


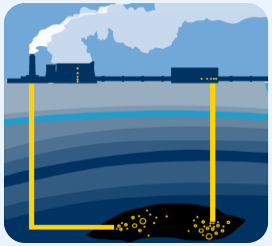



Fuelling Spain's Future

Grid synergies of EV Charging

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Recap: Project Objectives and Scope

Objectives

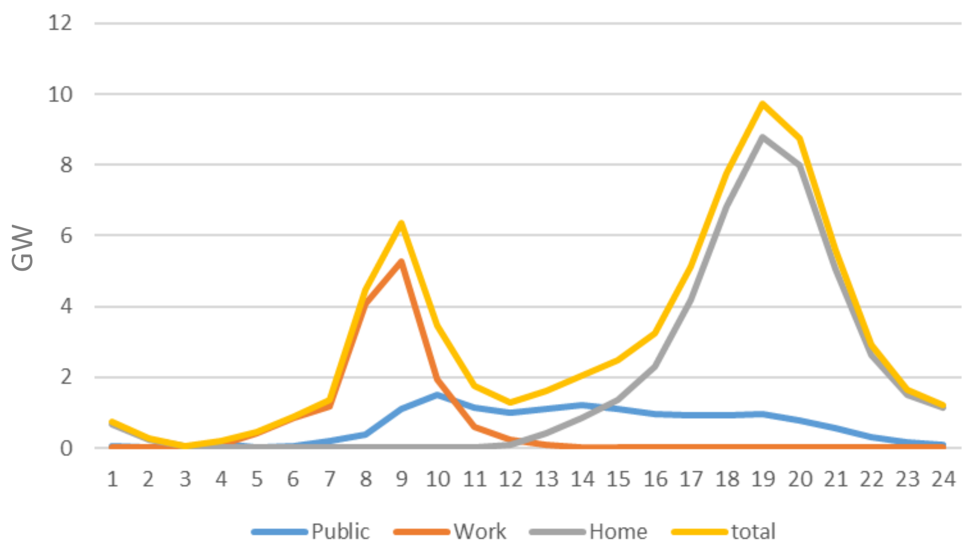
- Deployment of electric vehicles will have an impact on the electricity system
- This impact will be significant in the medium to long term when EV numbers are substantial.
- A new EV charging infrastructure needs to be created. Decisions made now may have significant cost impacts for the electricity system.
- This project
  - identifies the synergies between EV deployment and the electricity grid
  - determines the impact of EV charging options (net cost or benefit)

Scope

- Identify distinct charging options
  - Passive (uncontrolled)
  - “Smart” (Managed charging)
  - “Active” Vehicle to Grid (V2G)
- Use “whole system” approach to identify impact of charging on each part of electricity system.
- Evaluate impacts of charging options using whole system operational model (2030, 2050).
- