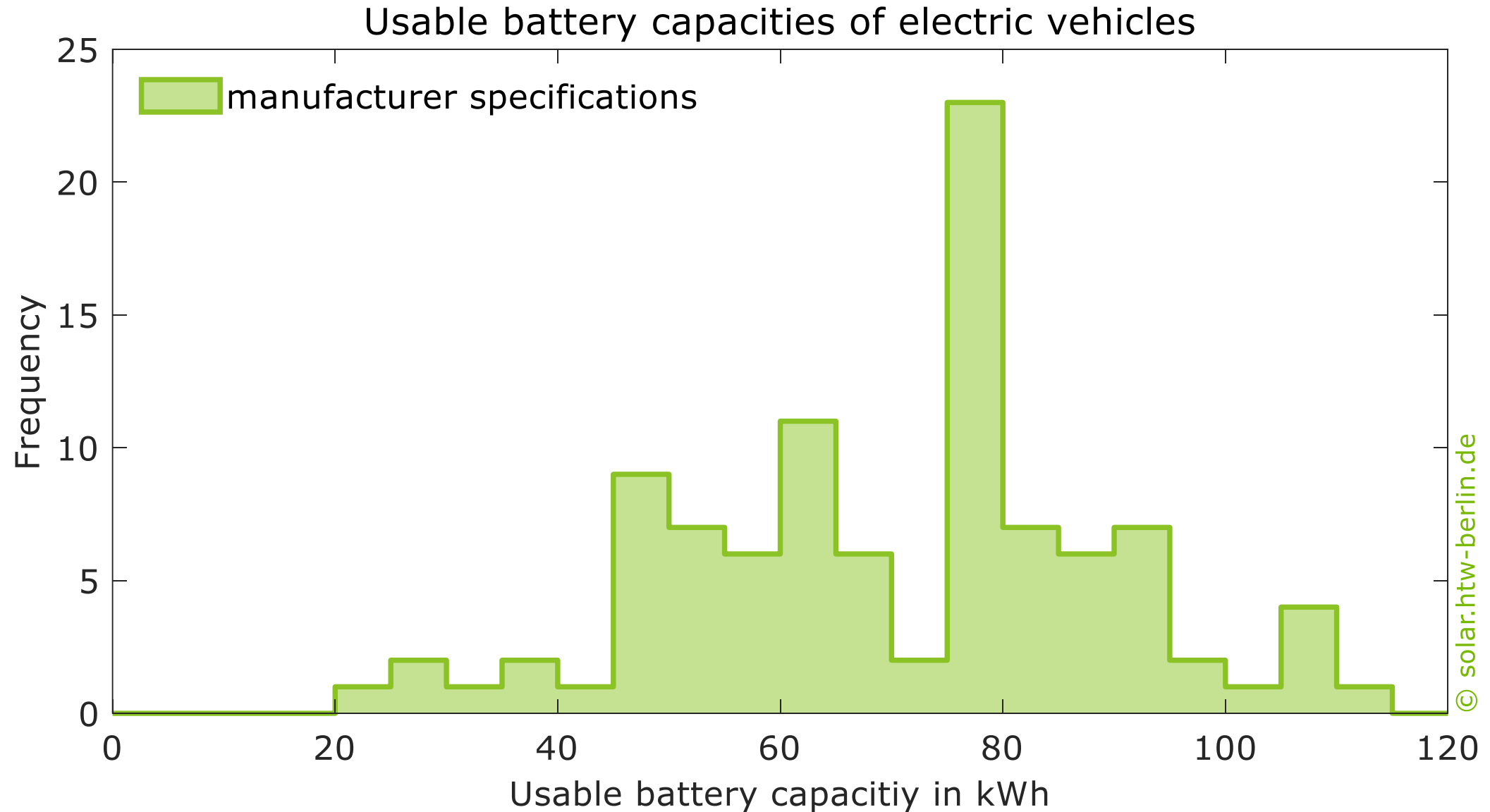
Figures on the market for electric vehicles in Germany in 2024



Structure and charging process of electric vehicles

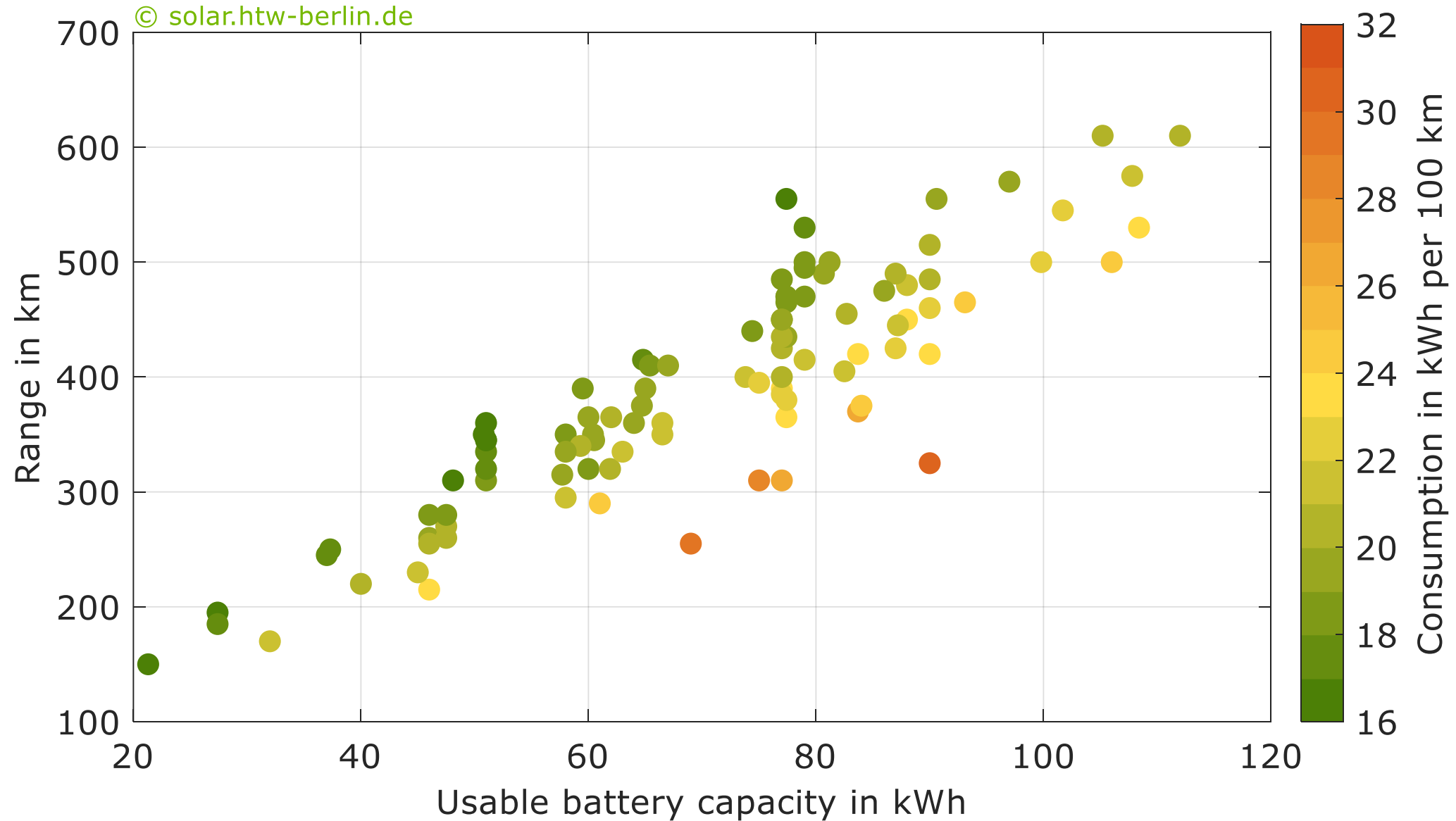


Usable battery capacities of various electric vehicles



Manufacturer specifications for the net capacity of 88 electric vehicles. Data: ADAC, as of 3/2025 (electric vehicles in the test: This is how long the range really is).

Range and consumption of various electric vehicles



Manufacturer specifications on net capacity and data from the ADAC Ecotest of 88 electric vehicles, as of 3/2025 (electric vehicles in the test: This is how high the range really is).

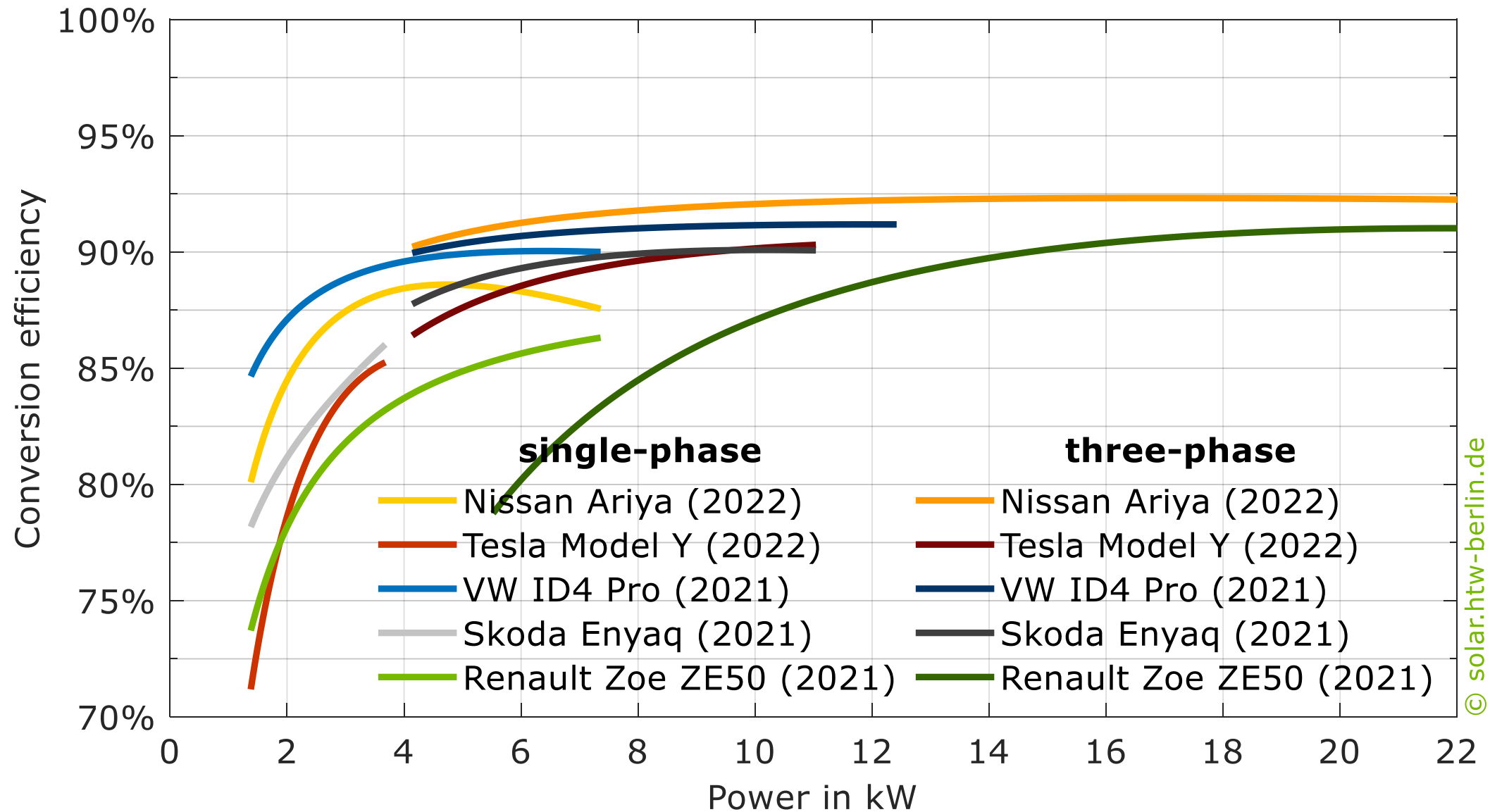
Self-consumption of electric vehicles

- Among other things, the auxiliary units and control units in the 12 V on-board network draw power when switched on.
- Active sensors and monitoring can increase the consumption significantly.
- The increased self-consumption contributes to the high losses when charging at low power.

manufacturer and vehicle model	self-consumption
Nissan Leaf e+	150 W
Renault Zoe 40	200 W
VW ID3 and VW ID4	250 W
Kia EV6 and Kia e-Niro	250 W
Tesla Model 3 and Tesla Model Y	350 W

Data: Sevdari et al. (Experimental validation of onboard electric vehicle chargers to improve the efficiency of smart charging operation).

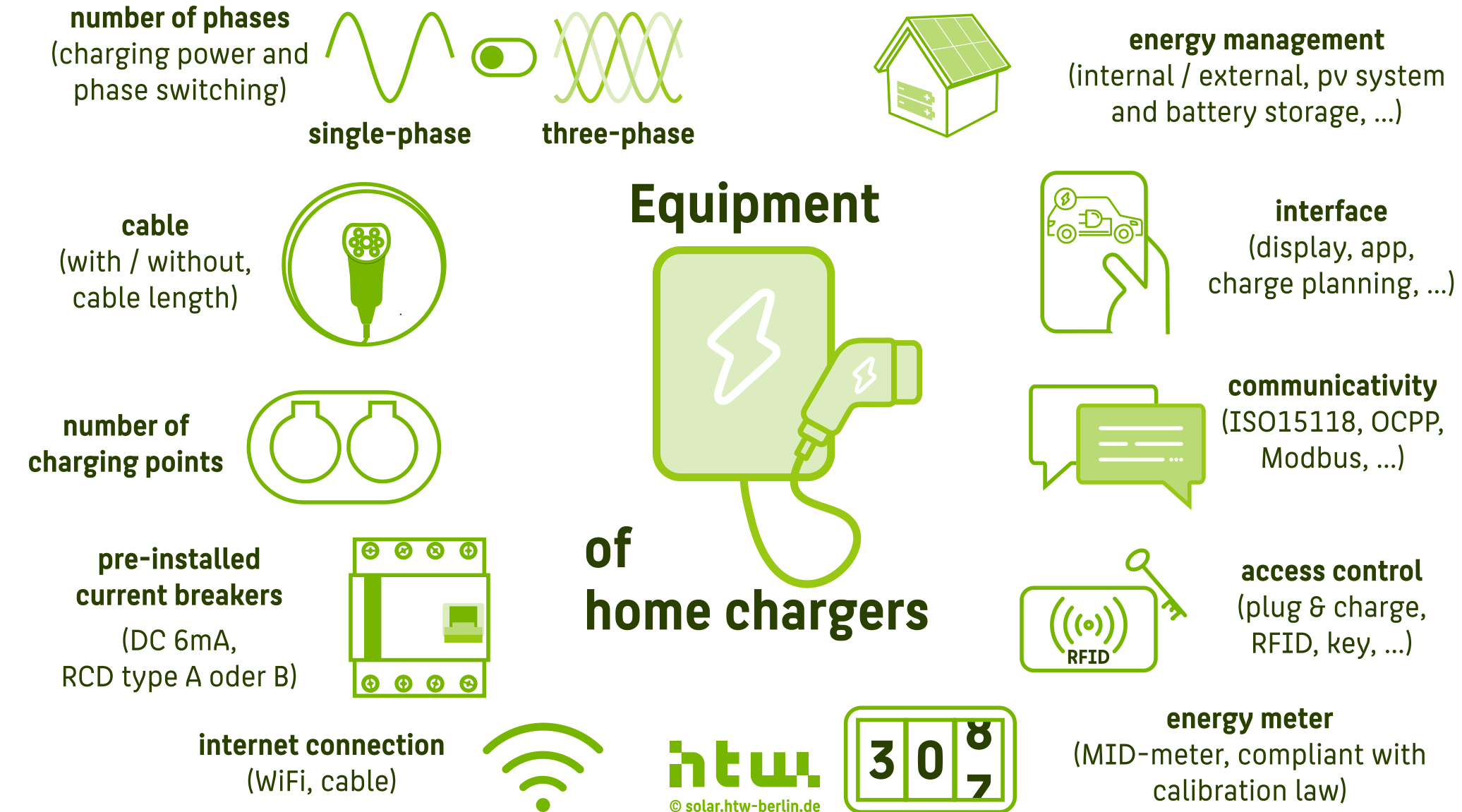
Charging efficiency of various electric vehicles



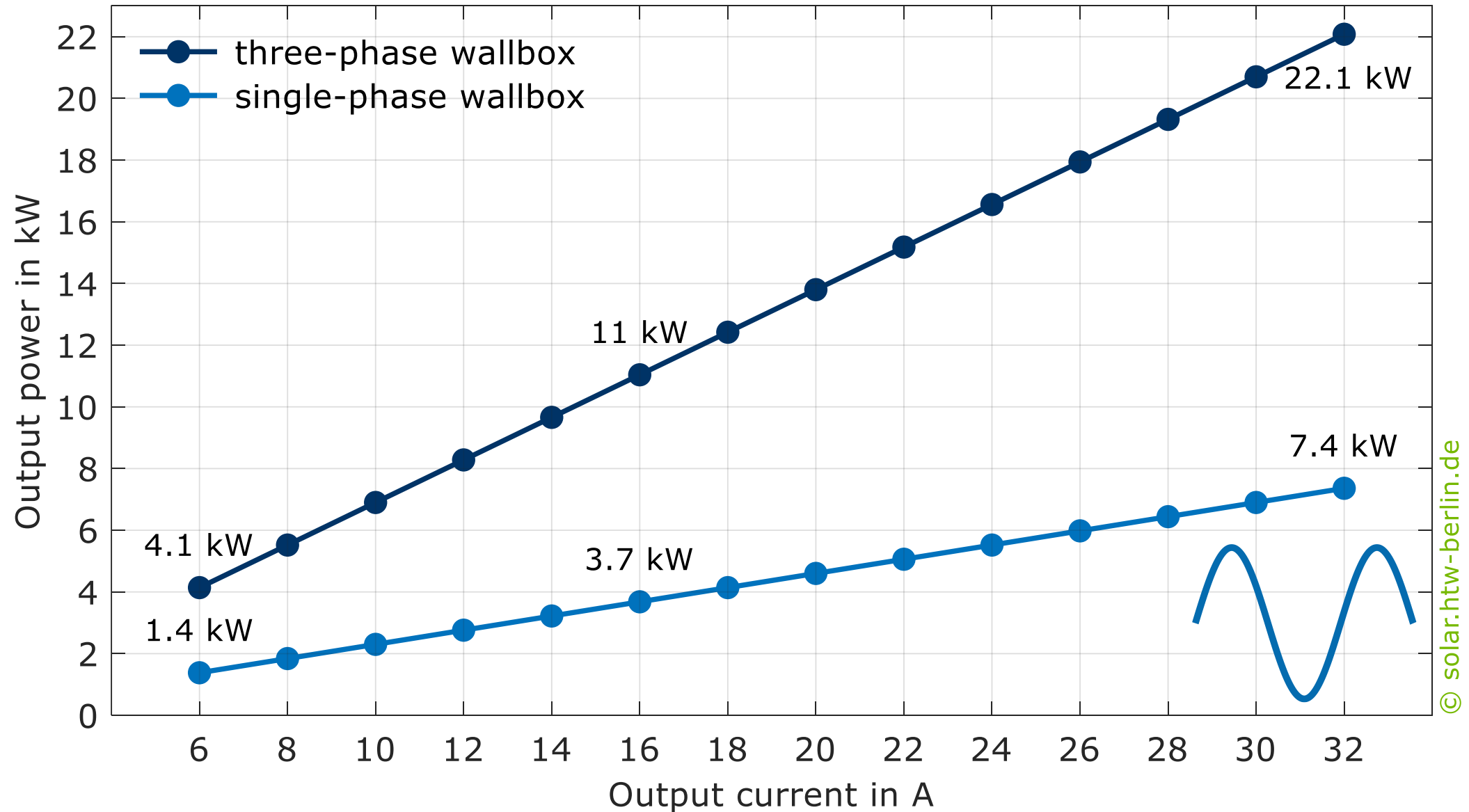
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Data: Sevdari et al. (Experimental validation of onboard electric vehicle chargers to improve the efficiency of smart charging operation).

Equipment of home charger solutions

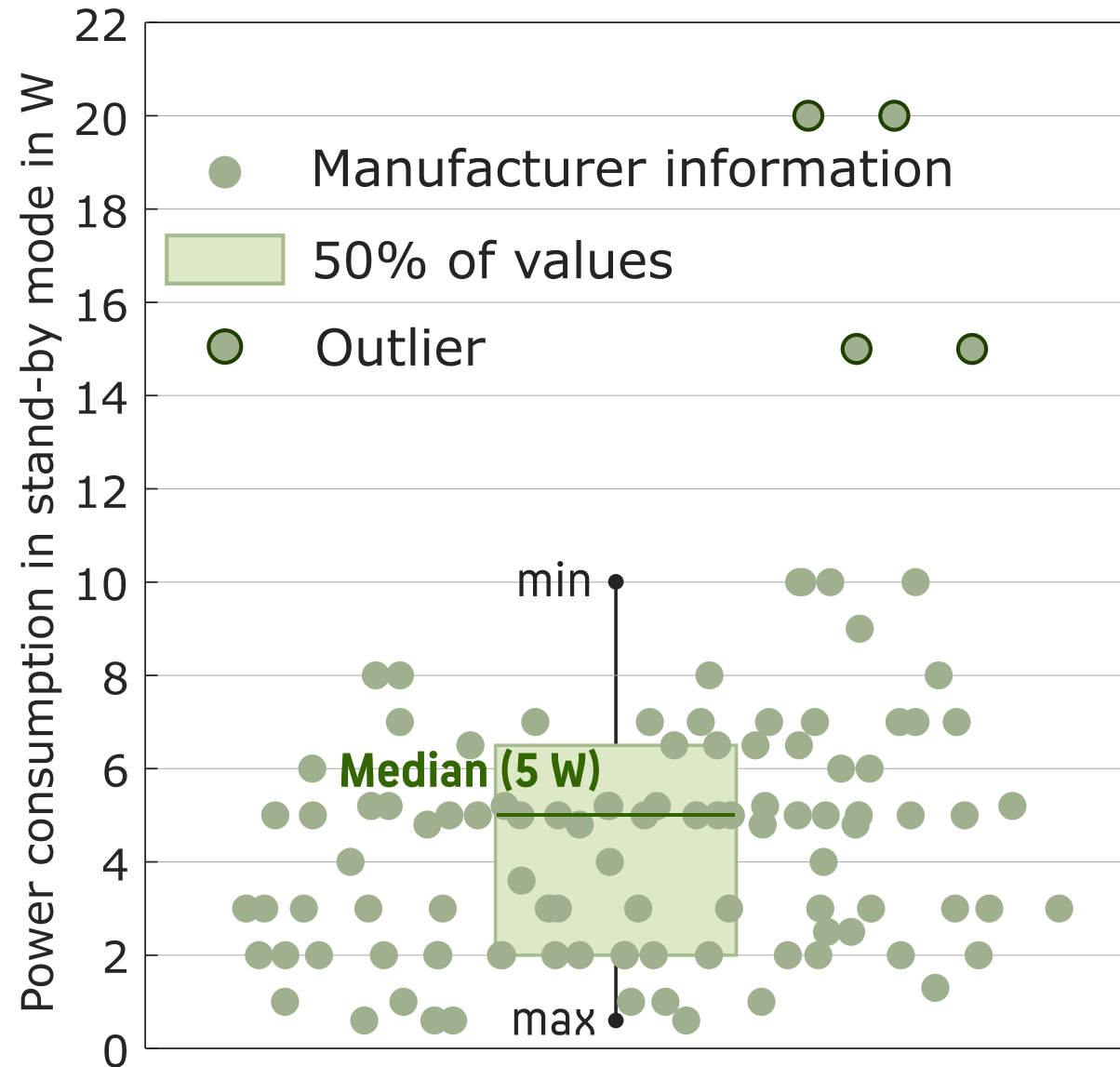


Output Power and Output Current of Wallboxes



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Power consumption in stand-by mode



Standby-by consumption

Home charging stations



105 products



28 manufacturer

Differences e.g. by:



WLAN / LTE / Bluetooth



RFID module



Display / LED



sleep mode

A++

energy-efficient components

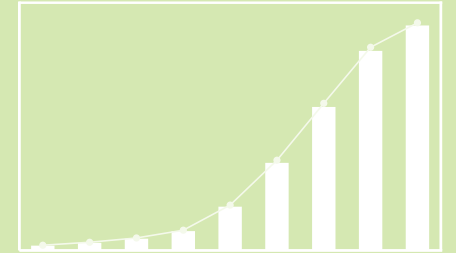
Data: pv magazine

htw
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Scope of the study „Solar Charging of Electric Vehicles“

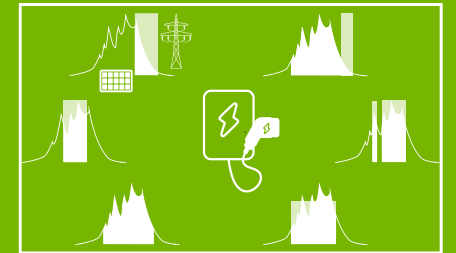
1

German market overview for electric vehicle and home chargers



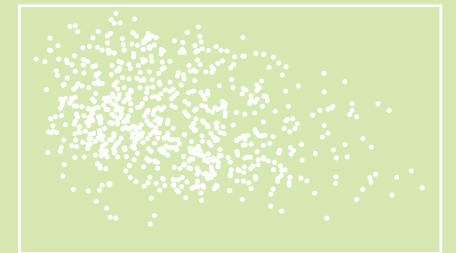
2

Features of smart unidirectional AC-home chargers

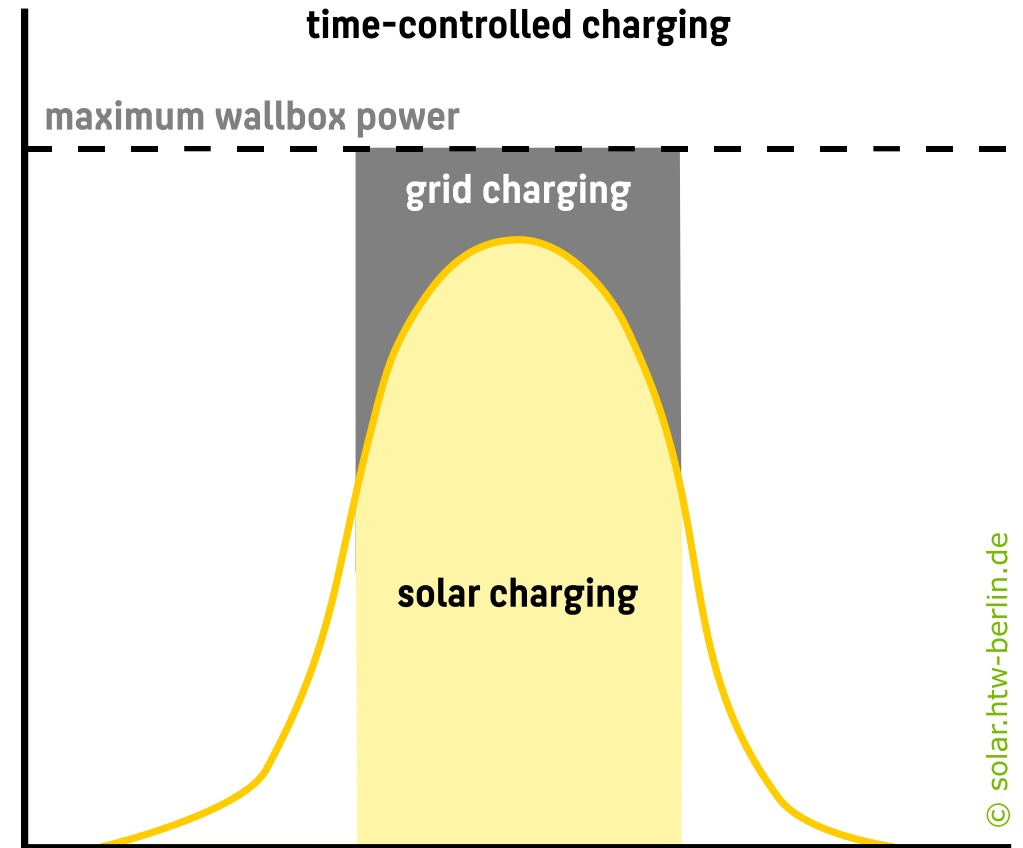
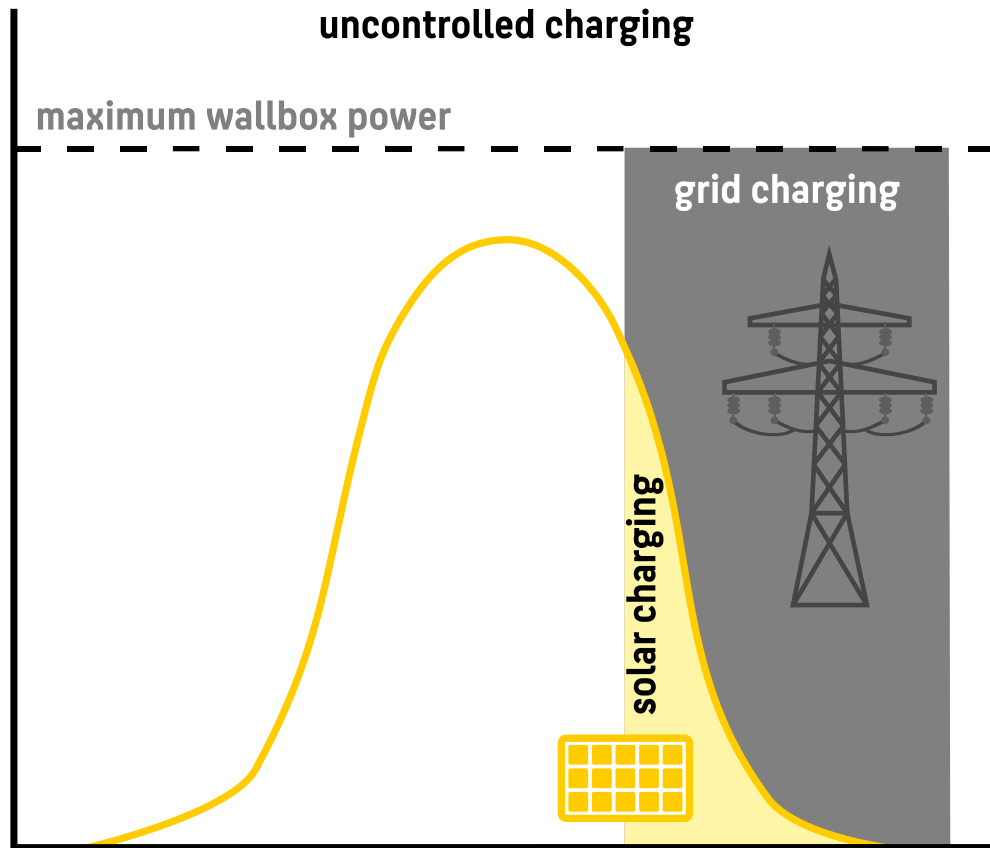


3

Comparison of energy flows in households with PV systems and electric vehicles

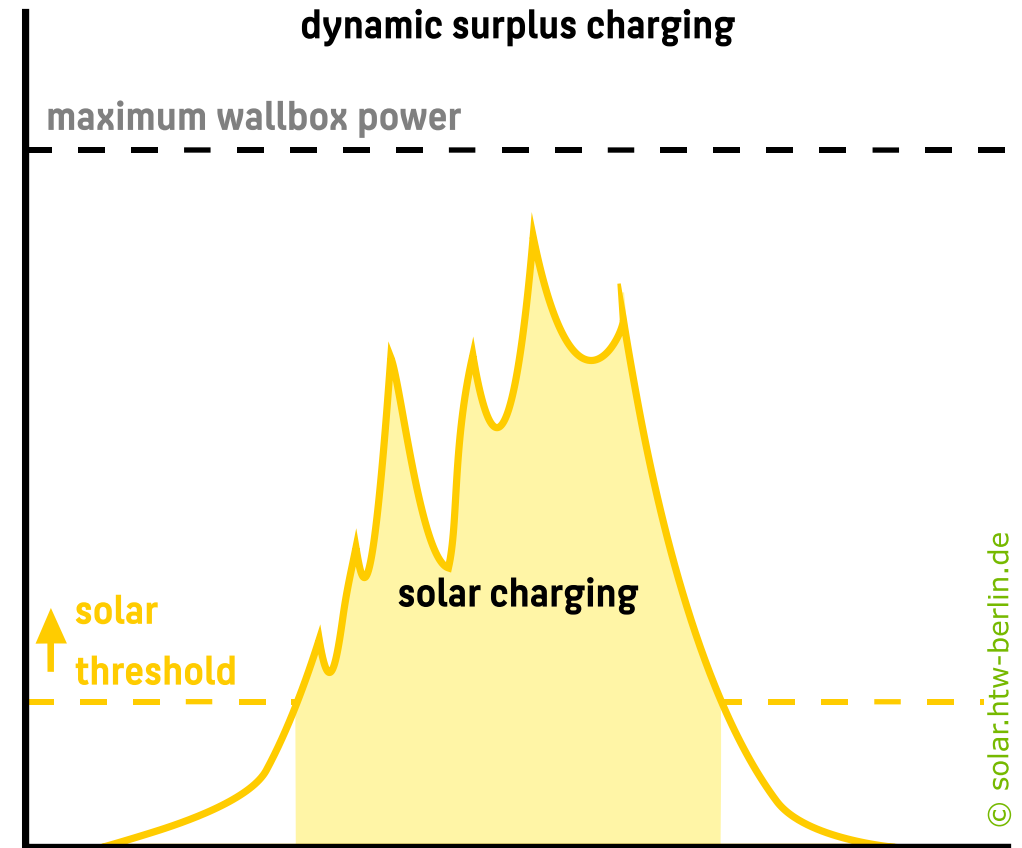
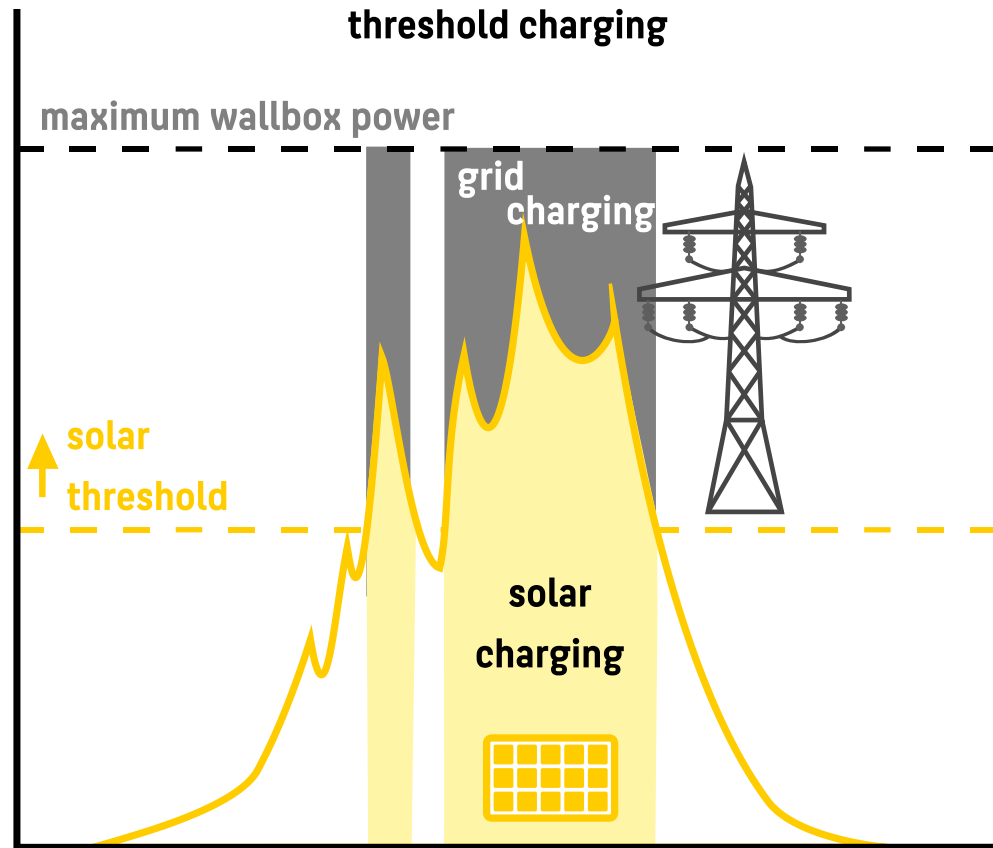


Concepts for solar charging

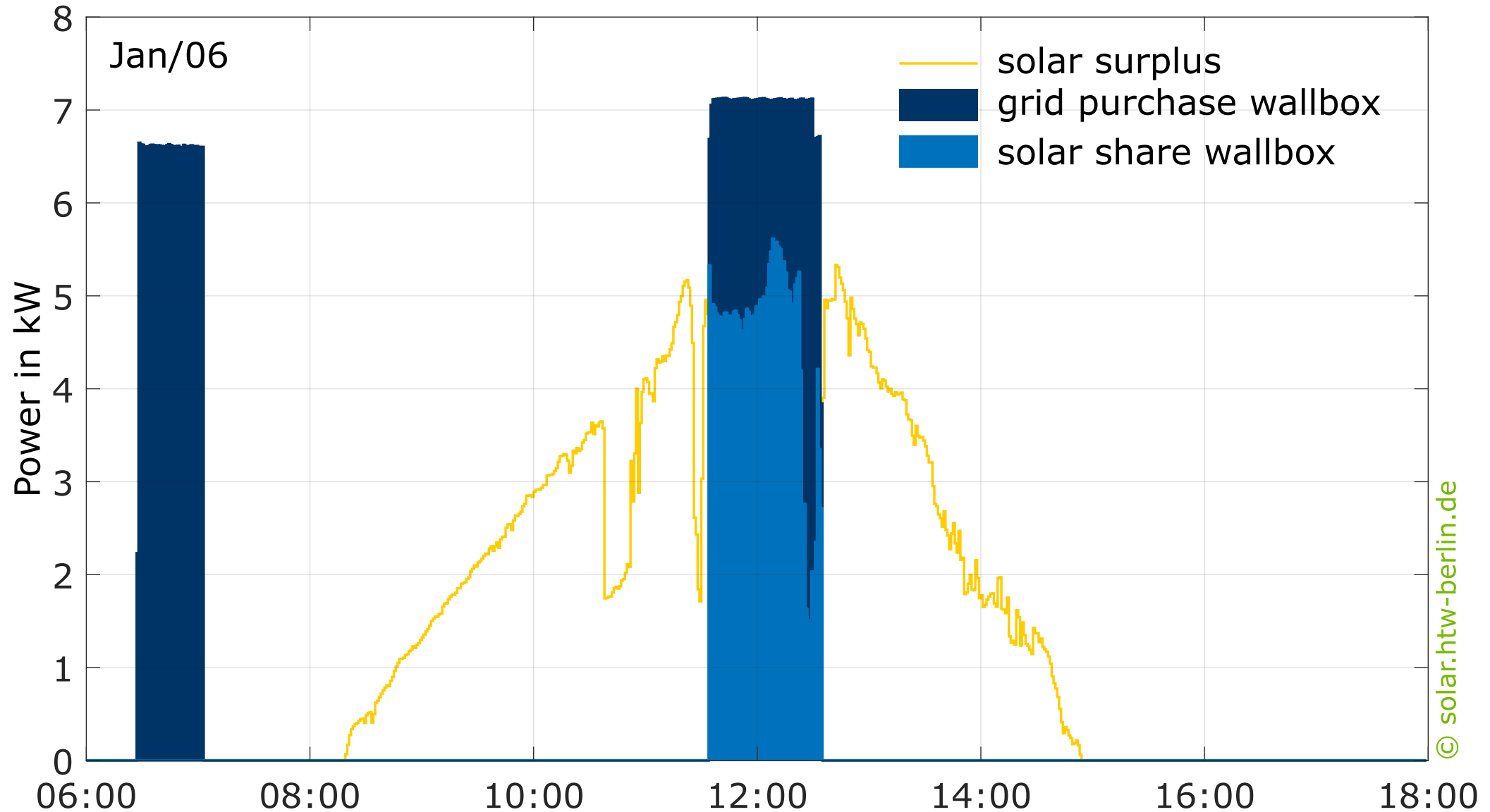


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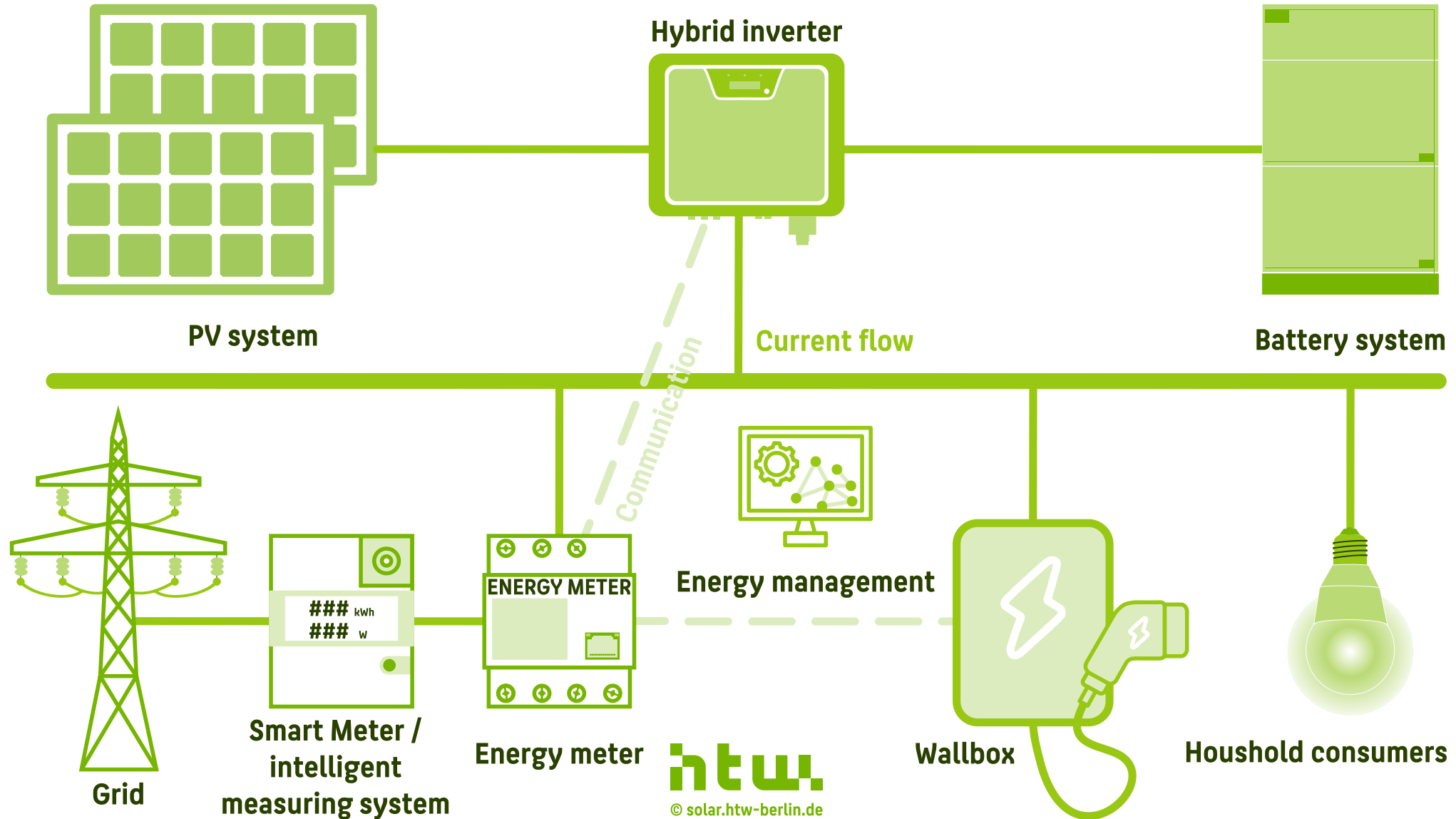
Concepts for solar charging



