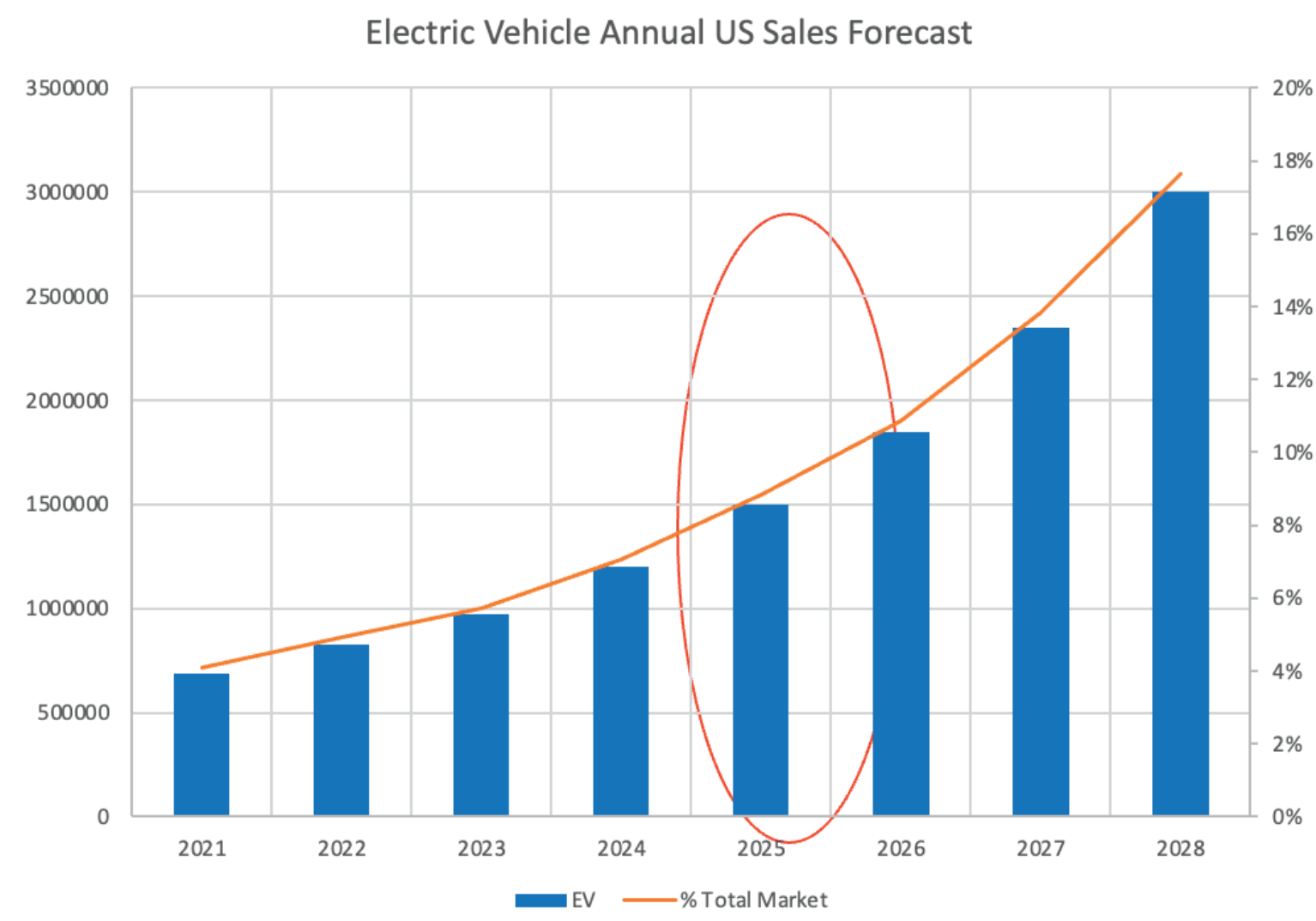


The imminent electric vehicle (EV) revolution may shift the archetype of electrical energy management in the home.

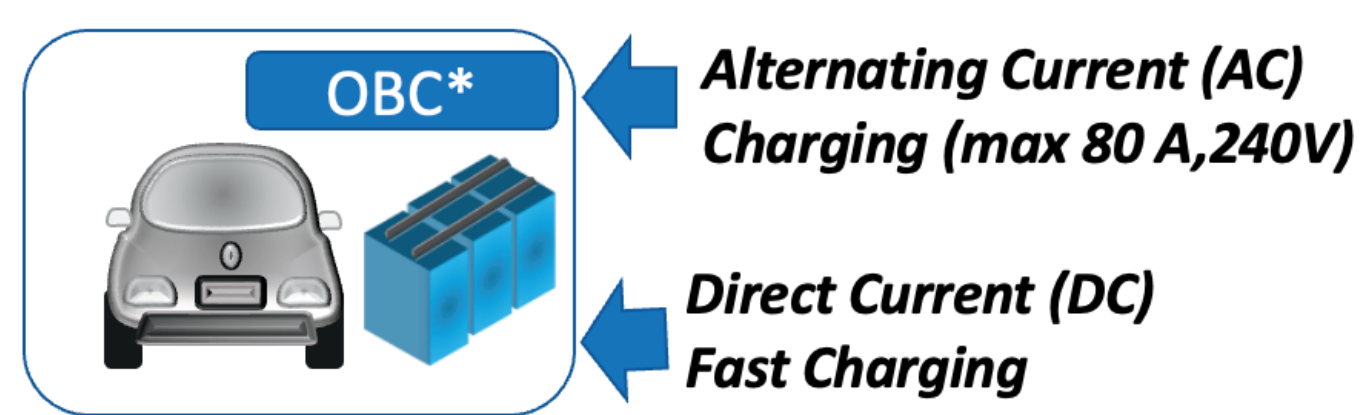
Is the EV charger the next home energy controller?

Unstoppable EV US Market Growth



In 2025, from S&P Global: 7 million 25% of Market

EV Charging Modes



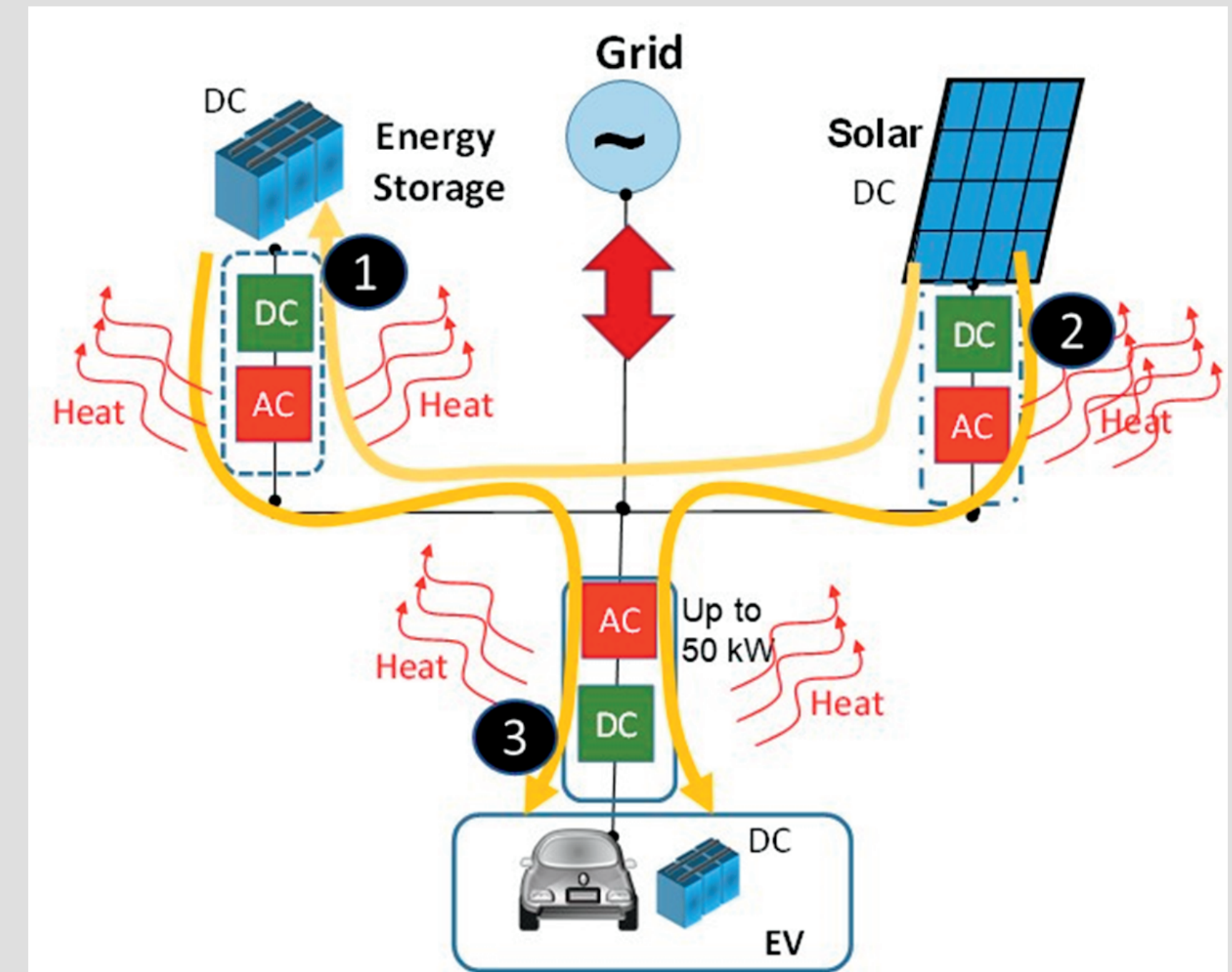
OBC* Limitations

- Size
- Weight
- Price

*OBC: On-Board (inside the vehicle) Charger

Inefficiencies in AC-Coupled Home Energy Systems

Up to 22% energy loss



Drivers For Increased EV Battery Capacities

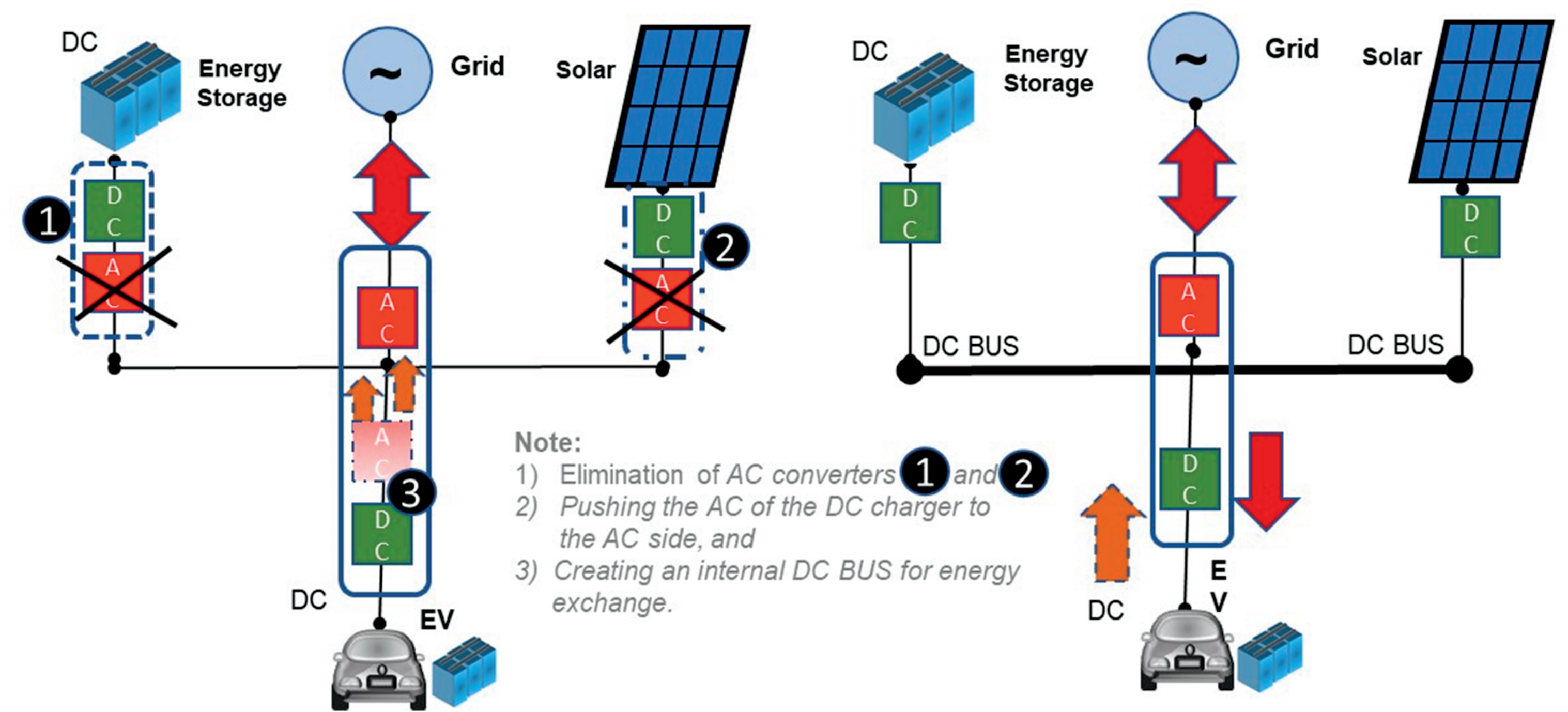
- Full-size vehicle (SUVs, pickups) popularity
- Longer range (range anxiety)
- ➔ Public ultra-fast DC charging station deployment.

Home Charging is AC Level II Charging

1. Max 240 Vac 80A (19.2 kW)
 2. Onboard Charger (OBC) capacity < 12kW
- Heat dissipation, small form factor
 - Exotic semiconductors (SiC, GaN)

