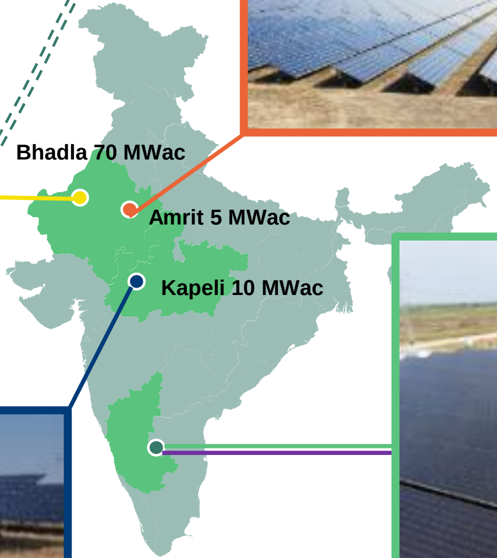
Competitiveness of storage with PV

Eero Vartiainen

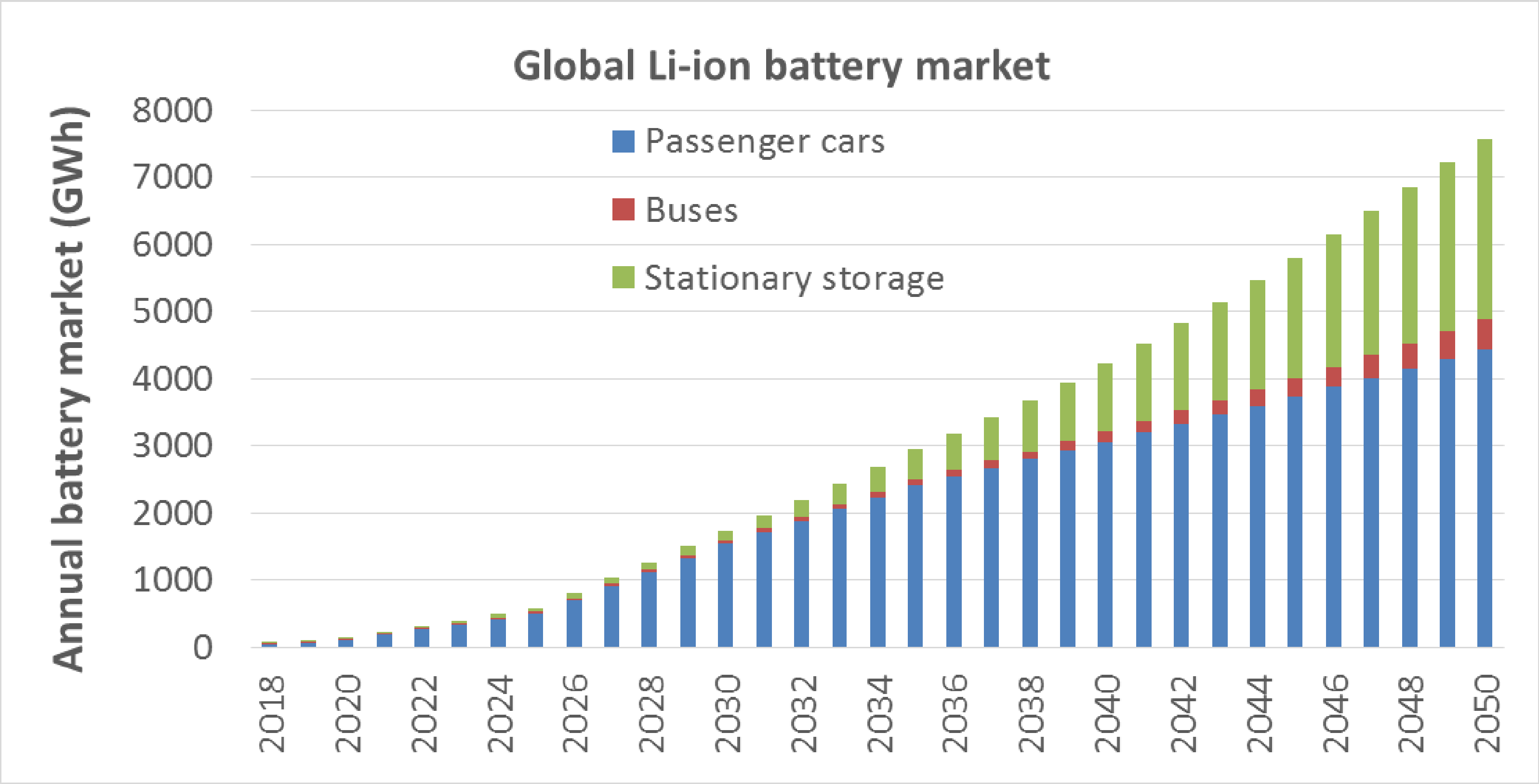
Fortum Growth, 9.9.2019

Fortum operational utility-scale PV portfolio



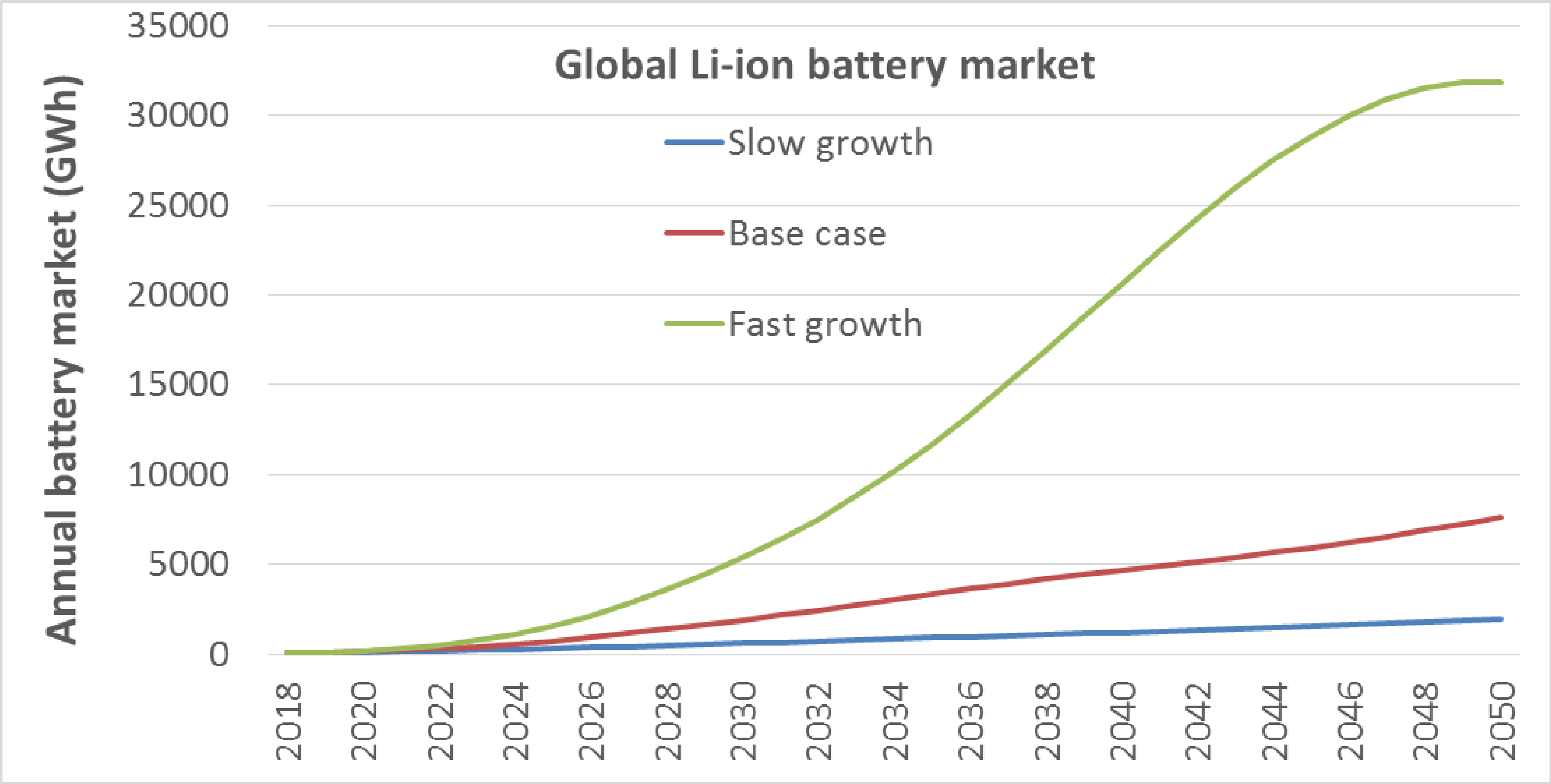
	DC Capacity	AC Capacity	Fortum share	Supply started
	MWp	MWac	MWac (%)	
Russia	**35**	**29**		
Bugulchanskaya	15	13	13 (100%)	2016-2017
Pleshanovskaya	10	8	8 (100%)	2017
Grachevskaya	10	8	8 (100%)	2017
India	**580**	**435**		
Amrit	5	5	2 (46%)	2012
Kapeli	12	10	5 (46%)	2014
Bhadla	88	70	32 (46%)	2017
Pavagada	125	100	46 (46%)	2017
Pavagada	350	250	250 (100%)	2019
Total portfolio	**615 MWp**	**464 MWac**		

Li-ion battery market will be dominated by electric vehicles, stationary storage share will increase to ~30% after 2040



- Annual Li-ion market ~100 GWh in 2019 (excluding consumer electronics)
- Share of EV's from new vehicles 1% in 2018, 30% in 2030 and 75% in 2050; battery capacity 50 kWh per EV
- Annual stationary storage market per annual PV market 0.04 kWh/kWp in 2018, 0.4 kWh/kWp in 2030 and 2 kWh/kWp in 2050

Annual Li-ion market will be ~7000 GWh in the base scenario, slow to fast scenario range 2000-30 000 GWh by 2050



- Base scenario assumes annual 75% EVs of 120 million new cars in 2050 and 2 kWh/kWp stationary storage with 1300 GWp PV
- Slow growth assumes annual 50% EVs of 60 million new cars in 2050 and 1 kWh/kWp stationary storage with 500 GWp PV
- Fast growth assumes annual 100% EVs of 180 million new cars in 2050, almost totally electrified transport sector and 3 kWh/kWp stationary storage with 4 TWp PV

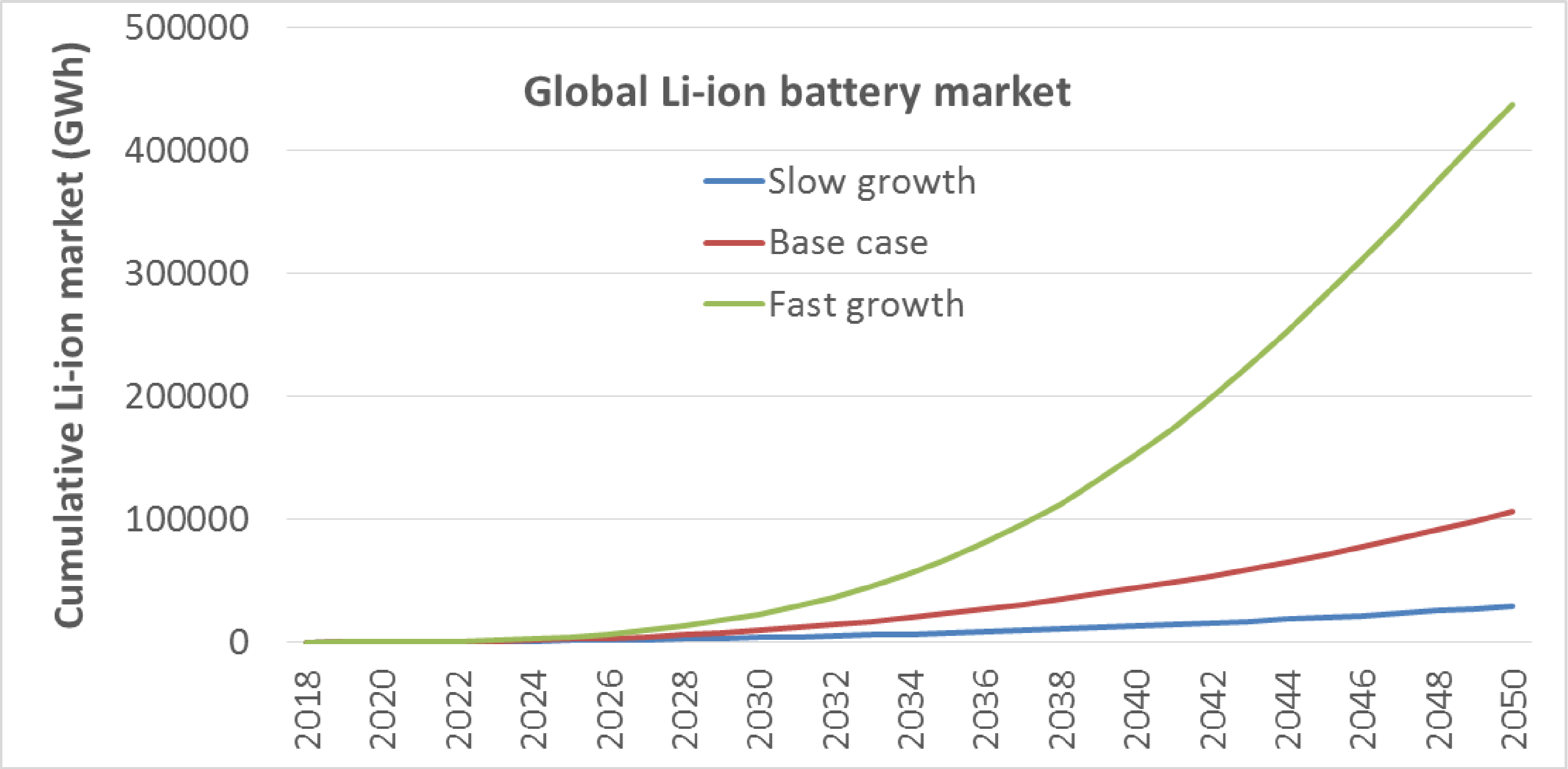
Base: CAGR 50% 2018-20, 50-30% 2020-25, 30-15% 2025-30, 15-5% 2030-40 and 5% after 2040

Slow growth: CAGR 30% 2018-20, 30-20% 2020-25, 20-10% 2025-30, 10-5% 2030-40 and 5% after 2040

Fast growth: CAGR 70% 2018-20, 70-40% 2020-25, 40-20% 2025-30, 20-0% 2030-50 and 0% after 2050

Source: Vartiainen E, Masson G, Breyer C,Moser D, Román Medina E. Impact of weighted average cost of capital, capital expenditure, and other parameters on future utility-scale PV levelised cost of electricity. Prog Photovolt Res Appl. 2019;1–15. https://doi.org/10.1002/pip.3189

Cumulative Li-ion market could grow 10-fold by 2025 and 100-fold by 2035 in the base case; even 1000-fold in fast growth after 2040



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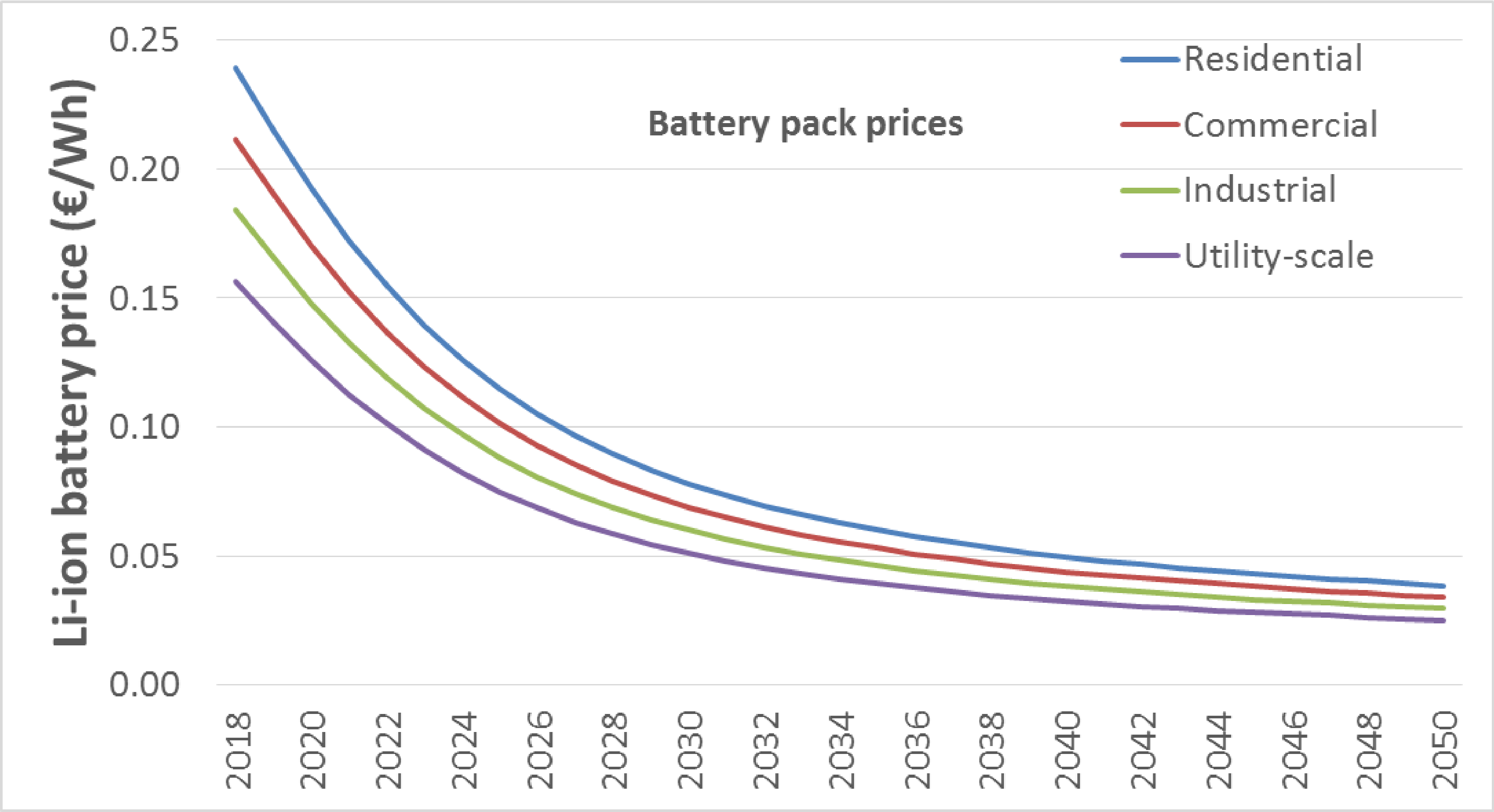
Average Li-ion battery pack price will decrease by 50% by 2025, by 75% by 2035 and almost 85% by 2050 in the base case