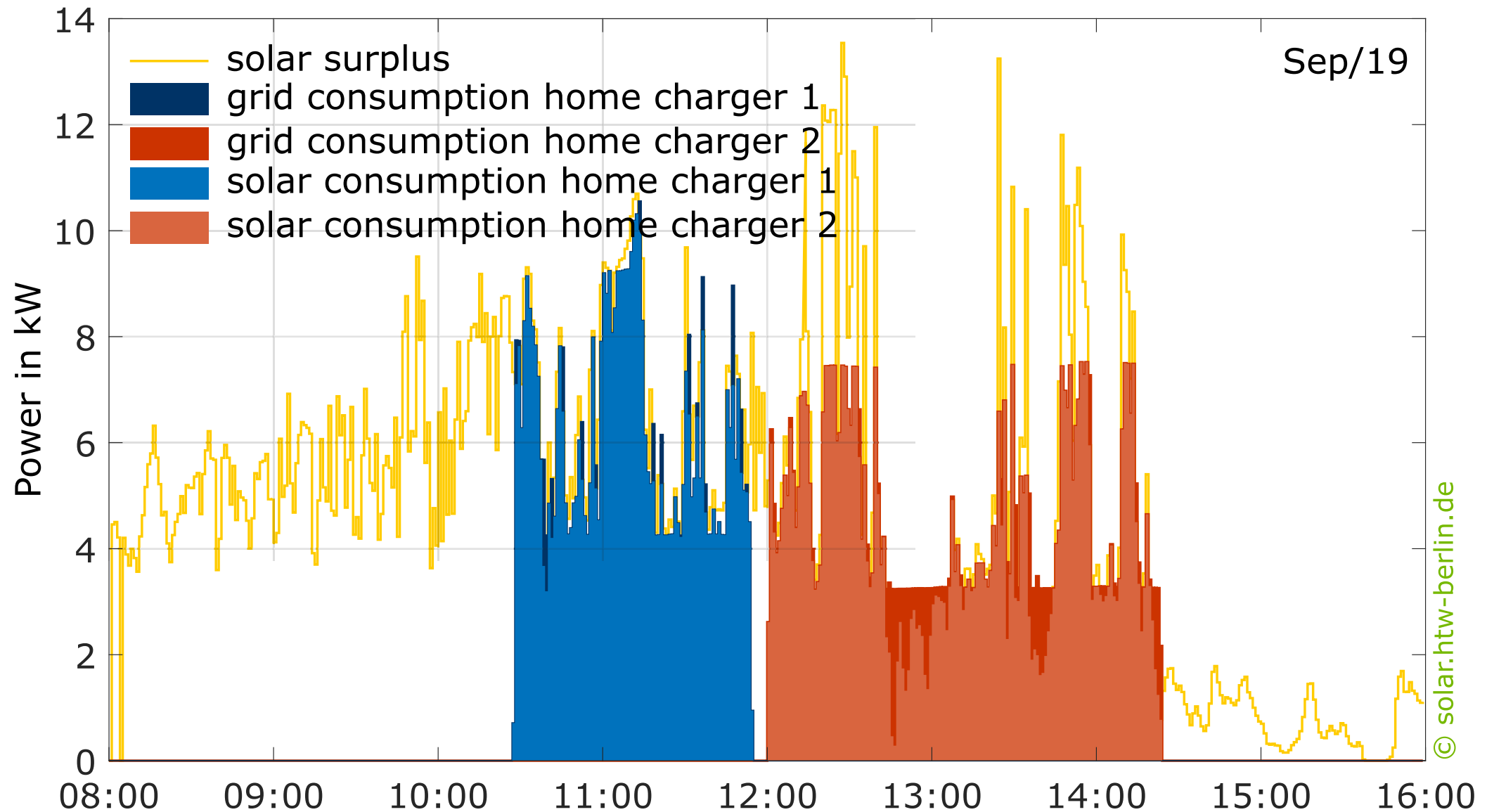
Uncontrolled charging



Components of a dynamic home charger control



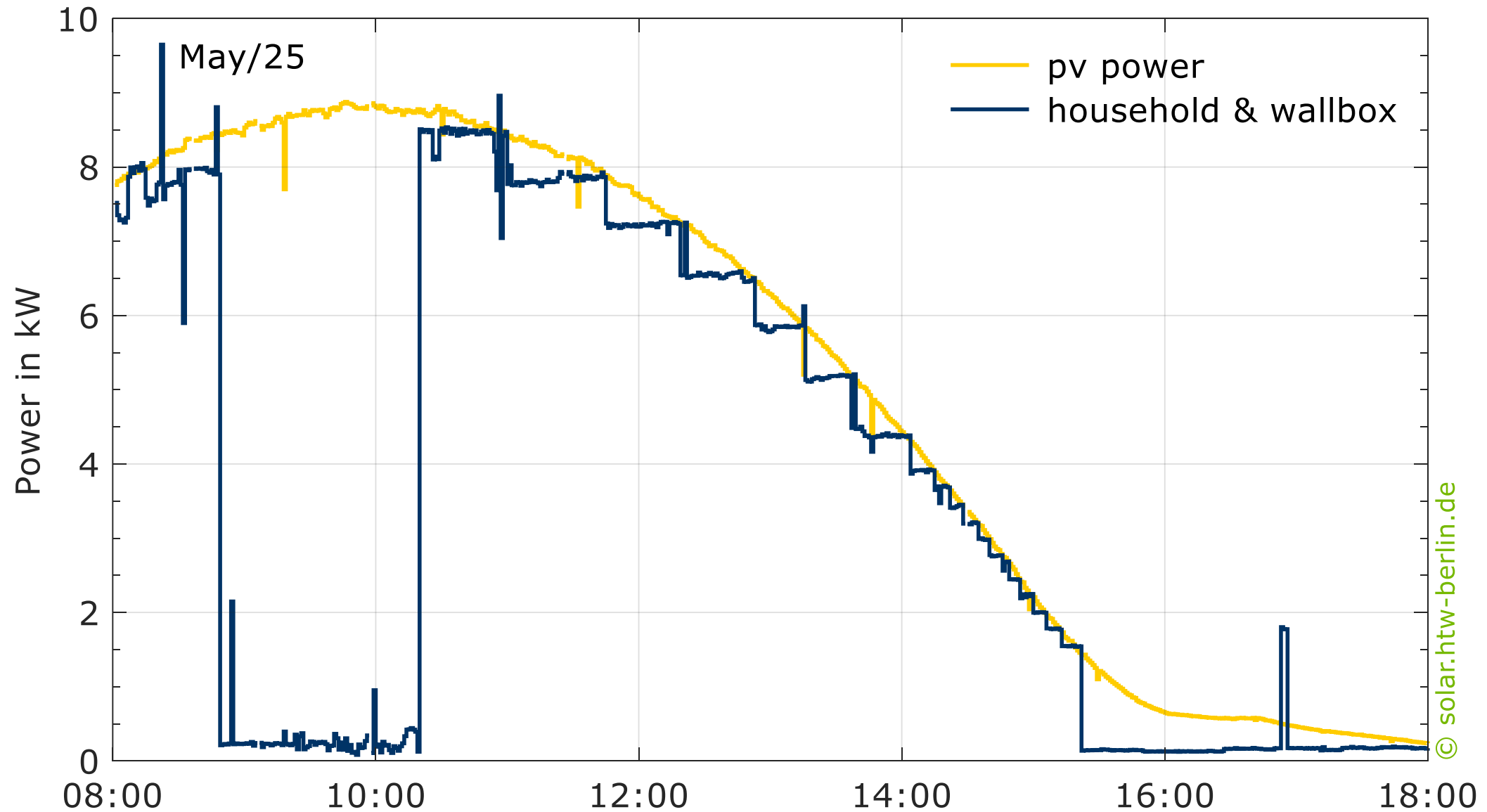
Dynamic surplus charging



Concepts and components of solar charging

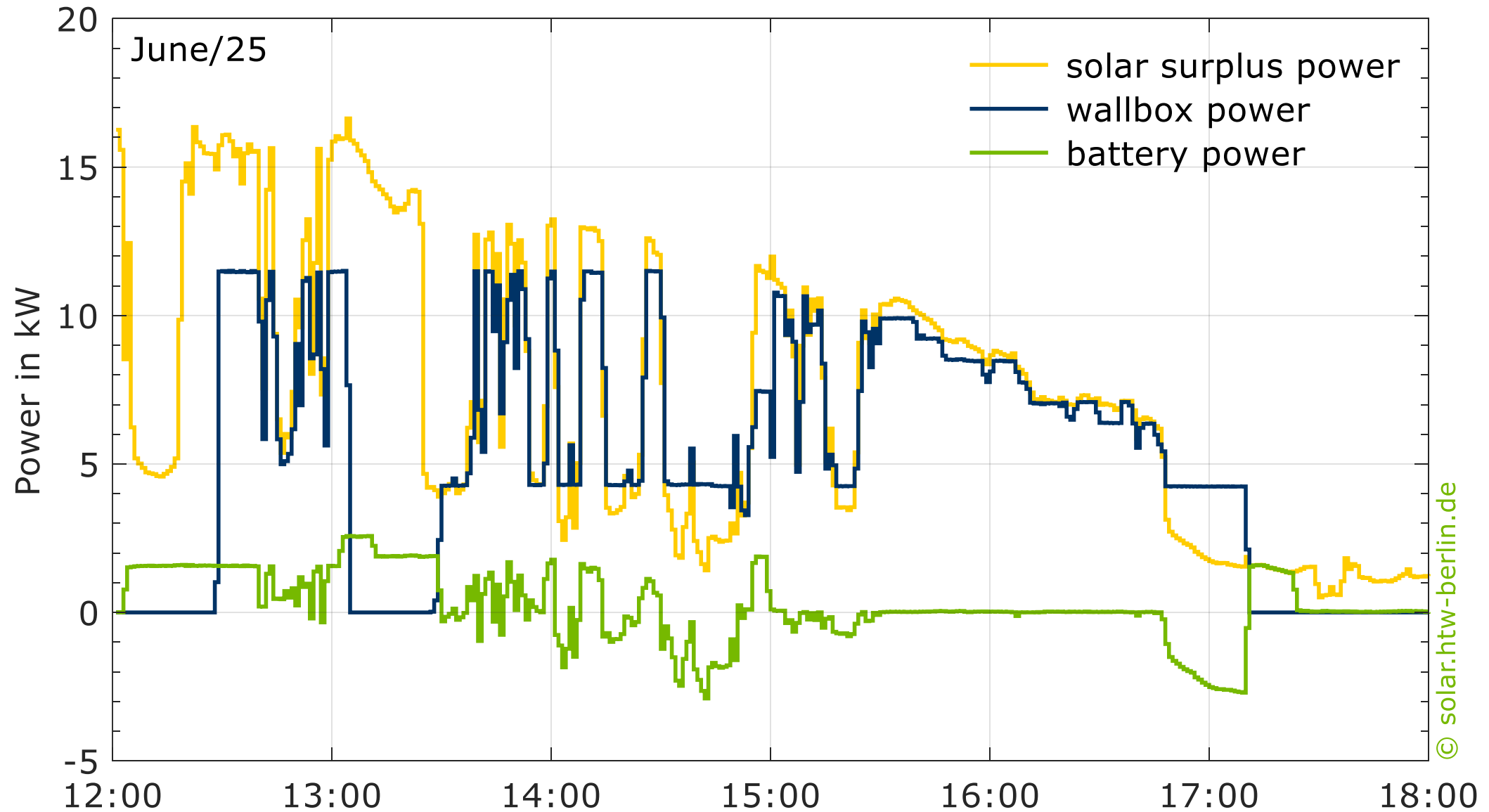
Solar charging concept	Required components (solar system + ...)	Solar driving energy
Uncontrolled charging (manual)	Home charger	5% to 15%
Time-controlled charging (automatic)	Home charger with controllable dry contact or home charger and energy management	10% to 50%
Threshold charging (automatic)	Home charger with potential-free contact or home charger and energy management, (electricity meter)	20% to 70%
Dynamic surplus charging (automatic)	Smart home charger and energy management, electricity meter	25% to 90%

Charging current increment

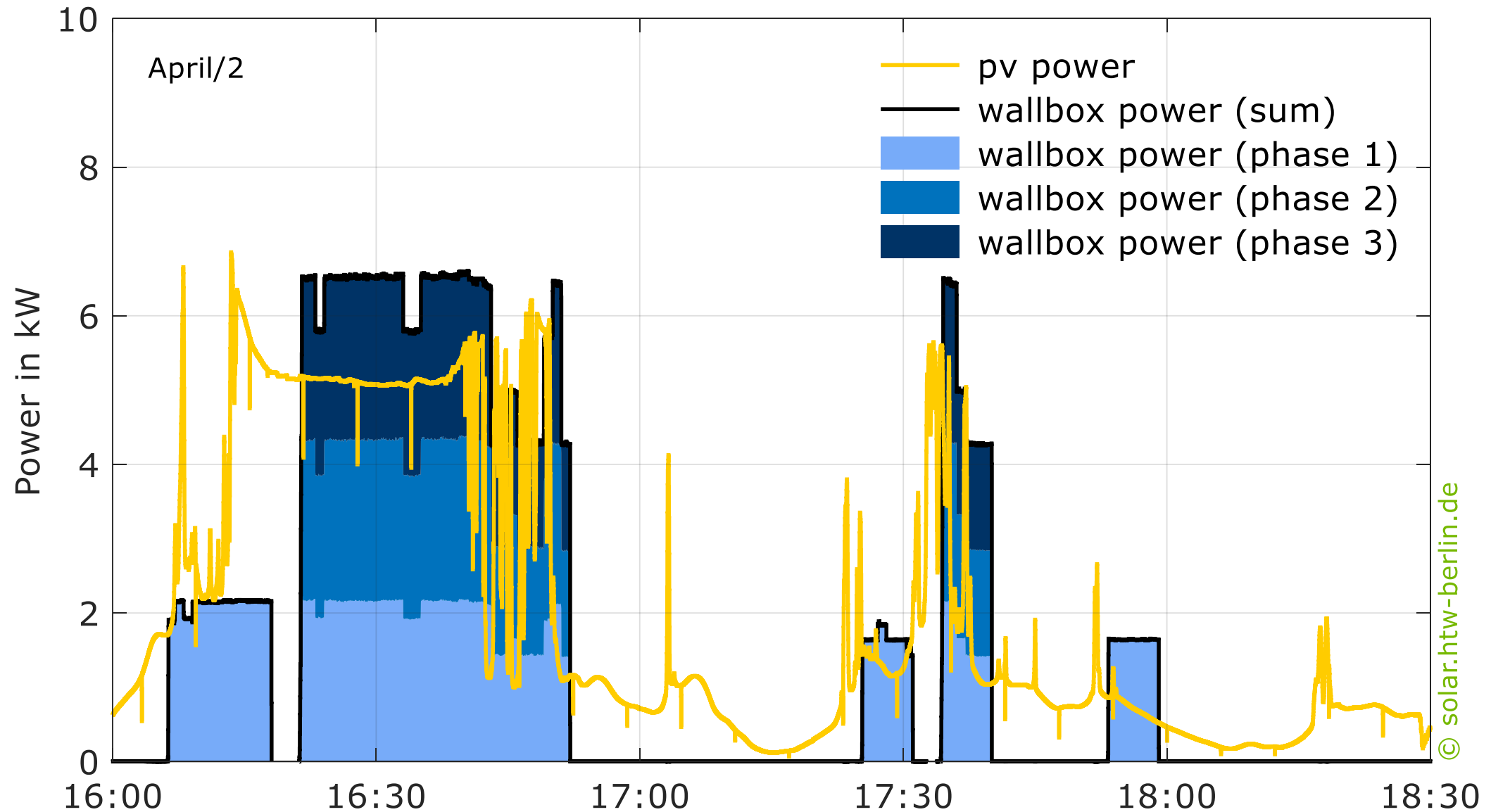


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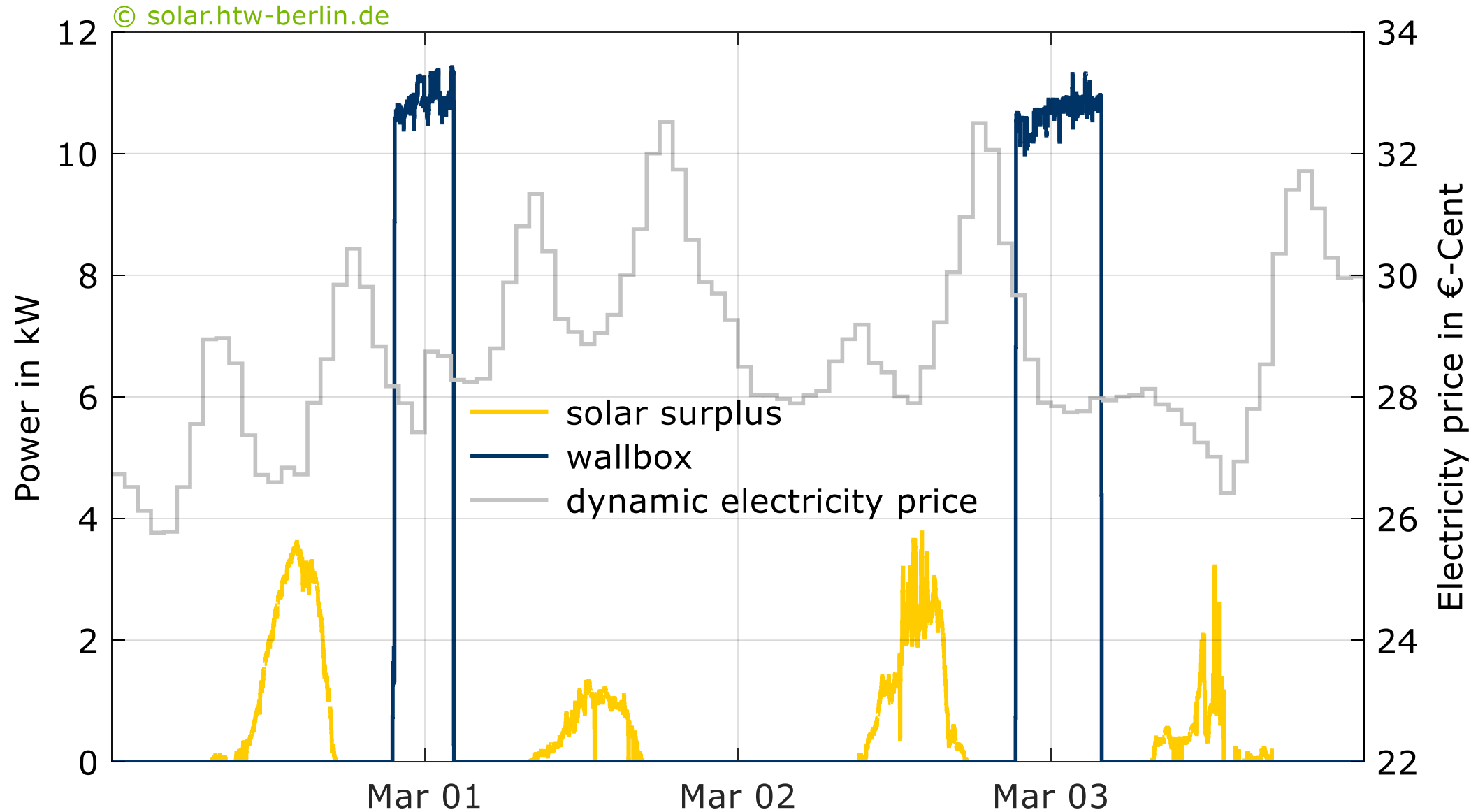
Charging delays