➔ Fast home charging & V2H/V2G requires DC

Reducing Losses During the Energy Exchange



Home Charging is AC Level II Charging

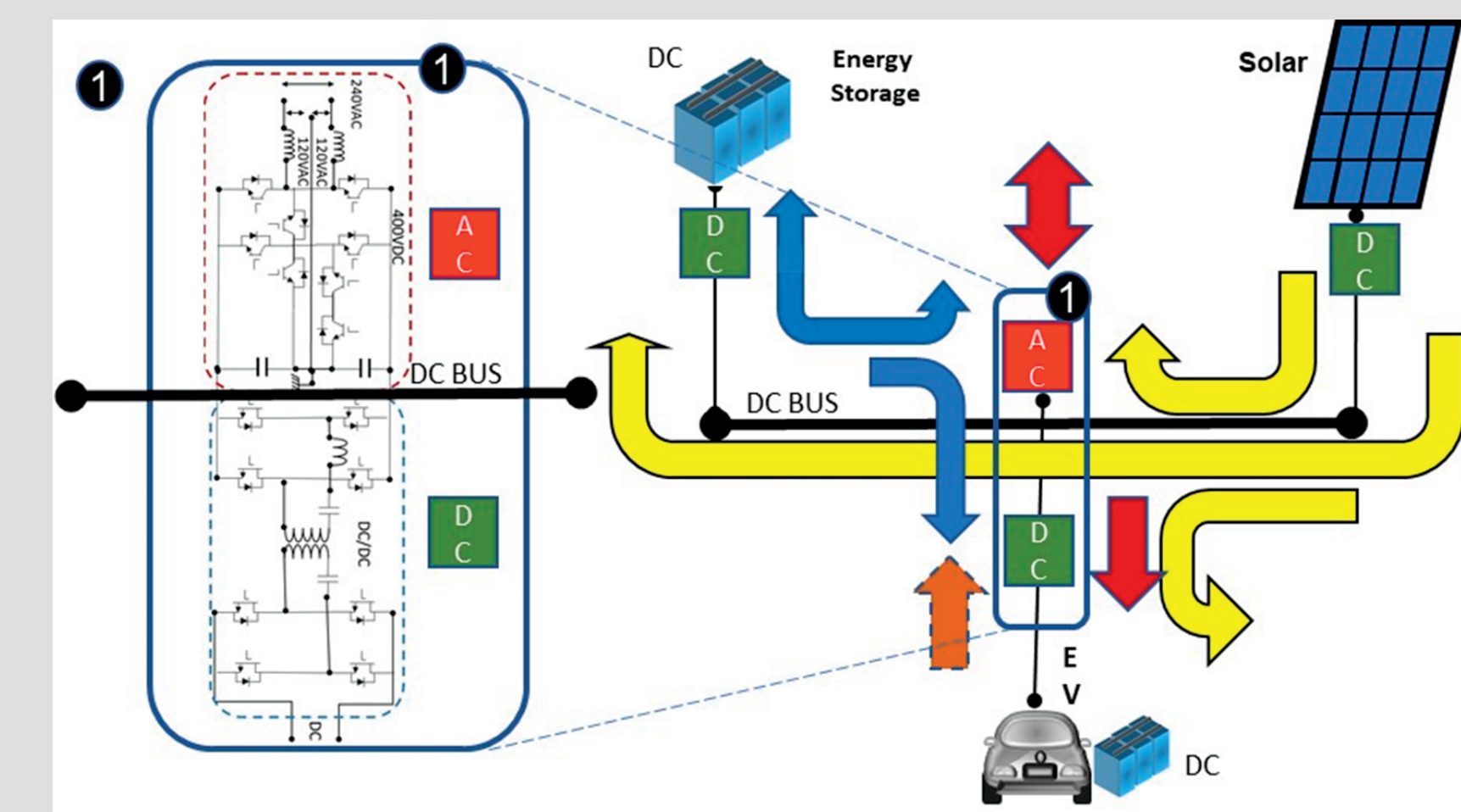
Brand & Model	Audi e-tron (2019)	BMW i3 (2019)	CHEVROLET BOLT (2021)	HONDA CLARITY ELECTRIC (2019)	HYUNDAI IONIQ electric (2020)	HYUNDAI KONA Electric Ultimate (2021)	JAGUAR I-PACE S EV400 (2020)	KIA e-Niro (2019)	VOLKSWAGEN e-Golf SE (2020)	Ford Mustang Mach-E Premium AWD (2021)
Battery (lithium-ion)	95 kWh	42.2 kWh	66 kWh	25.5 kWh	38.3 kWh	64 kWh	90 kWh	64 kWh	35.8 kWh	75.7 kWh
Nominal Voltage	396V	352V	350V	348Vmax	319.4V	356V	388V	356V	323V	346V
On-board Charger	9.6 kW	11 kW	7.2 kW	6.6 kW	7.2 kW	7.2 kW	7 kW	7.2 kW	7.2 kW	10.5 kW

Brand & Model	KIA Soul EV (2019)	NISSAN LEAF SL (2019)	NISSAN LEAF SL Plus (2019)
Battery (lithium-ion)	31.8 kWh	40 kWh	62 kWh
Nominal Voltage	375V	360V	360V
On-board Charger	6.6 kW	6.6 kW	6.6 kW