Base volume growth, learning rate 17.5%
Utility-scale 15% lower than industrial (average), commercial 15% and residential 30% higher than average
All prices in real 2019 euros, without VAT

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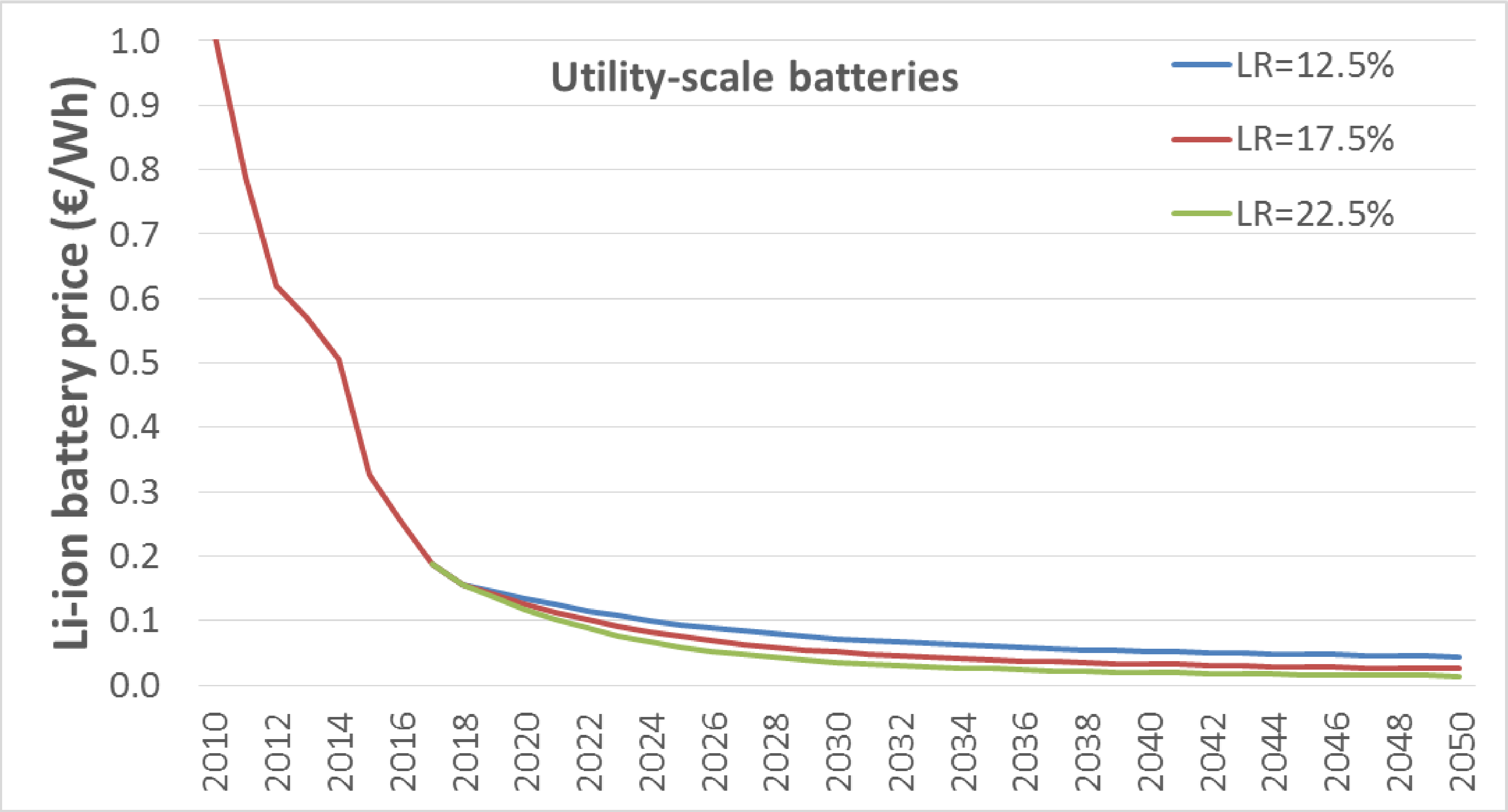
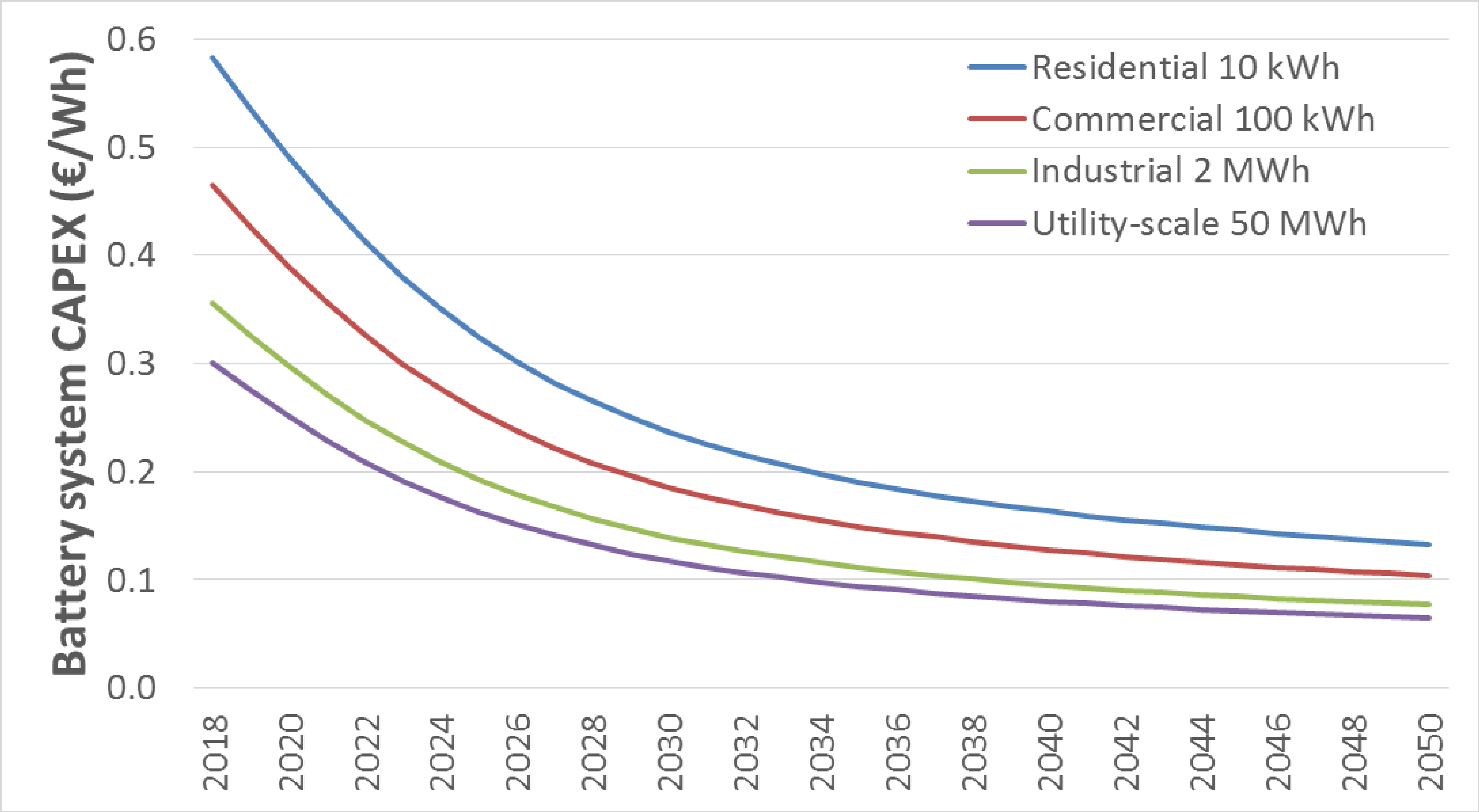
Li-ion battery prices have decreased by 85% from 2010 to 2018



Historical price source: BNEF
Future prices with base volume growth
All prices in real 2019 euros

Small residential battery system is about double the large utility-scale system CAPEX; system price will decrease by 75% by 2050



With base volume growth and 17.5% learning rate
All prices in real 2019 euros, without VAT

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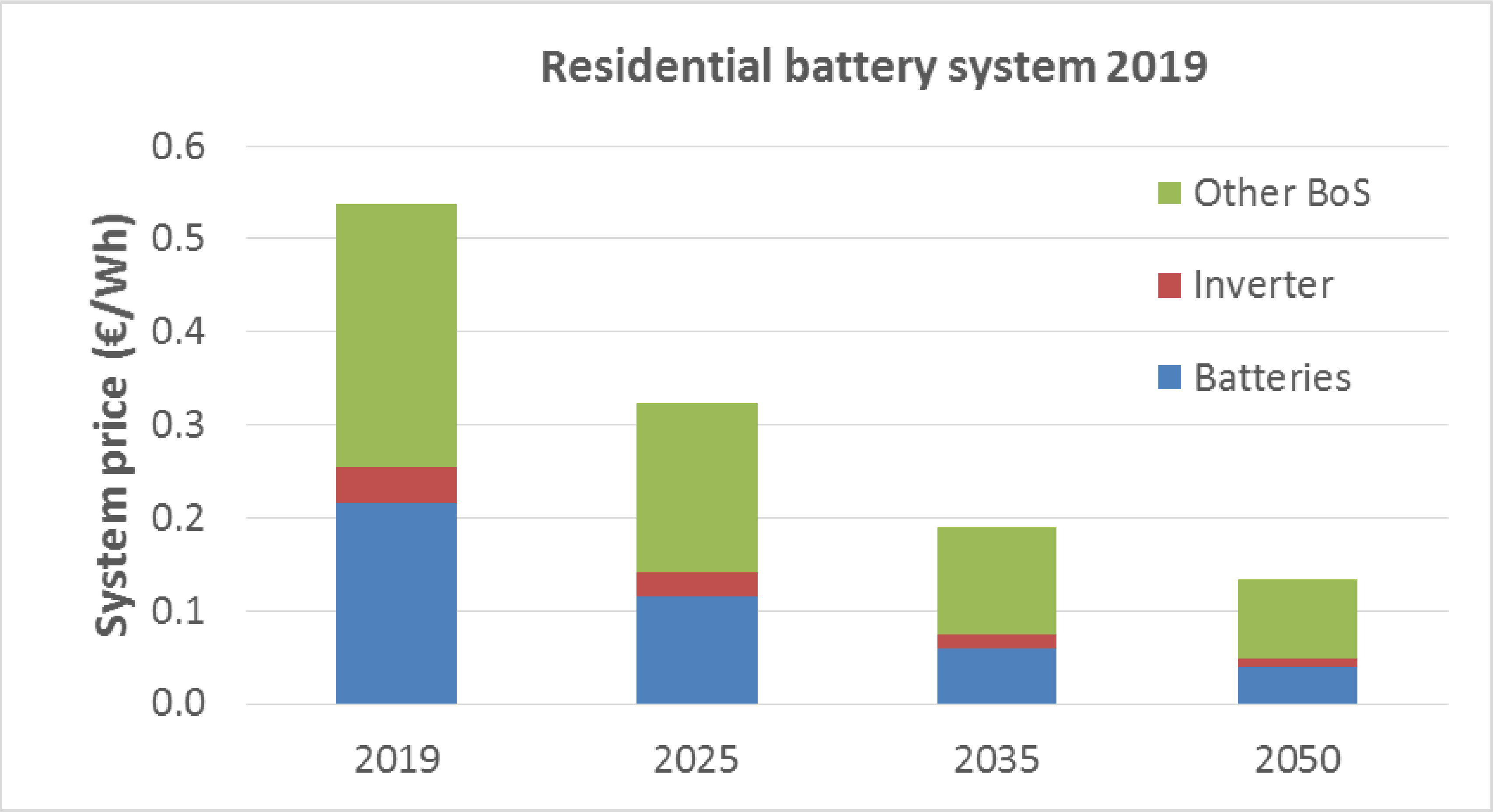
Share of batteries in the system CAPEX to decrease from current 40% below 30% by 2050



All prices in 2019 real euros, without VAT

When is PV or storage competitive ?

PV is competitive when value of PV electricity is higher than the generation cost which is measured by Levelised cost of electricity (LCOE)

PV profit = PV value – PV LCOE

Storage competitiveness depends on what it is compared with:

- When adding a storage to an existing PV system, storage is competitive if the profit is higher with the storage than without the storage

- When building a new PV + storage system, the investment is profitable when the value of generated PV electricity is higher than the LCOE of PV + storage

Profitability is often measured by Internal Rate of Return (IRR)

Average value of PV electricity for prosumer

Average value of PV generation P_{ave} is defined by the equation:

$$P_{ave} = SC * P_{retail} + (1 - SC - LOSS) * P_{feed\text{-}in}$$

where

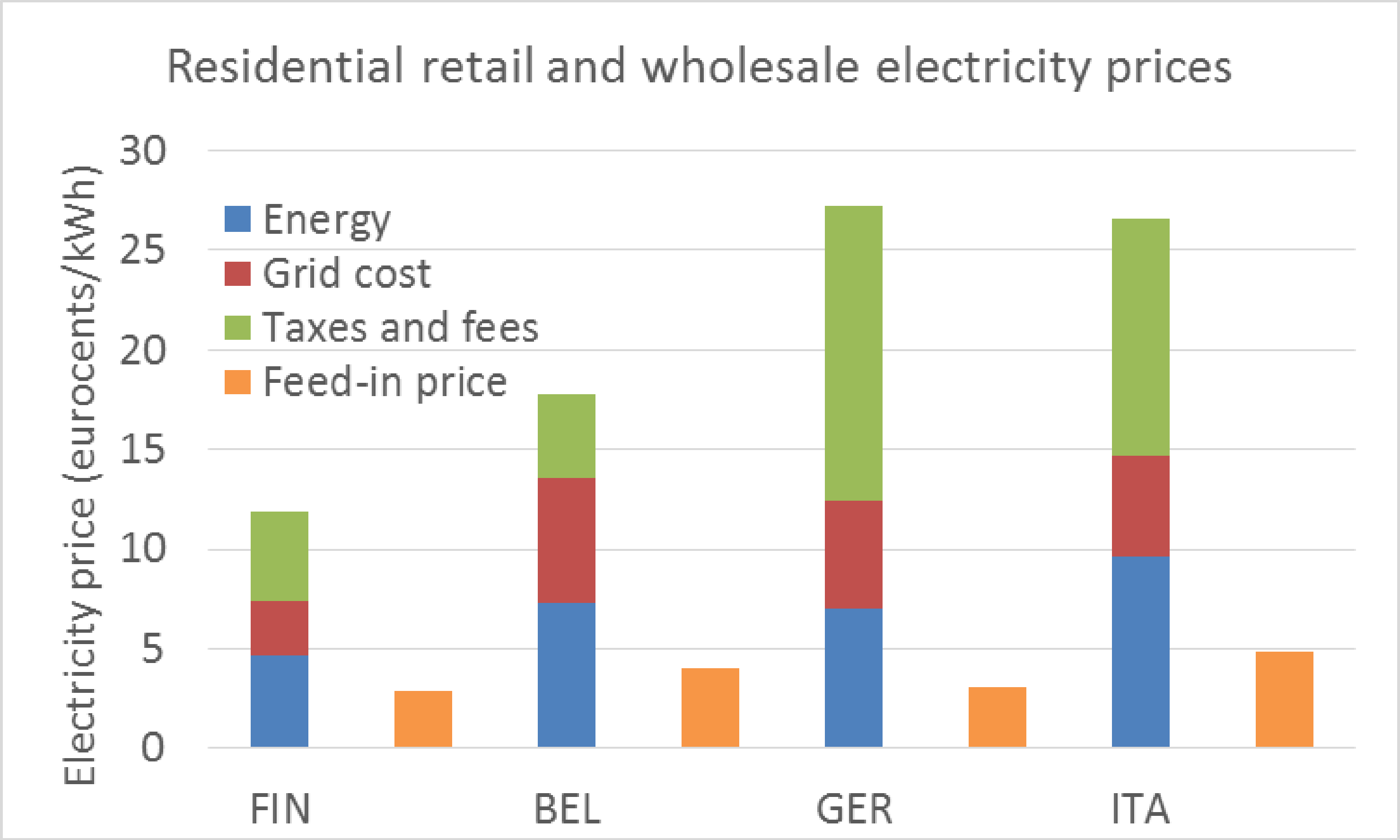
SC = ratio of self-consumption of the PV production
P_{retail} = variable retail electricity price
$P_{feed\text{-}in}$ = wholesale or other value of the electricity fed into the grid
$LOSS$ = ratio of the storage loss of the PV generation

and where P_{retail} is excluding any fixed monthly or annual and power-related fees in the customer bill.

Storage will increase SC and therefore P_{ave} because $P_{retail} > P_{feed\text{-}in}$

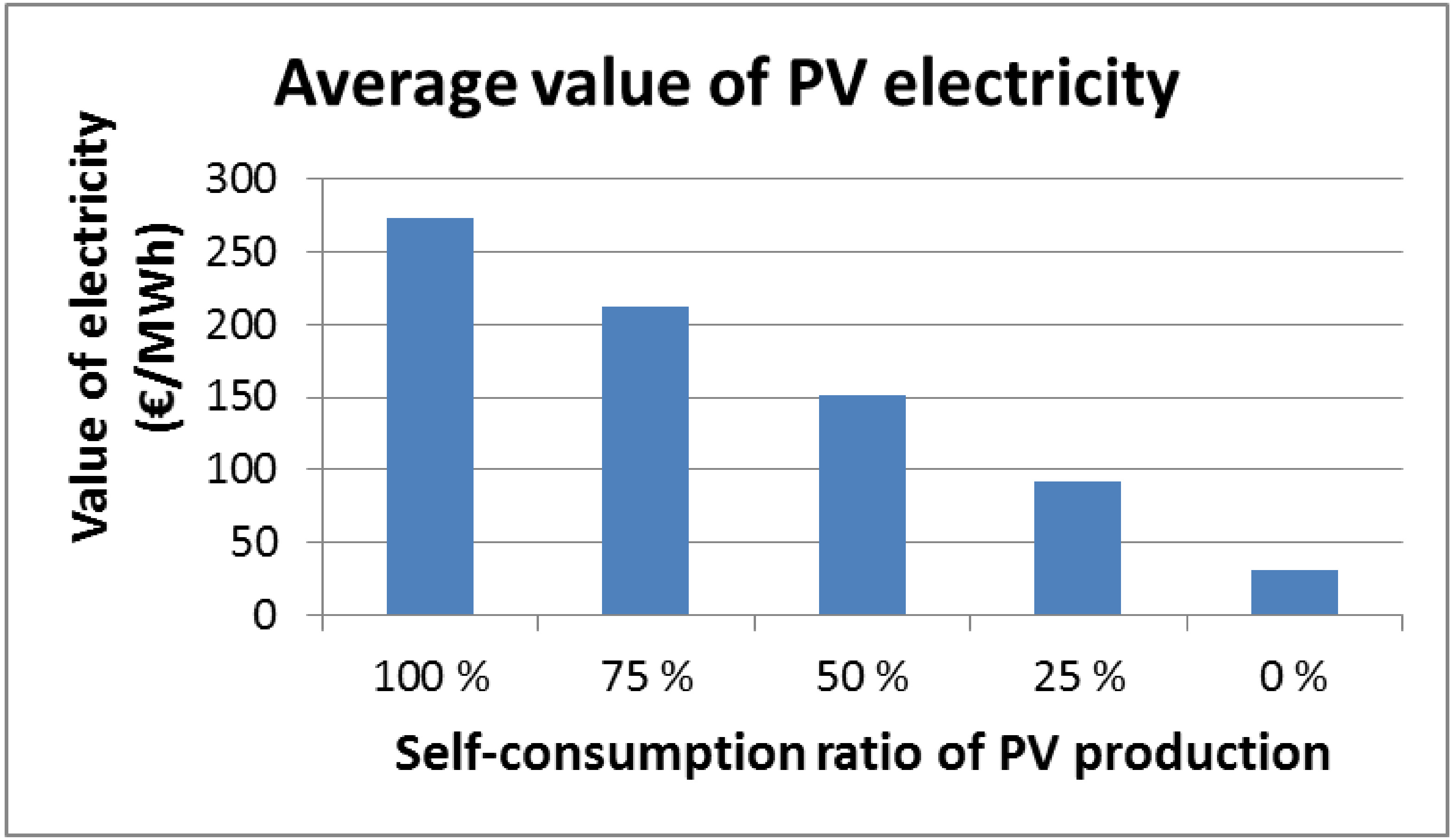
but the added value must compensate for the storage cost

Retail electricity prices are much higher than wholesale prices in Europe



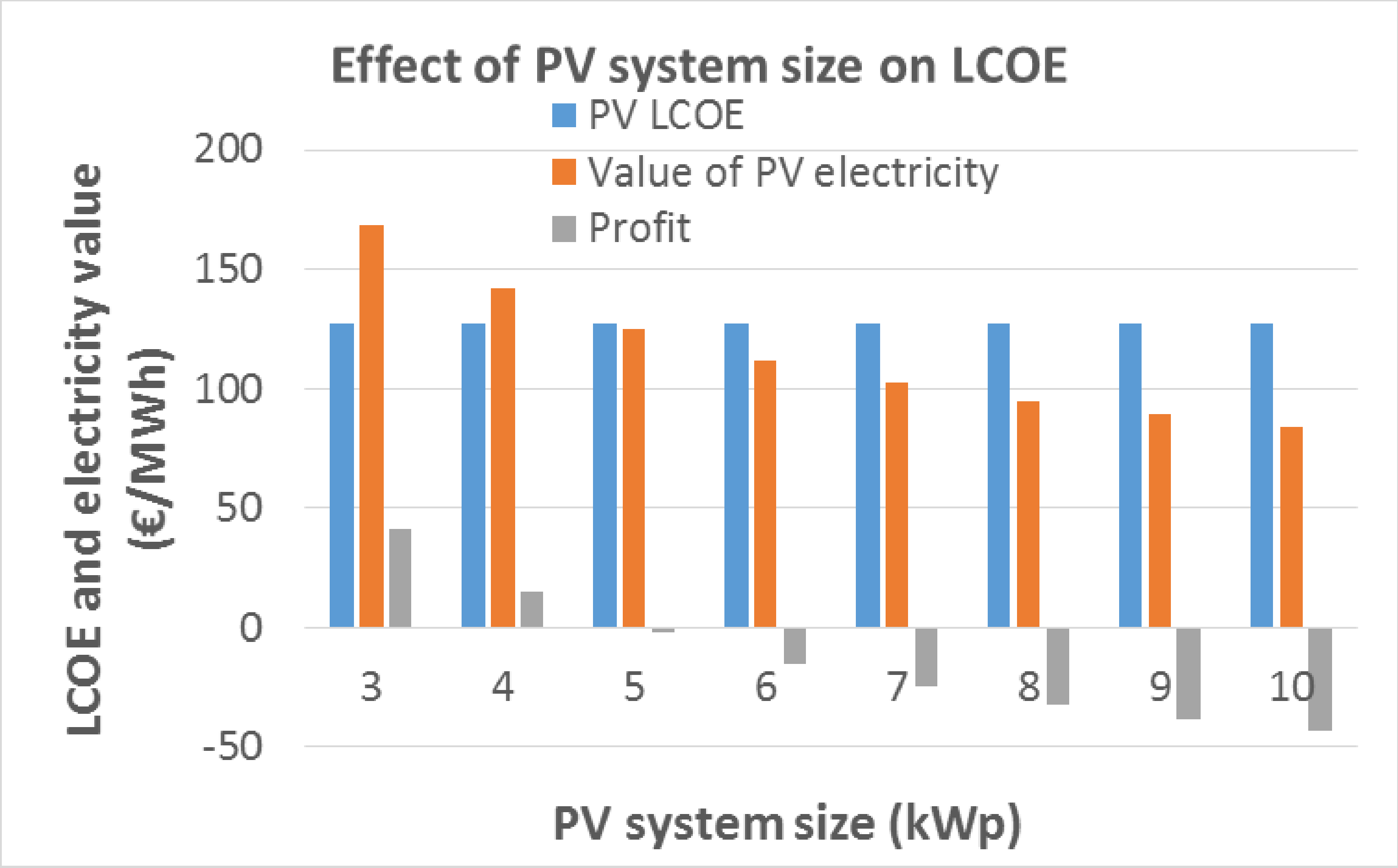
Source: Eurostat 2015 average prices for annual 5-15 MWh consumption; fixed fees excluded
Feed-in price is wholesale spot market average price 2017 minus 10%

Example of PV electricity value for a residential prosumer in Germany (without storage)



Source: Eurostat 2015 average prices for annual 5-15 MWh consumption
Note: Value of surplus electricity fed into the grid is average spot market price in 2017 – 10%

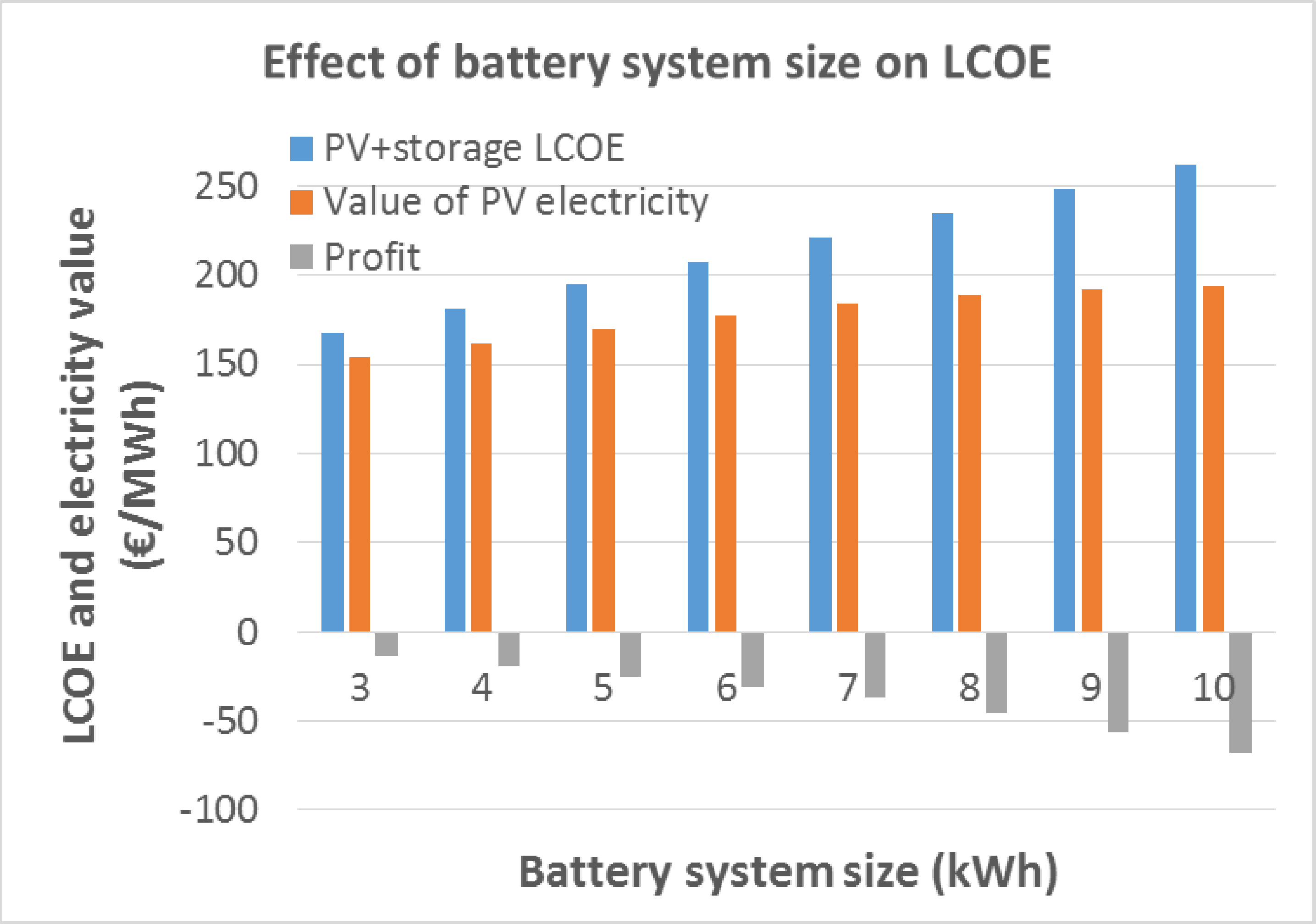
PV LCOE for a residential PV system in Germany in 2018: with 8% nominal WACC, systems up to 5 kWp are profitable with 5 MWh annual consumption (assuming no feed-in tariff)



PV self-consumption:
57% with 3 kWp
22% with 10 kWp

PV CAPEX 1.2 €/Wp + VAT and OPEX 19 €/kWp/a
PV yield 1040 kWh/kWp, annual degradation 0.5%, PV system lifetime 30 a
Annual electricity consumption 5 MWh, nominal WACC 8%, annual inflation 2%

LCOE for a residential PV+storage system in Germany in 2018: with 8% nominal WACC, storage is not yet profitable



PV self-consumption:
39% with 0 kWh
58% with 5 kWh
68% with 10 kWh

PV system size 5 kWp, usable storage capacity 80%, round-trip efficiency 90%, annual consumption 5 MWh
PV CAPEX 1.2 €/Wp + VAT and OPEX 19 €/kWp/a, storage CAPEX 600 €/kWh + VAT and OPEX 6 €/kWh/a
PV yield 1040 kWh/kWp, annual degradation 0.5%, PV system lifetime 30 a, storage system lifetime 15 a
Nominal WACC 8%, annual inflation 2%

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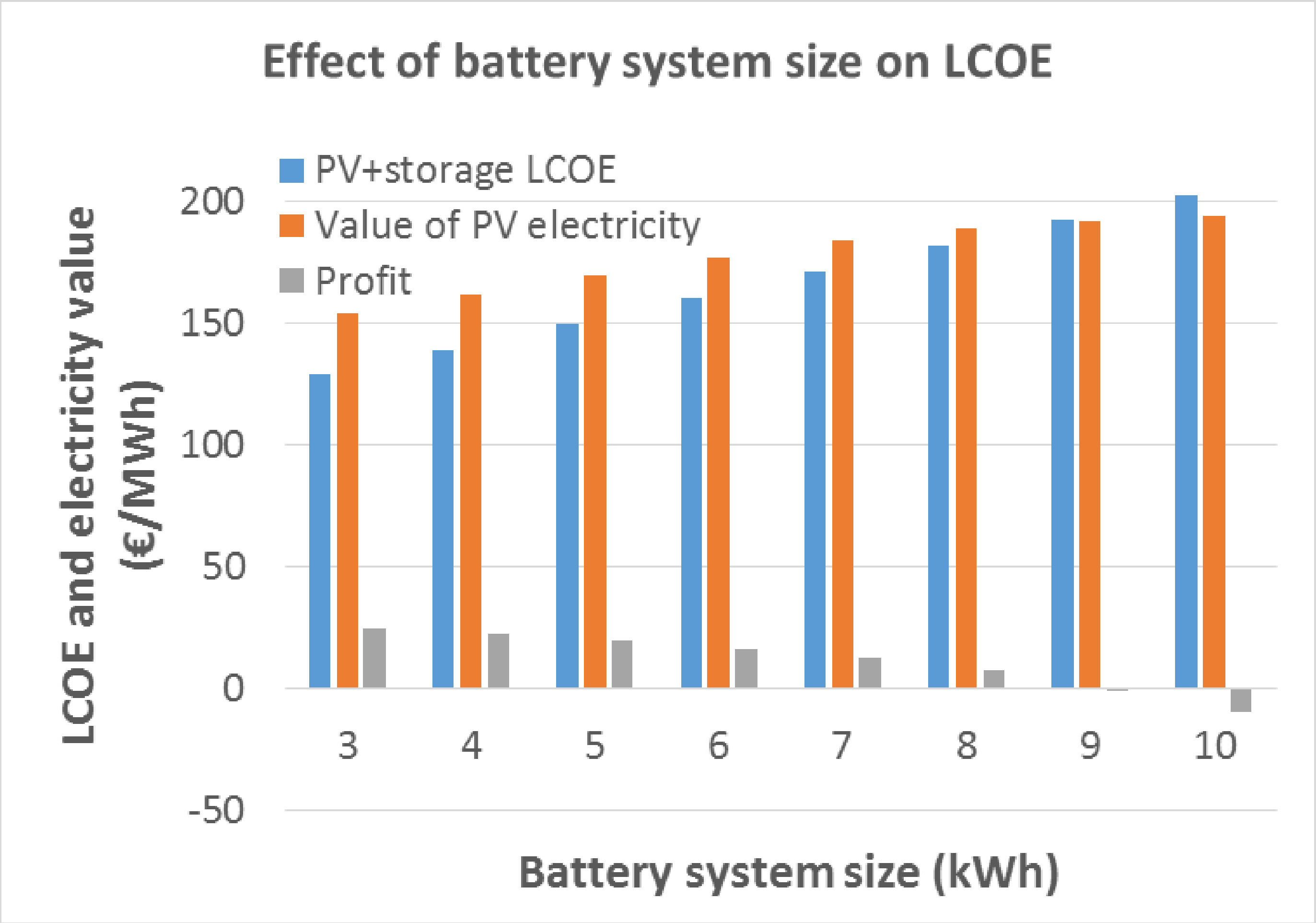
BUT with 5% nominal WACC, storage up to 9 kWh is profitable



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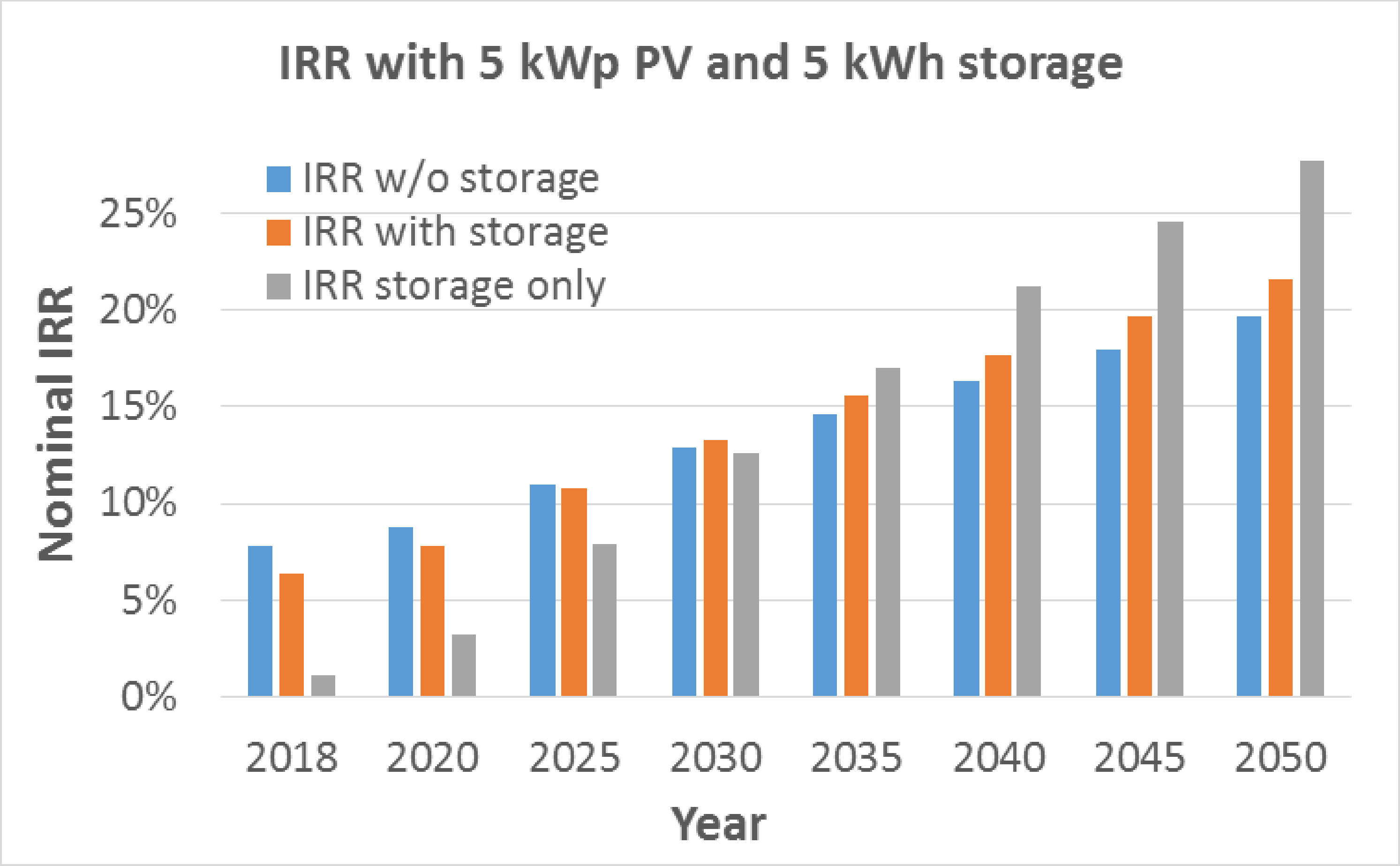
PV CAPEX 1.2 €/Wp + VAT and OPEX 19 €/kWp/a, storage CAPEX 600 €/kWh + VAT and OPEX 6 €/kWh/a
PV yield 1040 kWh/kWp, annual degradation 0.5%, PV system lifetime 30 a, storage system lifetime 15 a
Nominal WACC 5%, annual inflation 2%