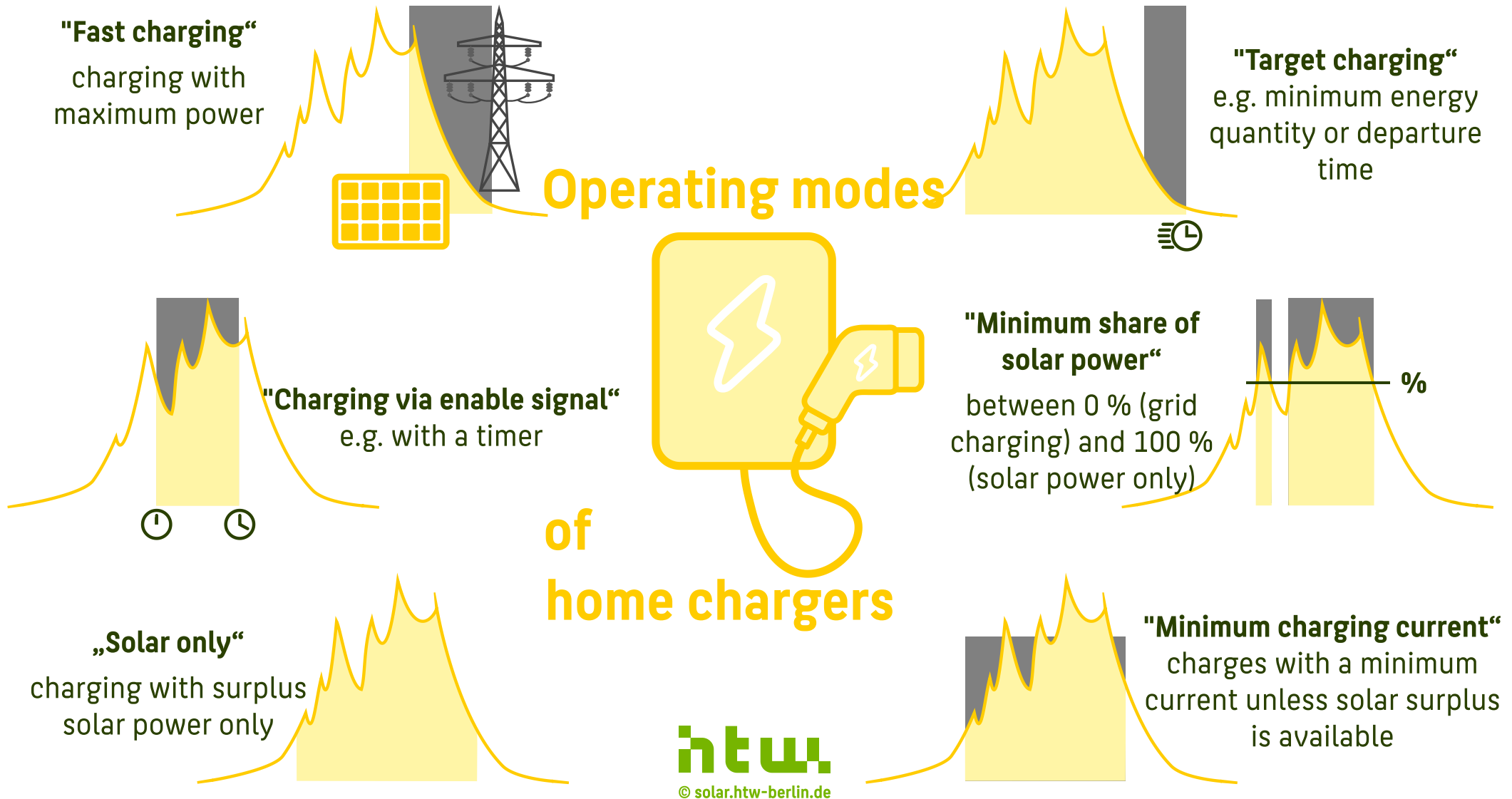
Phase switching



Dynamic electricity tariffs



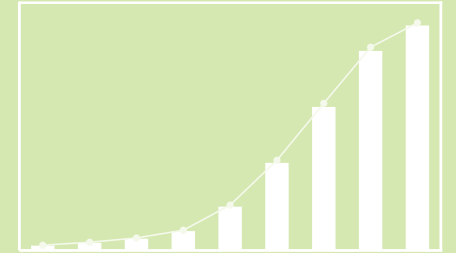
Operating modes of smart home chargers



Scope of the study „Solar Charging of Electric Vehicles“

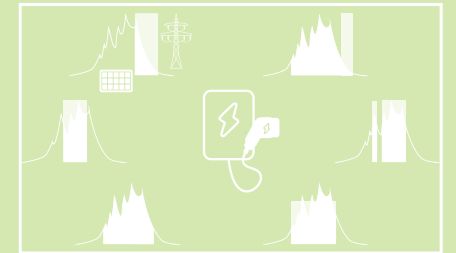
1

German market overview for electric vehicle and home chargers



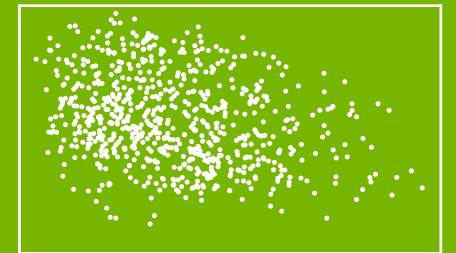
2

Features of smart unidirectional AC-home chargers



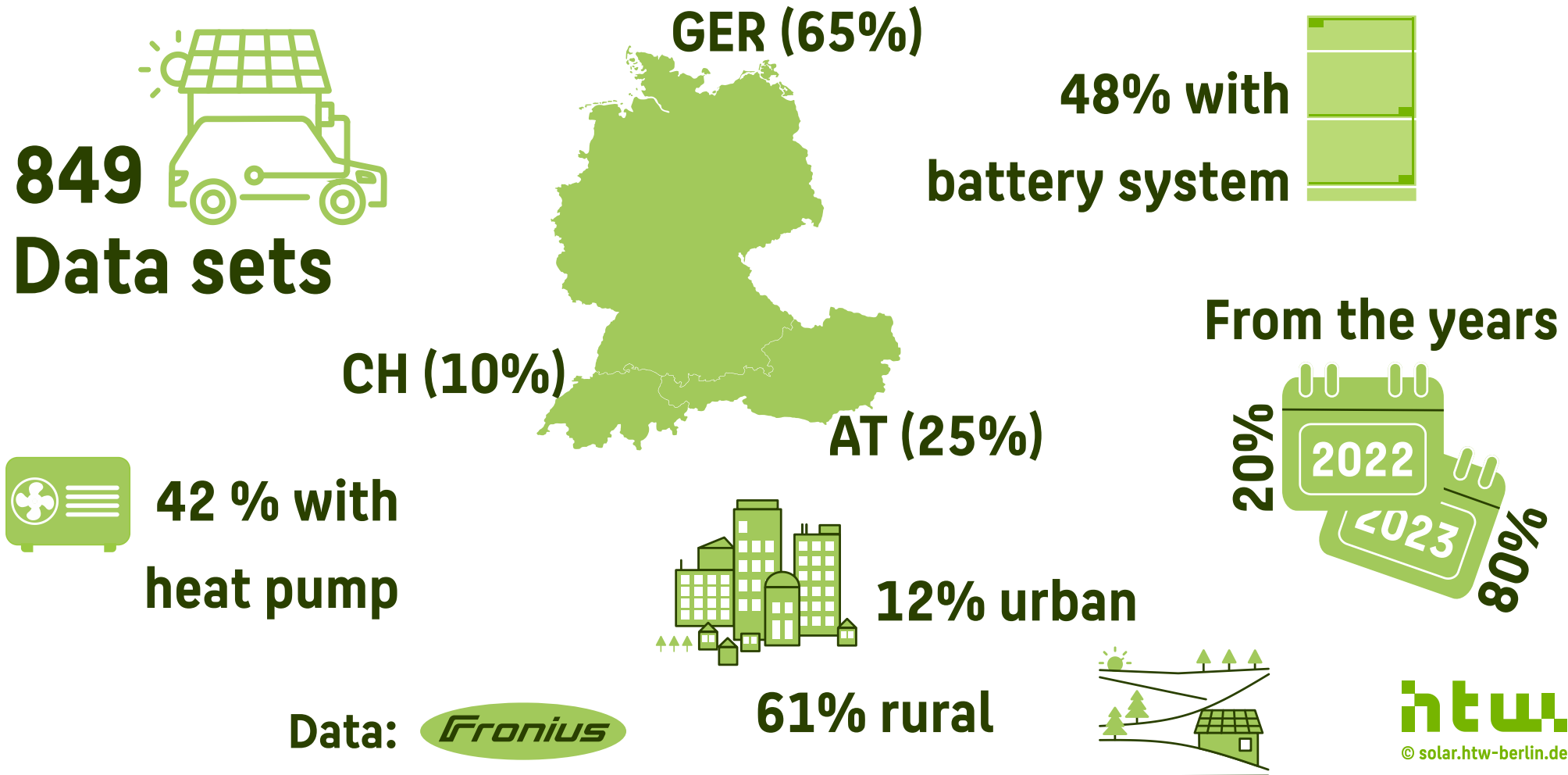
3

Comparison of energy flows in households with PV systems and electric vehicles

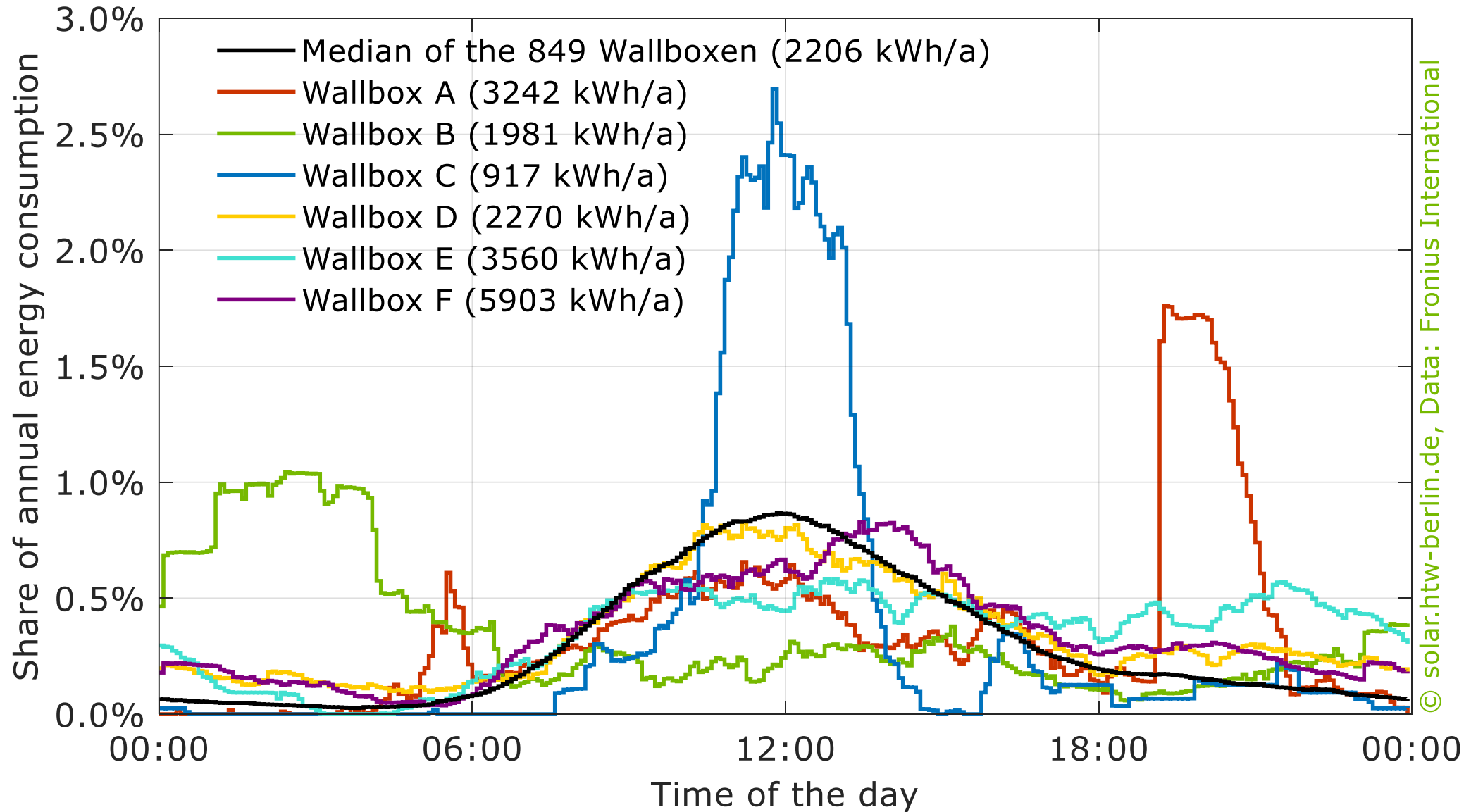


What data is the study based on?

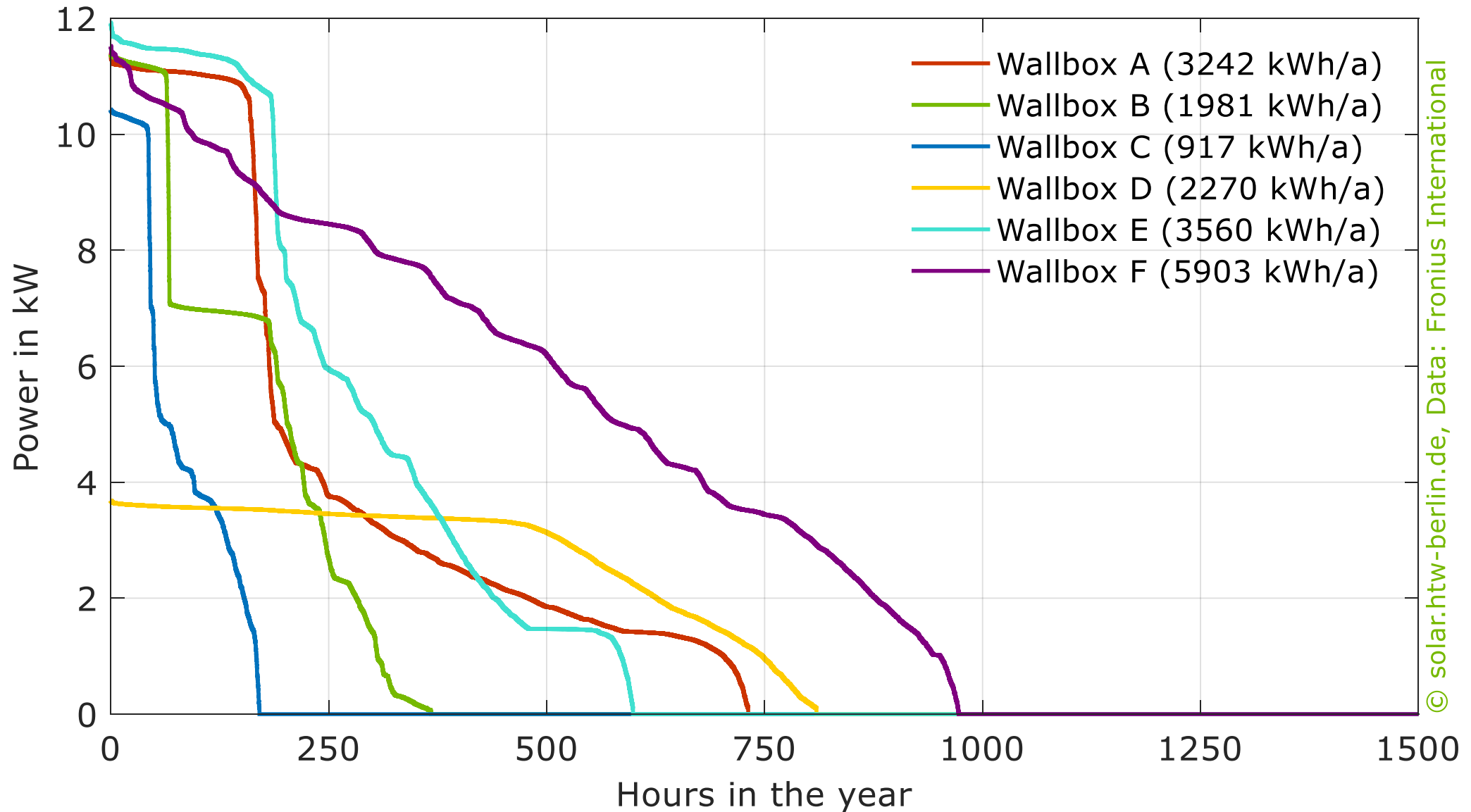
Basic data description of operational data of home chargers



How does the charging behavior differ?



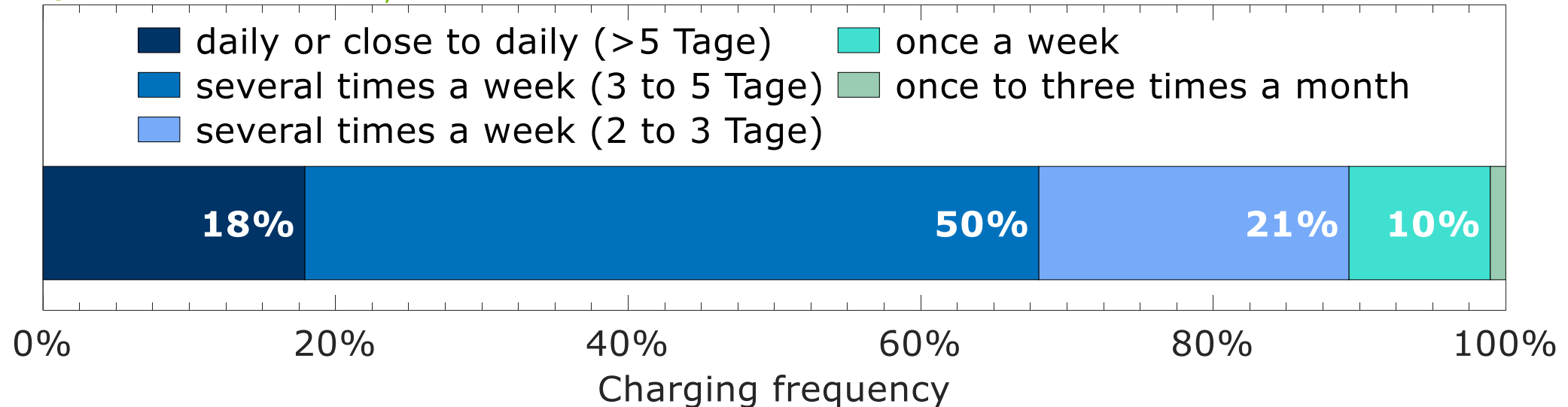
How does the charging behavior differ?



How often are electric vehicles charged?

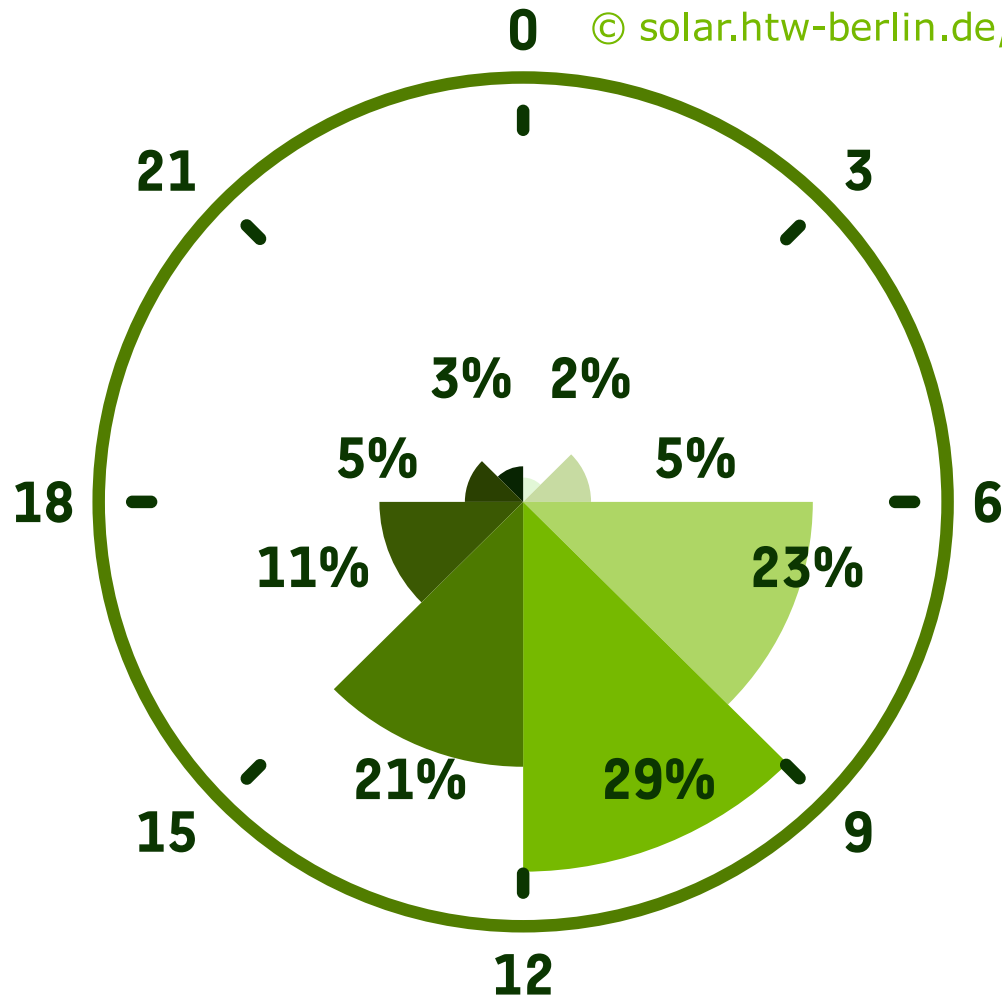
- Charging routines define the charging behavior, including:
 - Charging after the charge level falls below a certain level,
 - Charging by solar offer,
 - Charging at certain times,
 - daily plugging in of the electric vehicle and use of the energy management charging plan.