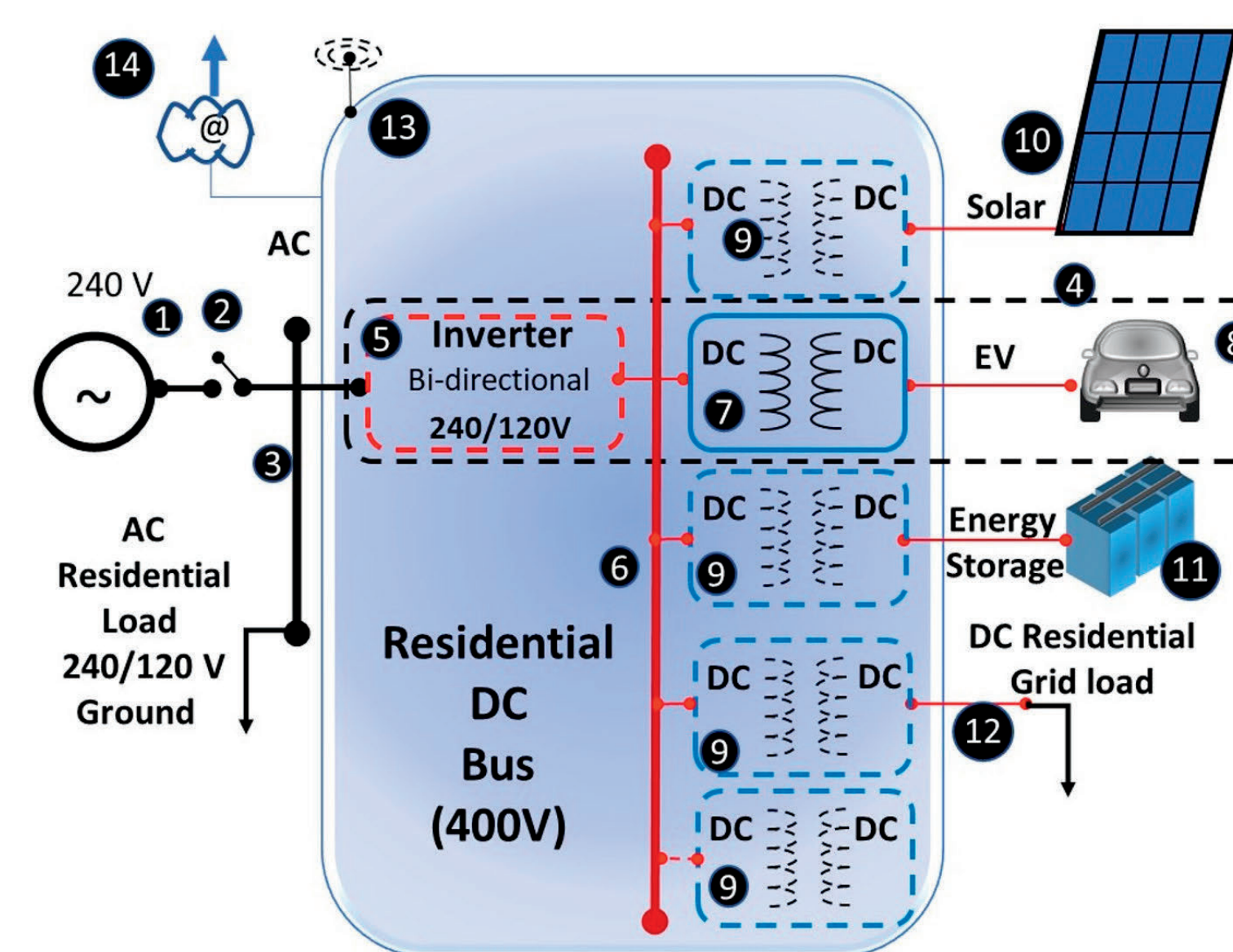
Brand & Model	Model 3 Performance (2021)	Model X Performance (2021)	Model S Performance (2021)
Battery (lithium-ion)	79.5 kWh	100 kWh	100 kWh
Nominal Voltage	360V	350V	400V
On-board Charger	11.5 kW	11.5 kW	11.5 kW

DC EV Charger as an Efficient Energy Manager

- Eliminates redundant solar panel inverter
- Splits AC from the DC charger
- Bi-directional DC bus
- Delivers excess or deficit of energy to grid
- Fast DC charging w/o conversion losses
- DC-DC coupling to DC appliances, HVAC, LED lighting, HWH, etc.