A 5 kWp PV system with 5 kWh storage becomes better investment than PV alone after 2025 in Germany



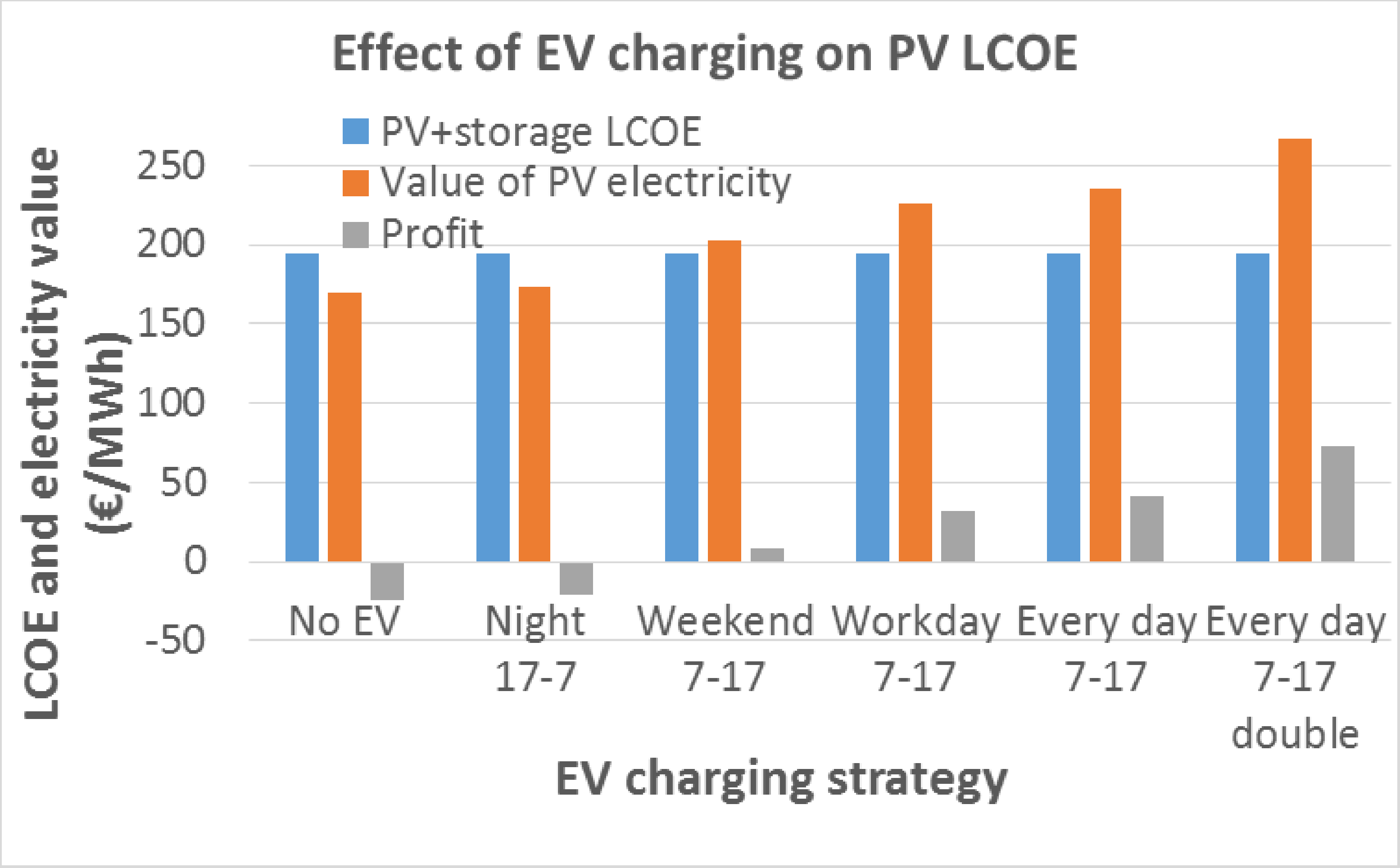
PV self-consumption:
39% with 0 kWh
58% with 5 kWh

PV system size 5 kWp, usable storage capacity 80%, round-trip efficiency 90%, annual consumption 5 MWh
PV CAPEX 1.2-0.55 €/Wp + VAT and OPEX 19-11 €/kWp/a, storage CAPEX 600-130 €/kWh + VAT and OPEX 6-3 €/kWh/a
PV yield 1040 kWh/kWp, annual degradation 0.5%, PV system lifetime 30 a, storage system lifetime 15 a
Annual inflation 2%

The impact of electric vehicles depends on the charging pattern, average daily consumption of 10 kWh is assumed

- Every night from 17 to 7
- Saturday and Sundays from 7 to 17
- Every weekday from 7 to 17
- Every day from 7 to 17
- Every day from 7 to 17 with double consumption

Adding an EV to the 5 kWh battery system makes it profitable if the car is at home during at least on weekend daytime



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PV yield 1040 kWh/kWp, annual degradation 0.5%, PV system lifetime 30 a, storage system lifetime 15 a
Nominal WACC 8%, annual inflation 2%; annual consumption 5 MWh

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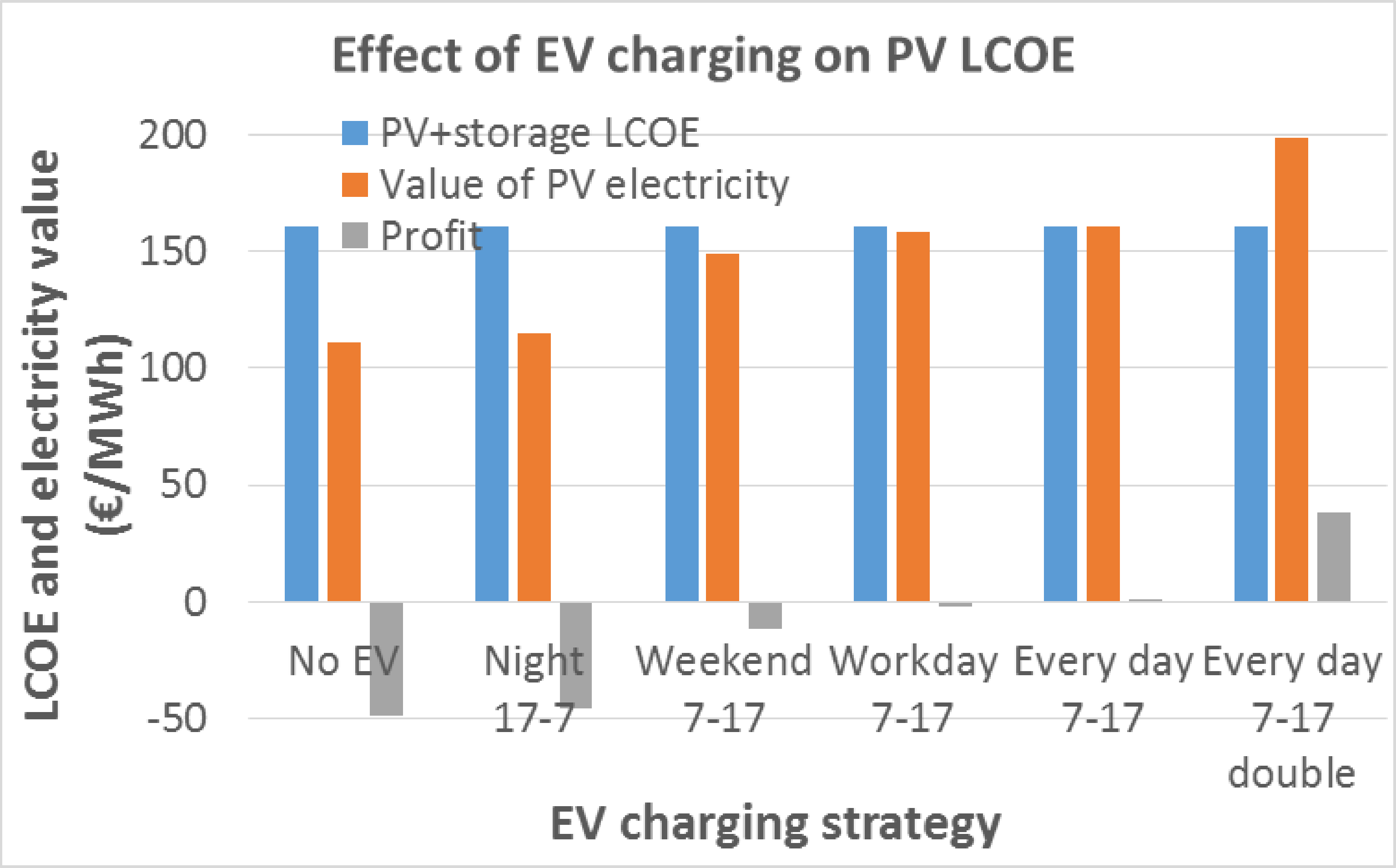
If one EV is always at home in daytime, even a 10 kWp PV system could be profitable with 8% nominal WACC in Germany