© solar.htw-berlin.de, Data: Fronius International

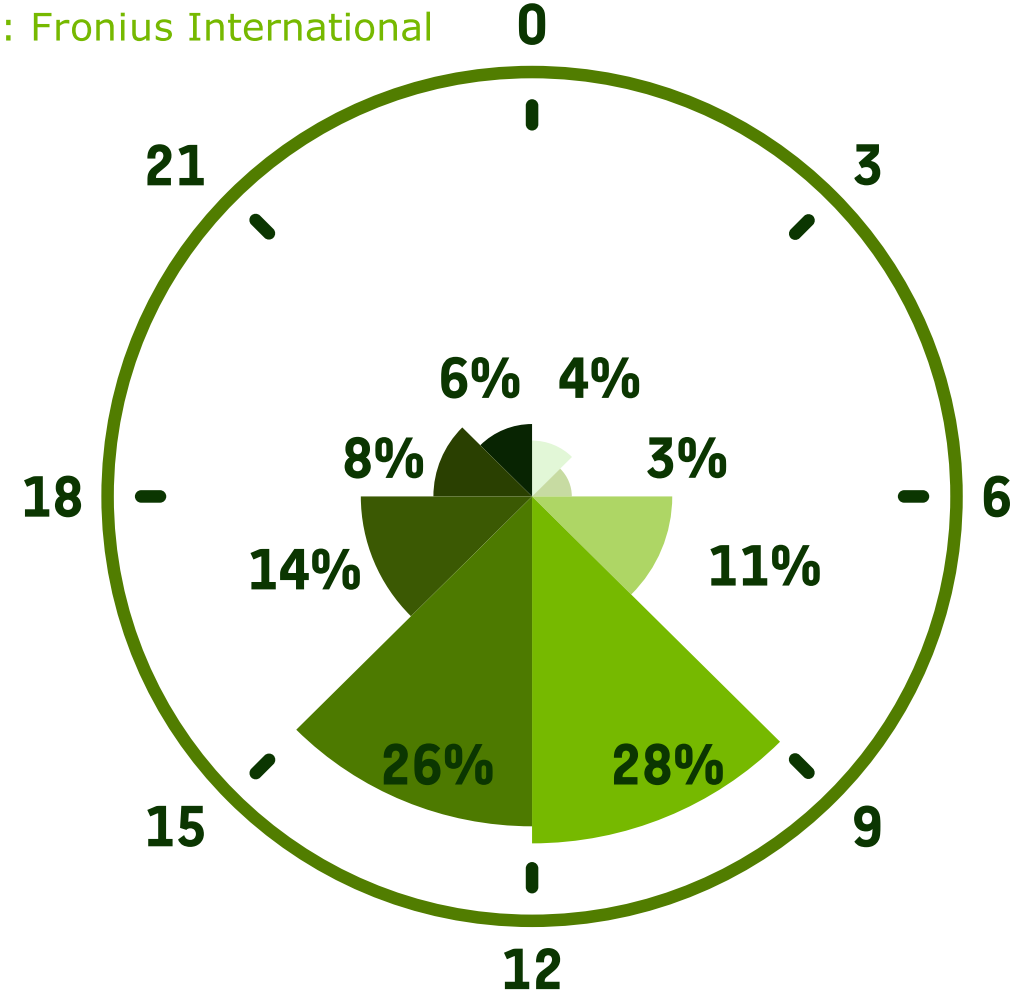


When are electric vehicles charged?

© solar.htw-berlin.de, Data: Fronius International



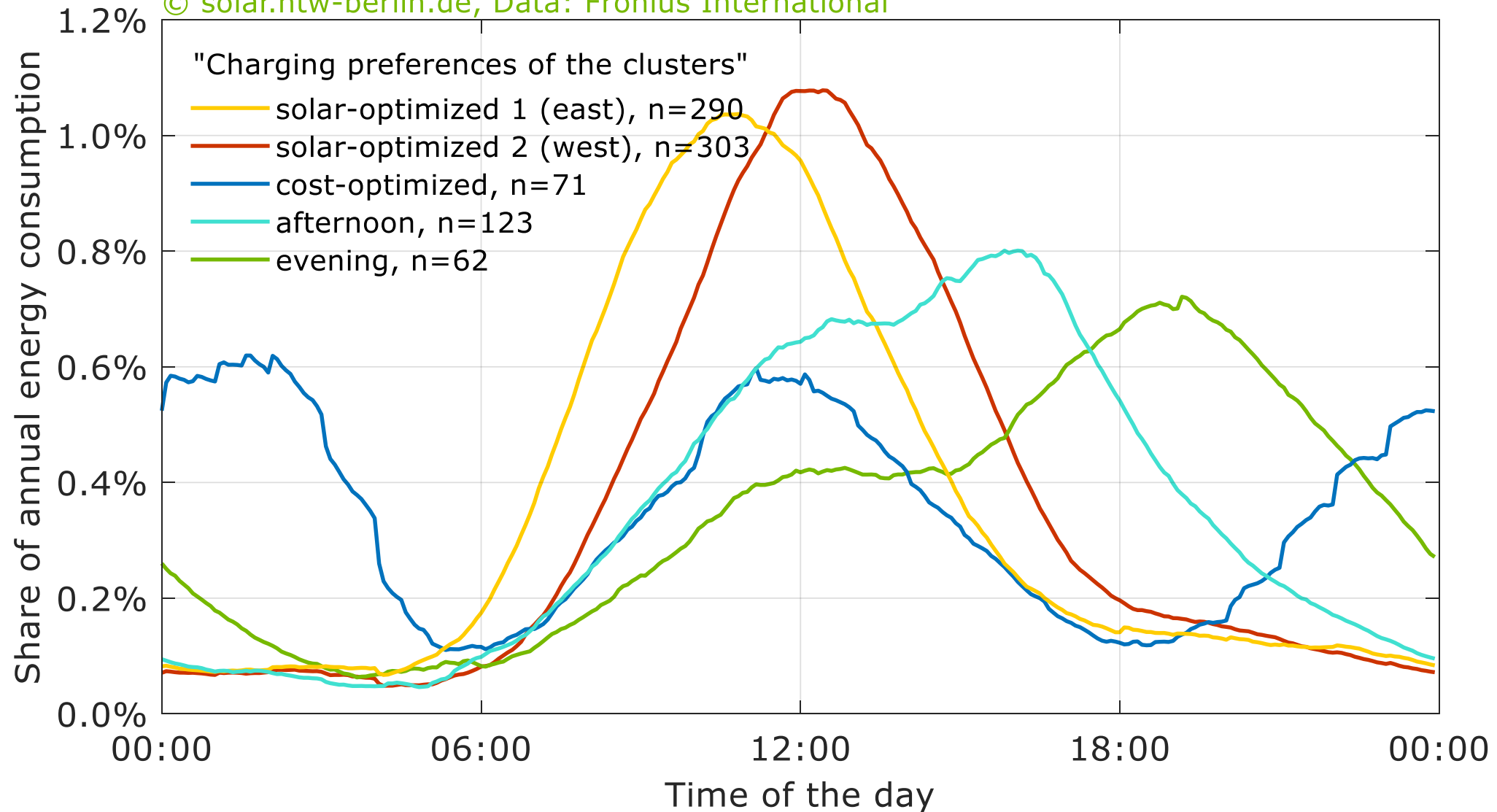
Start time of the charging process



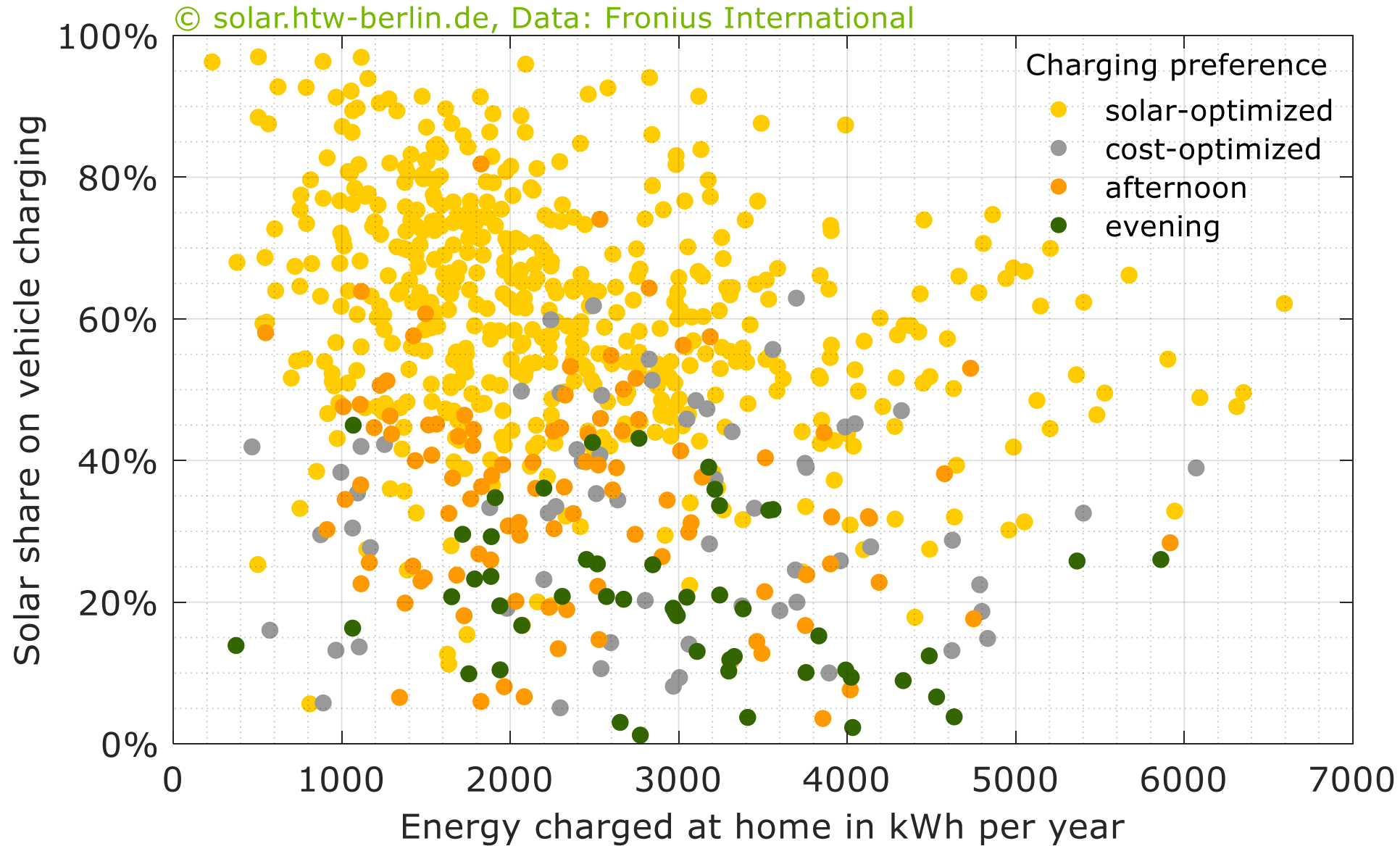
Energy share in the time slot

Clustered charging preferences of the analyzed households

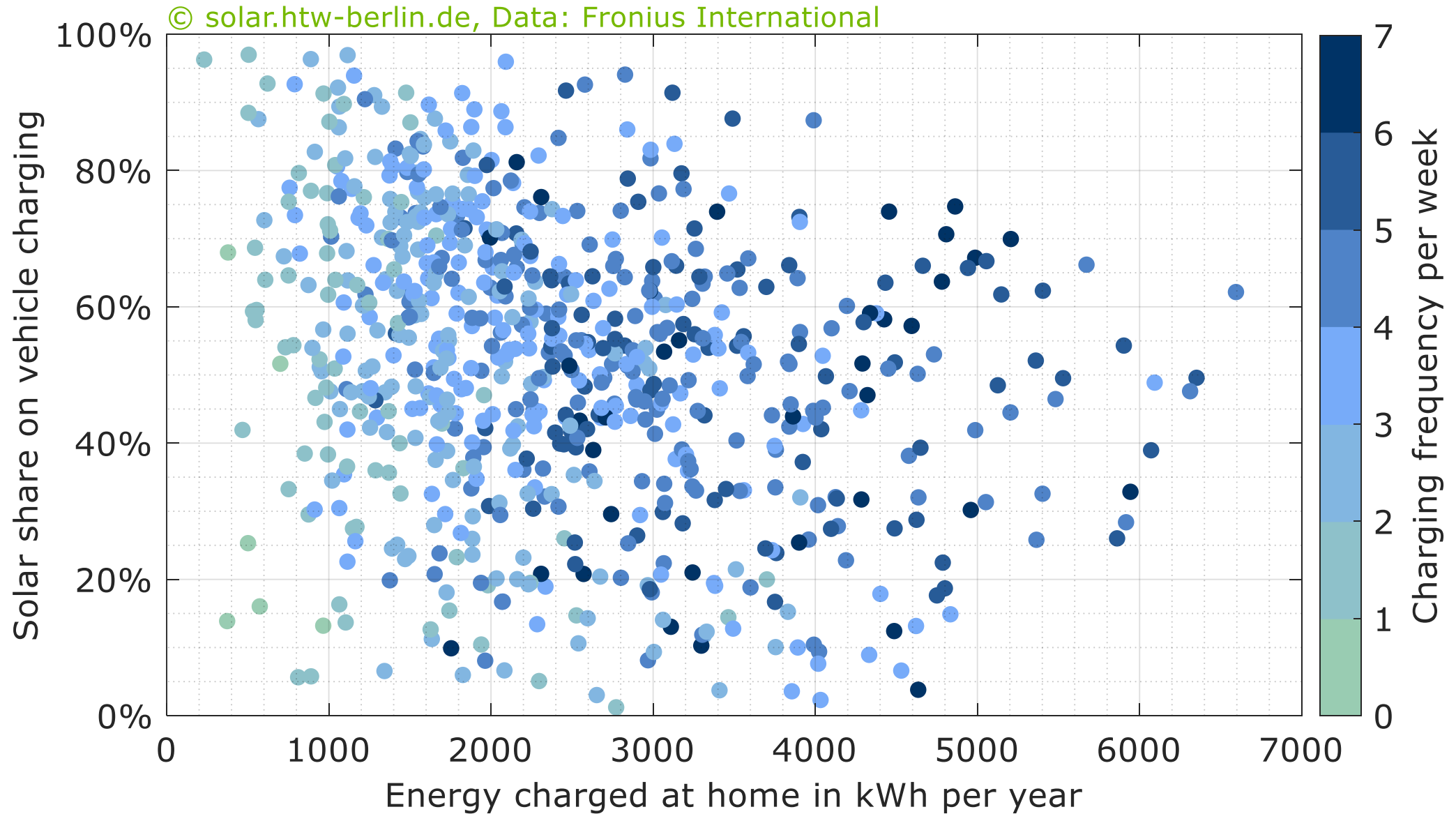
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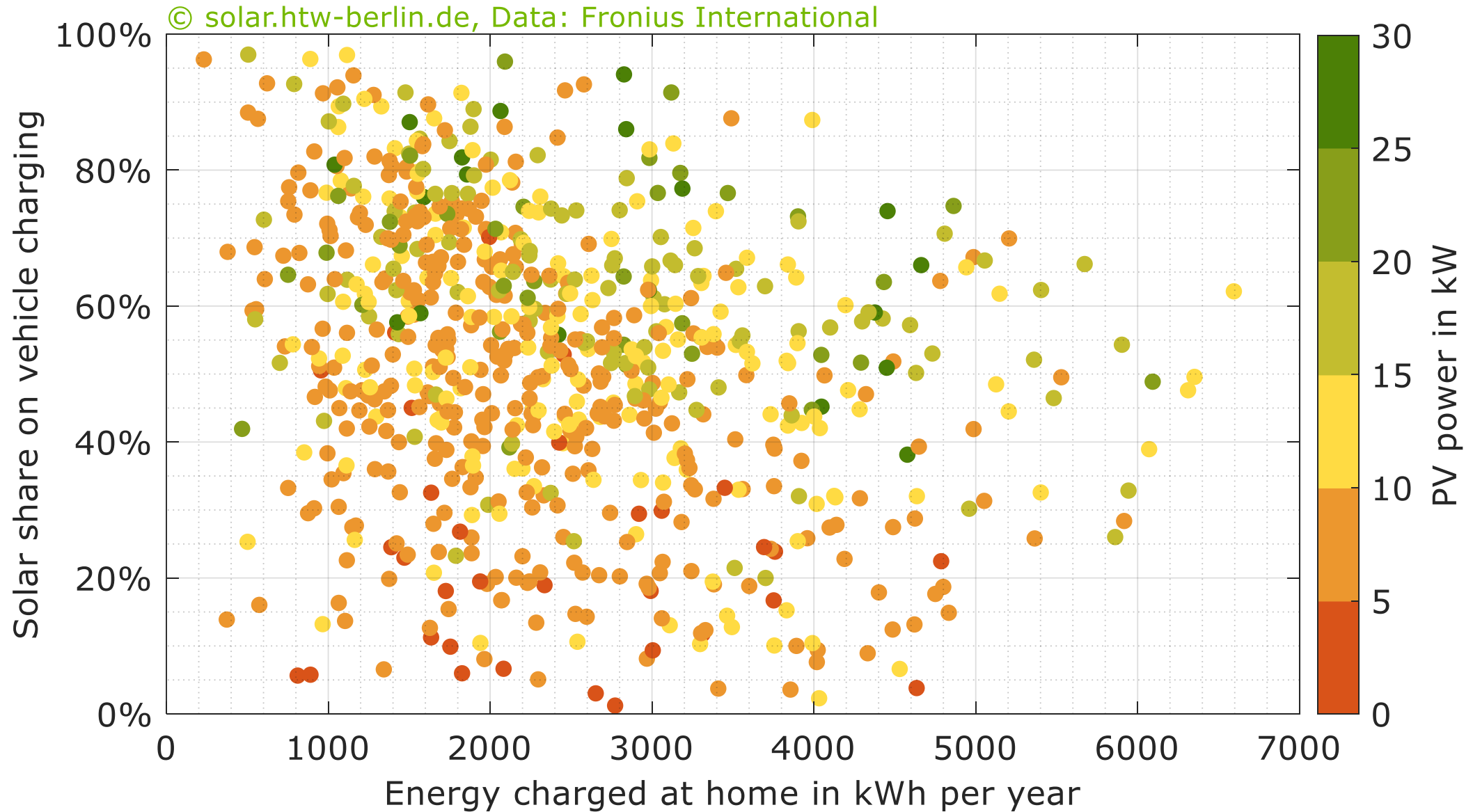
What is the amount of solar energy used for charging?