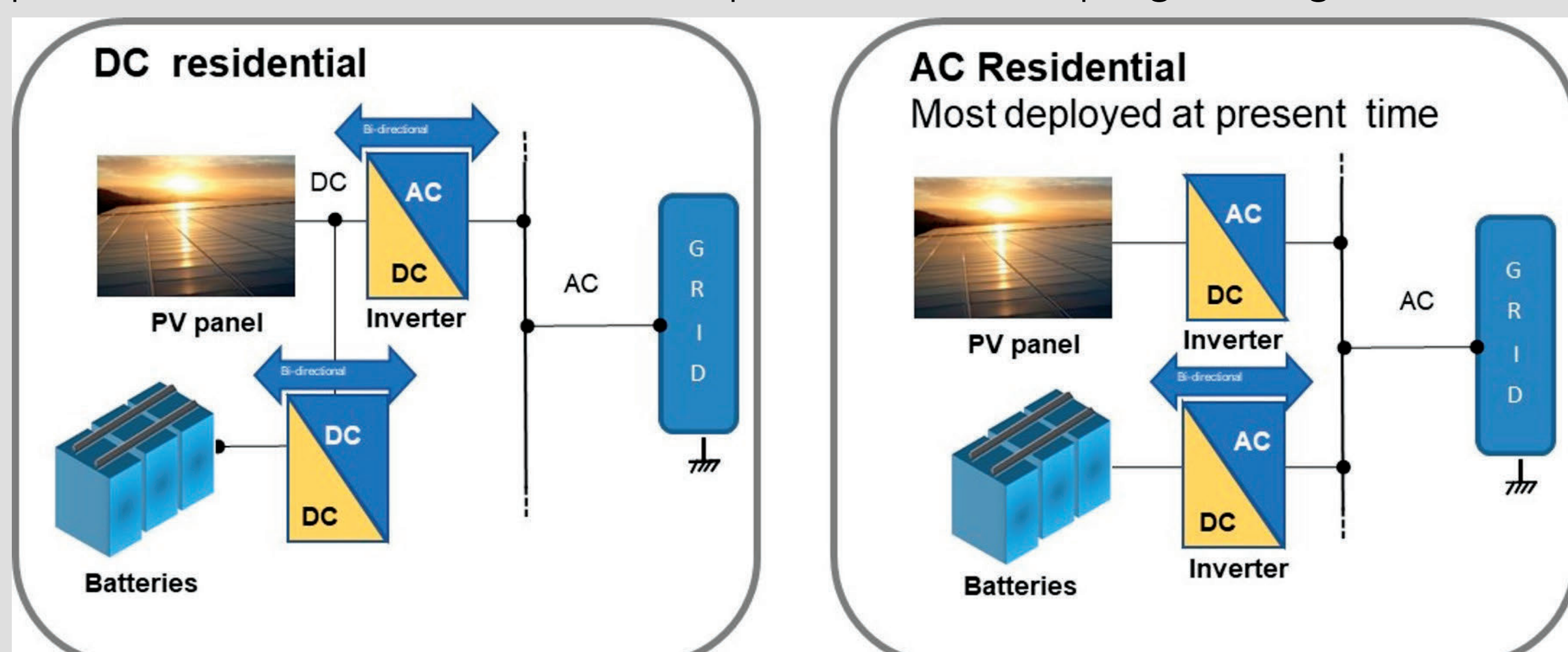
DC BUS with Efficient ESS and Fast EV Charging



1. Power grid AC
2. AC switch/breaker
3. AC residential 240/120V
4. Core of bidirectional DC charger
5. Split (240/120) bi-directional inverter
6. Internal DC-BUS 360-420V
7. Isolated DC/DC converter
8. EV
9. Additional DC/DC converter
10. Solar panel
11. Energy storage
12. DC residential load
13. DC charger-energy management (body)
14. Wireless and internet connection

Rooftop Solar Conversion Losses

DC photovoltaic solar finds similar incompatibilities wrt coupling to AC grid



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