PV system size 10 kWp, battery system 5 kWh, usable storage capacity 80%, round-trip efficiency 90%,
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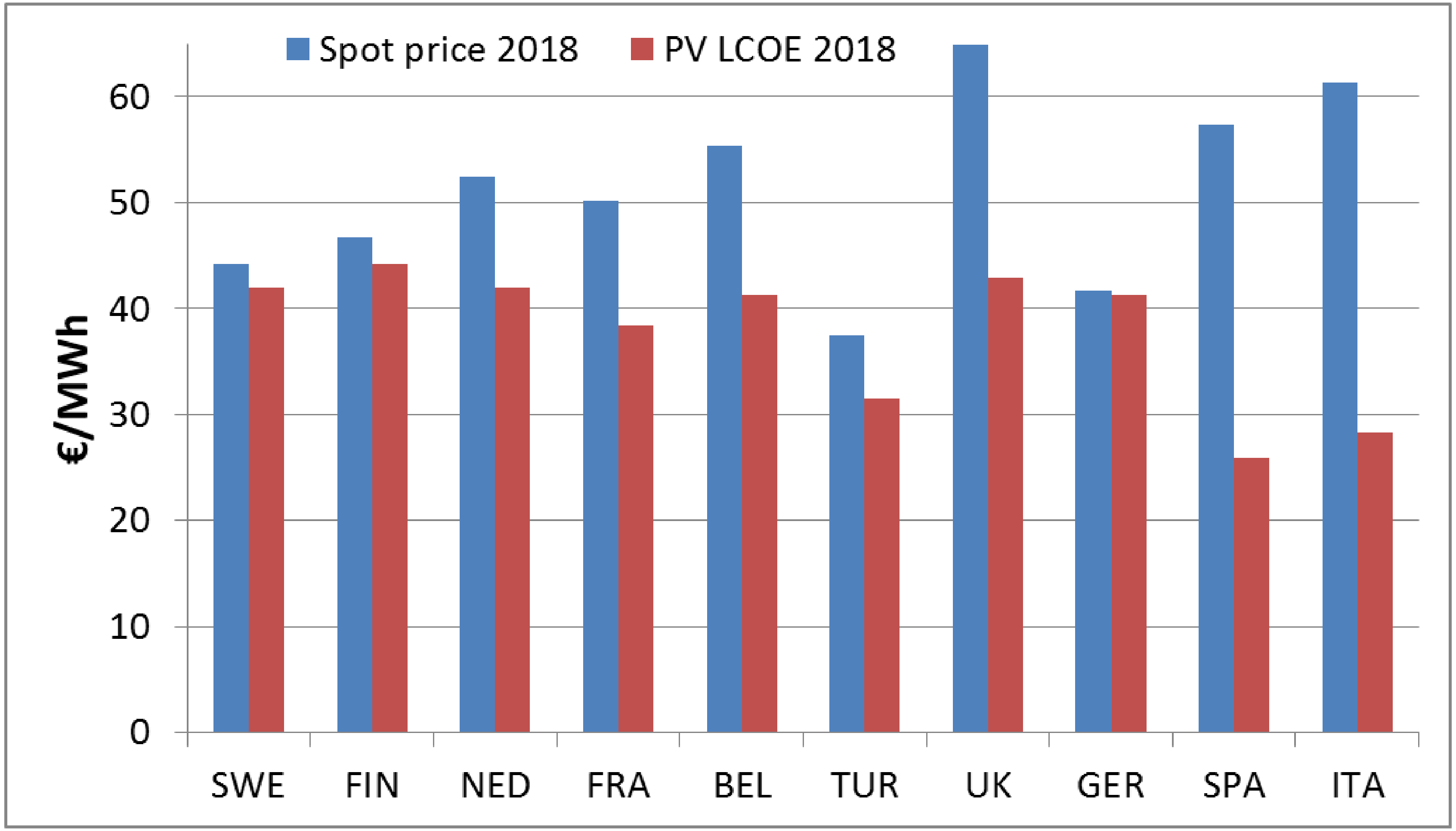
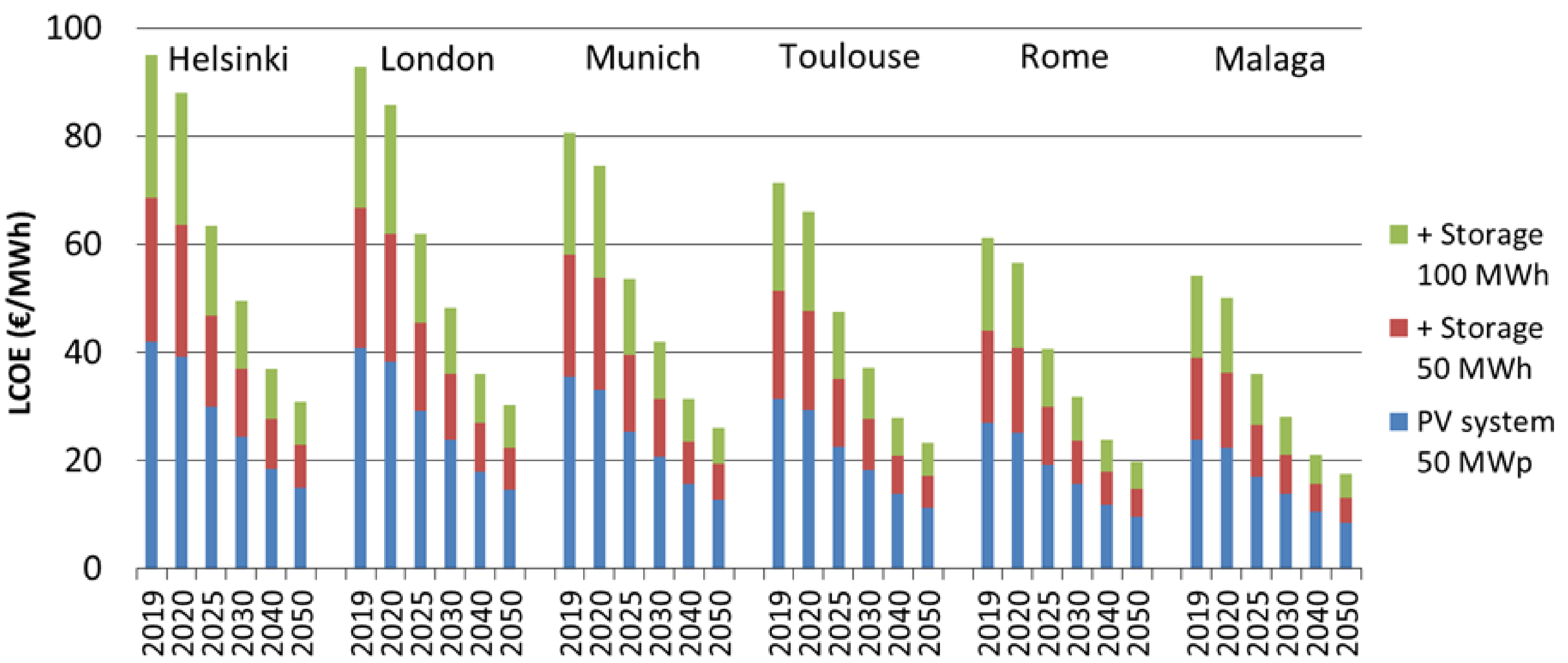
PV yield 1040 kWh/kWp, annual degradation 0.5%, PV system lifetime 30 a, storage system lifetime 15 a
Nominal WACC 8%, annual inflation 2%; annual consumption 5 MWh

Utility-scale PV was already cheaper than average spot market electricity price all over Europe in 2018



Average spot price in day-ahead market
PV LCOE with 0.5 €/Wp CAPEX and 7% nominal WACC

Li-ion battery storage cost decreasing even faster than PV making utility-scale PV+storage a competitive option soon



CAPEX 2018 PV 0.5 €/Wp and storage 0.3 €/Wh, CAPEX 2050 PV 0.17 €/Wp and storage 0.07 €/Wh
In real 2018 euros, nominal WACC 7%, battery replacement investment included after 15 years
From system and economical point of view, 1-2 kWh storage capacity per 1 kWp PV is optimal
Source: Vartiainen E, Masson G, Breyer C,Moser D, Román Medina E. Impact of weighted average cost of capital, capital expenditure, and other parameters on future utility-scale PV levelised cost of electricity. Prog Photovolt Res Appl. 2019;1–15. https://doi.org/10.1002/pip.3189

Conclusions

- PV alone is already competitive in most countries and market segments
- PV + battery electricity storage starts to be competitive in countries like Germany, Italy and Denmark with high retail electricity price
- **The main benefit of storage is that it will allow larger PV systems and thus much higher renewable share in the energy system**

Ackknowledgements

- The study has been partly made under the framework of European PV Technology and Innovation Platfform (ETIP PV)

- To learn more about utility-scale PV LCOE, please attend oral session 7EO.3 on Friday 13th September at 8:30-16.45 in Audit 2 to see presentation ”Impact of Weighted Average Cost of Capital, Capital Expenditure and Other Parameters on Future Utility-Scale PV Levelised Cost of Electricity” by Eero Vartiainen and co-authors Gaëtan Masson, Christian Breyer, David Moser and Eduardo Román Medina

- Paper has been published online in Progress in Photovoltaics:

https://onlinelibrary.wiley.com/doi/full/10.1002/pip.3189

- **Thank you for your attention!**