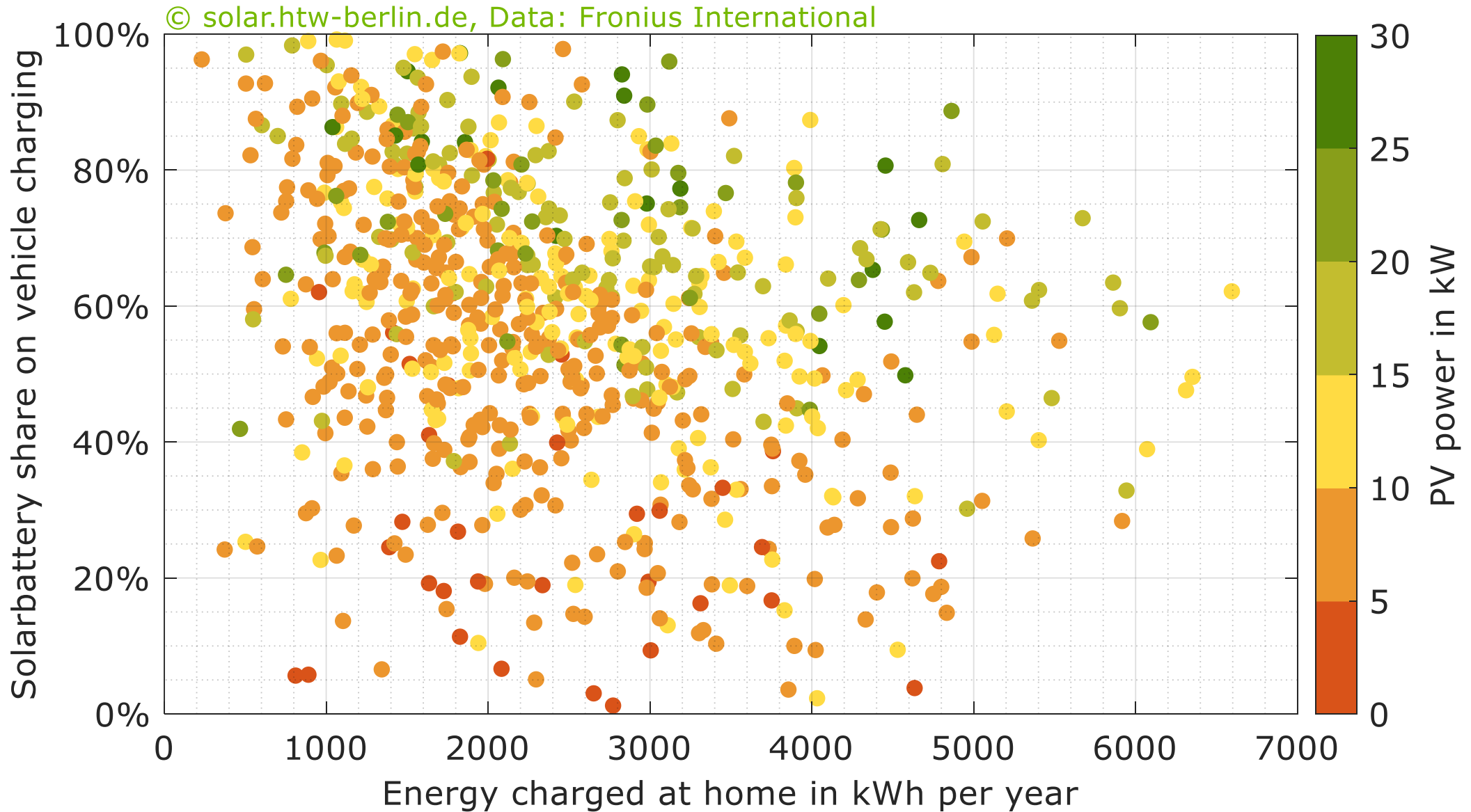
What is the amount of solar energy used for charging?



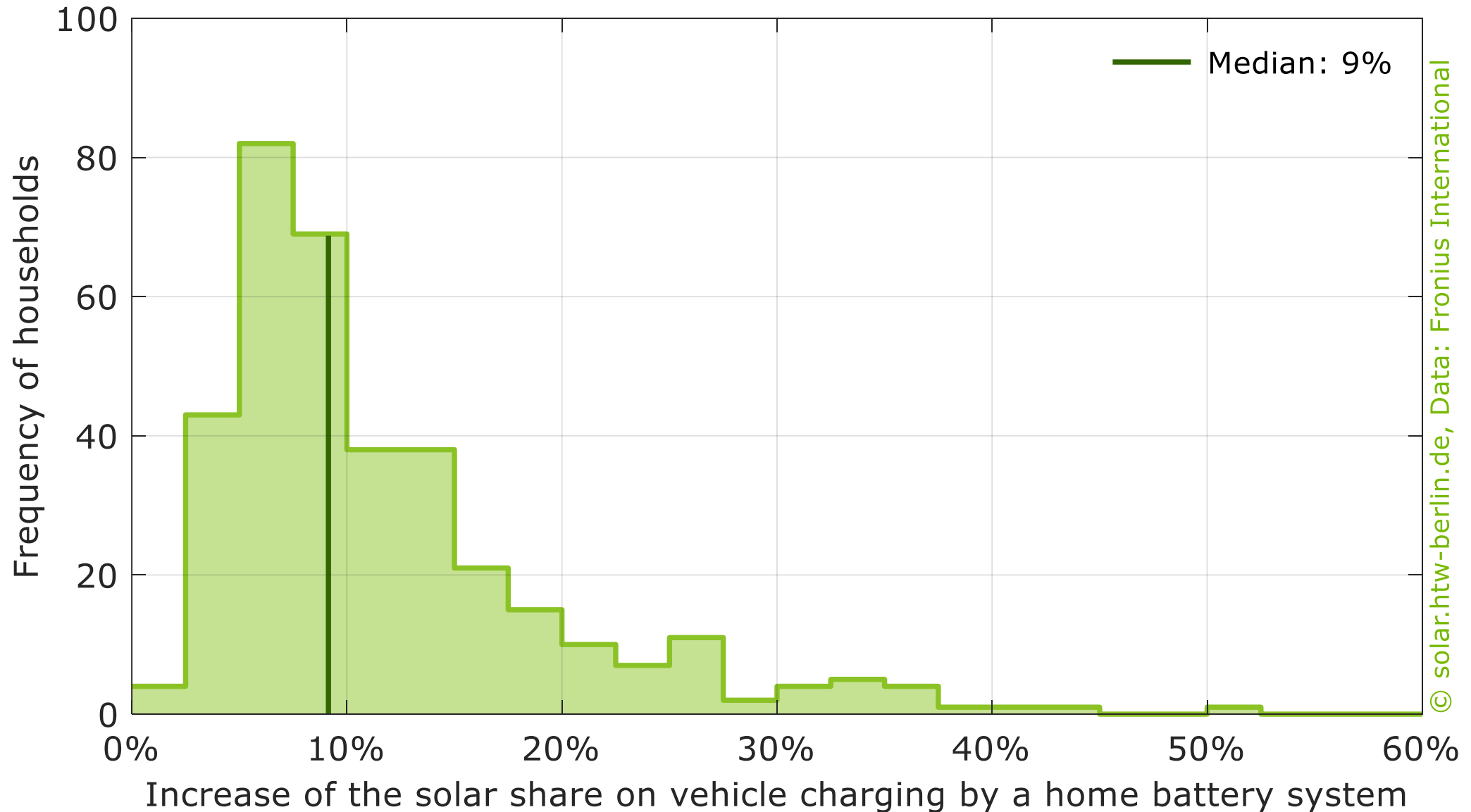
What is the amount of solar energy used for charging?



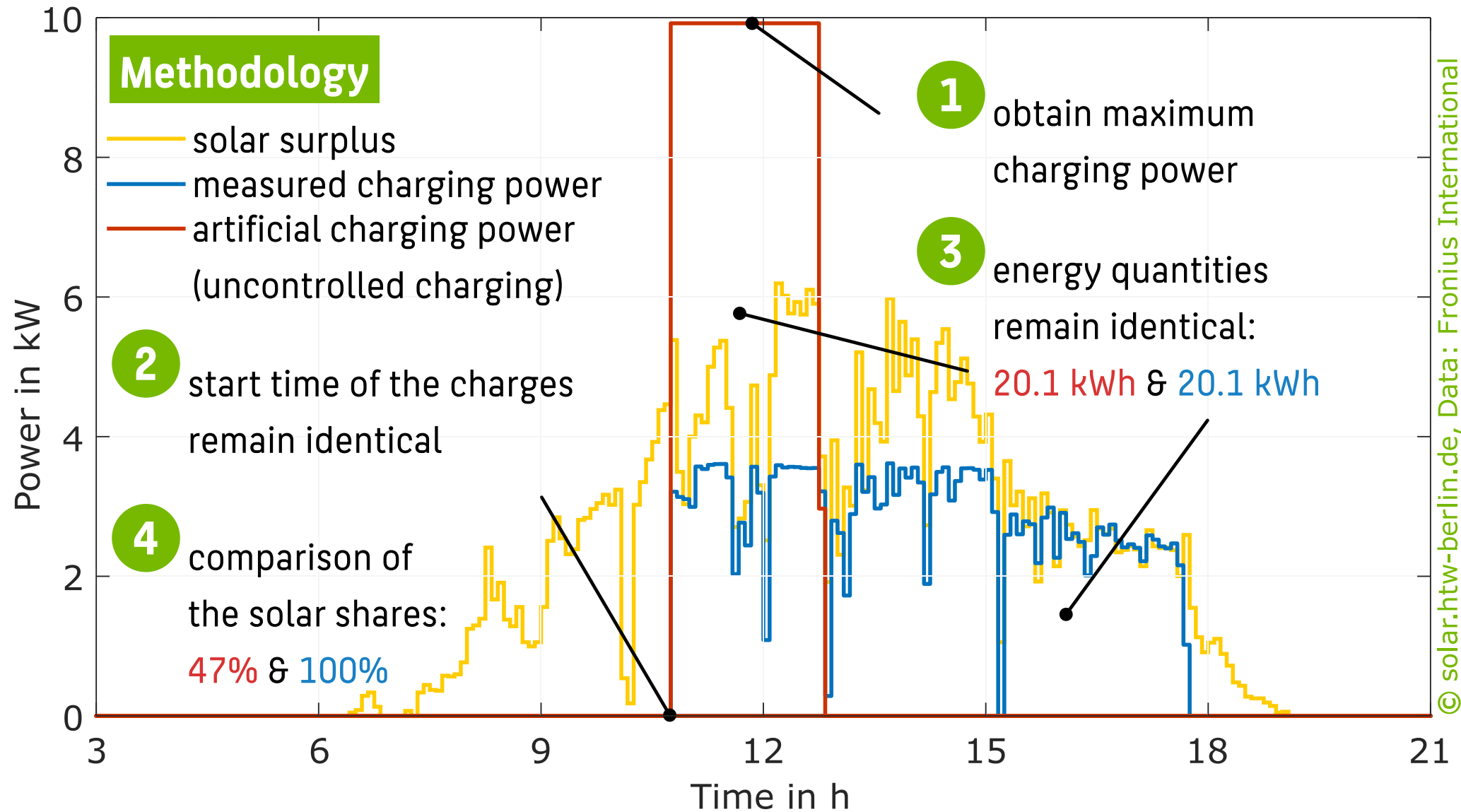
What is the amount of solar energy used for charging with a battery?



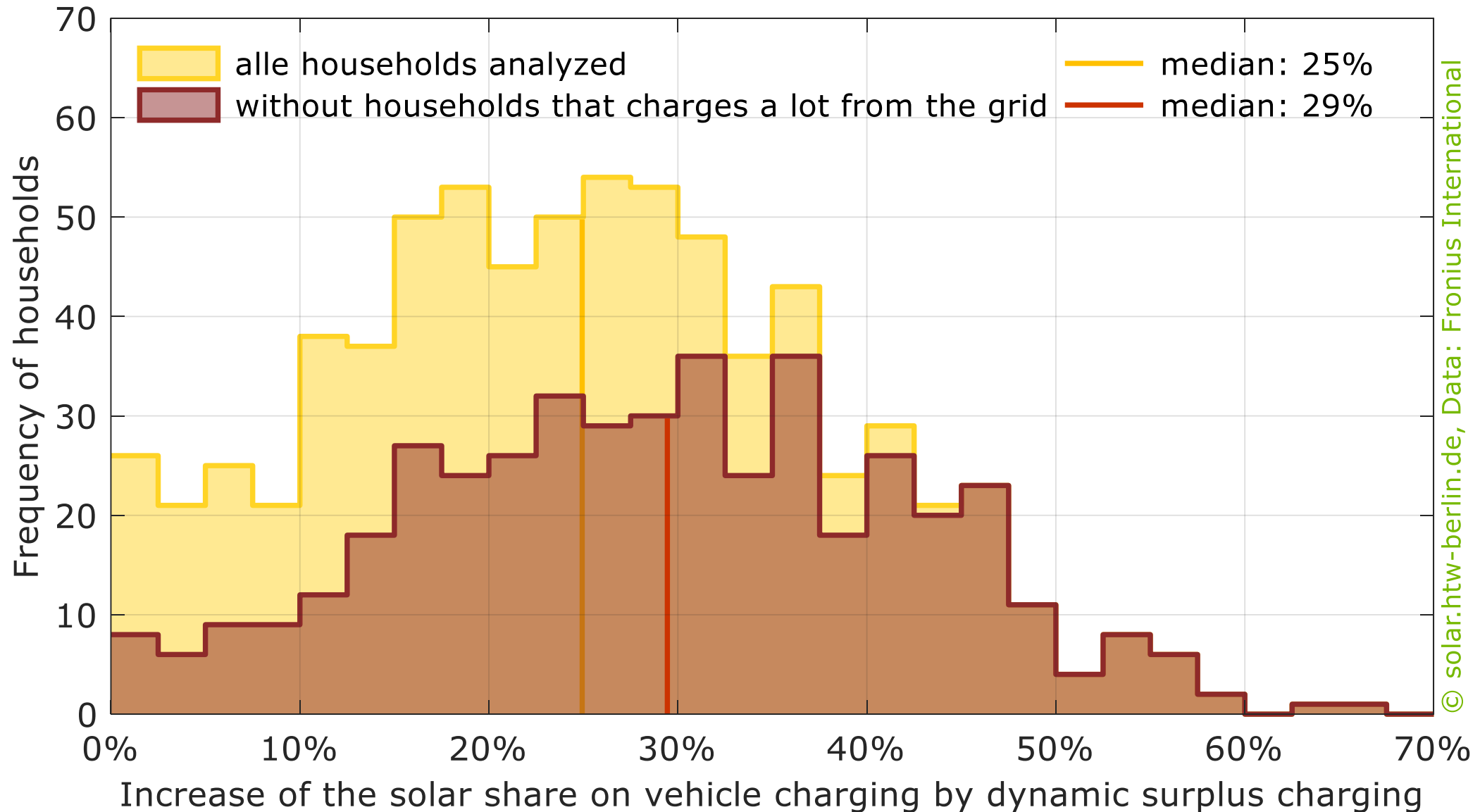
How much does a home battery system increase the solar share?



How much does dynamic surplus charging increase the solar share?

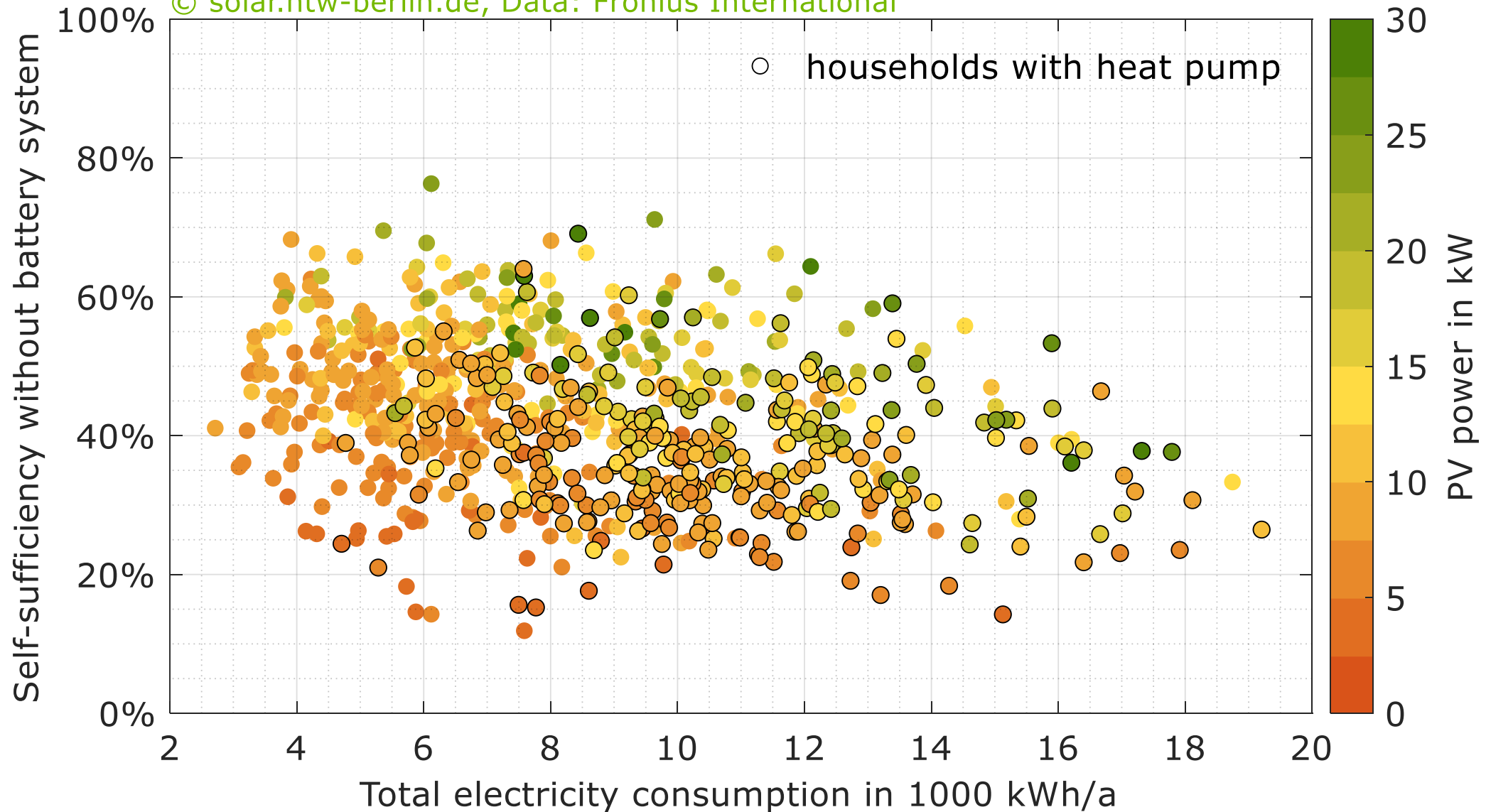


How much does dynamic surplus charging increase the solar share?

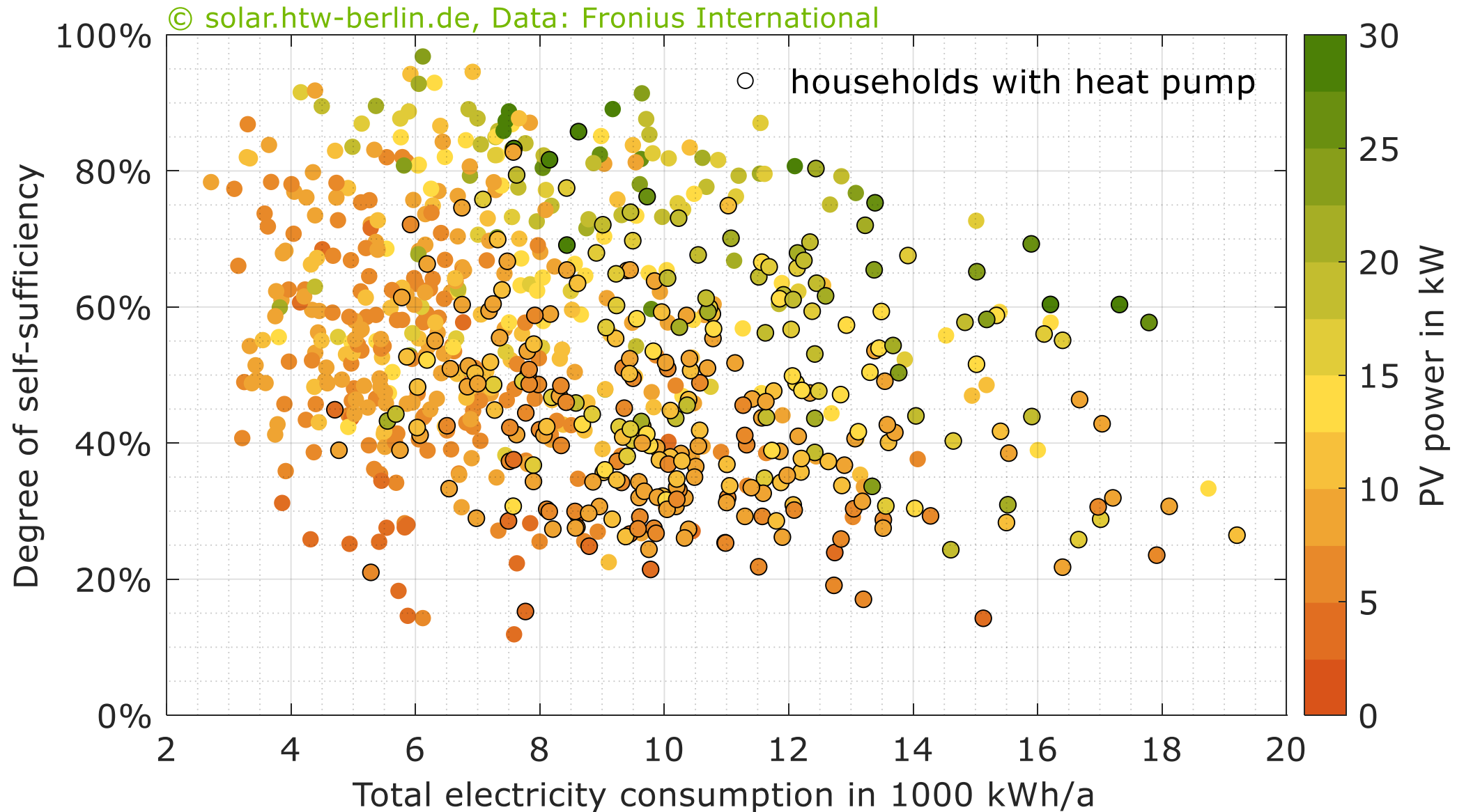


What level of self-sufficiency can a battery-less household achieve?

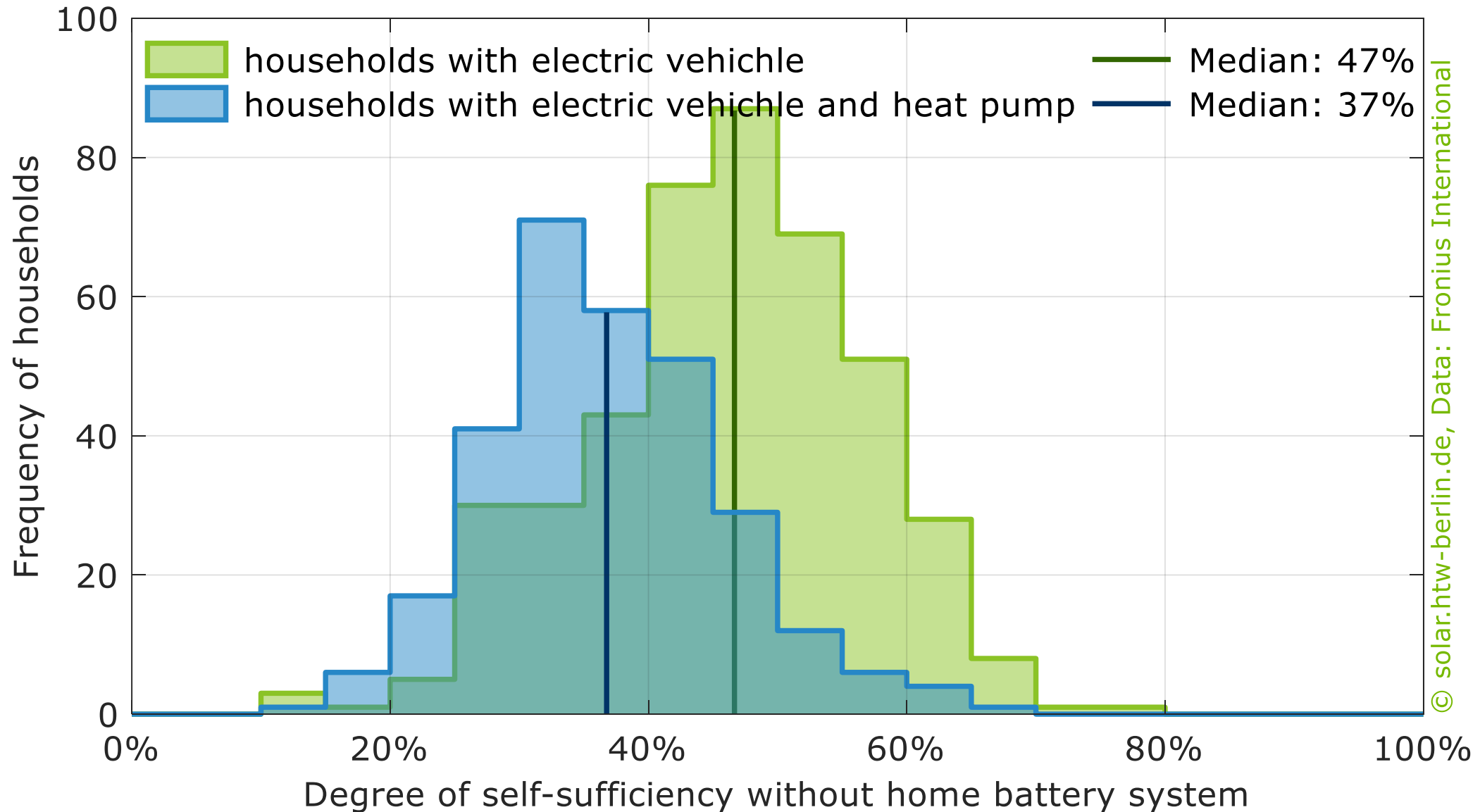
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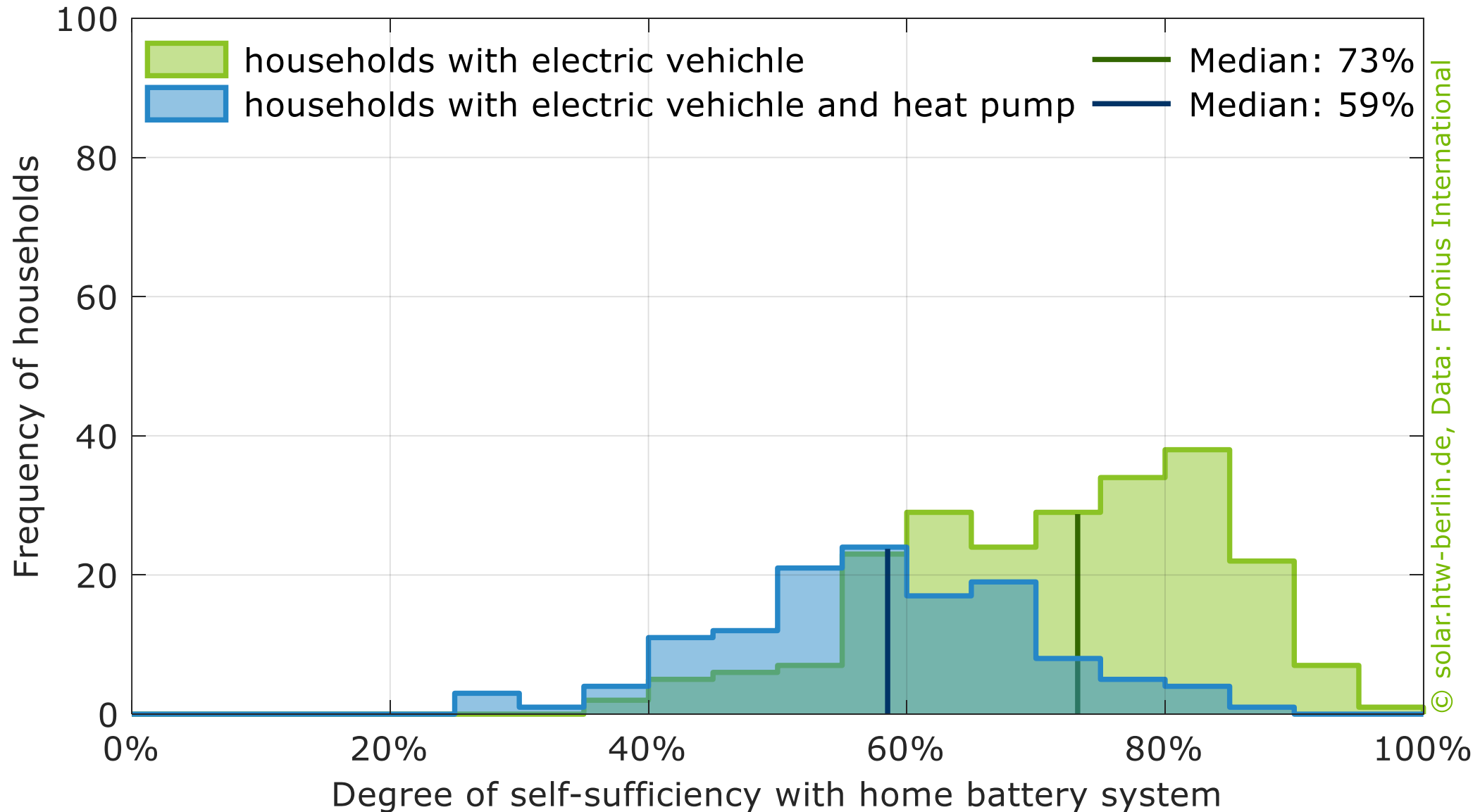
What is the household's self-sufficiency with battery integration?



What level of self-sufficiency can a battery-less household achieve?

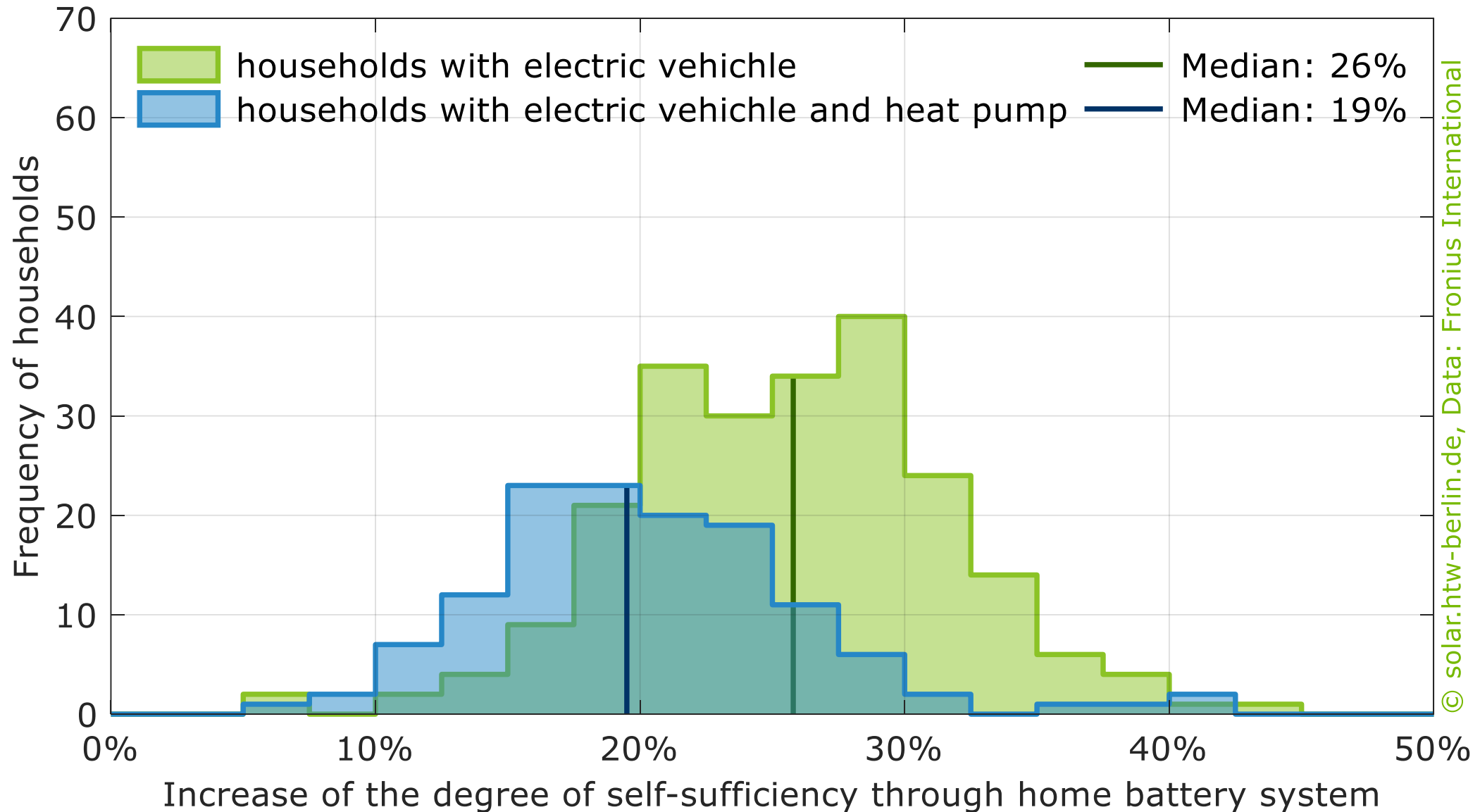


What is the household's self-sufficiency with battery integration?



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How much does a home battery system increase the self-sufficiency?



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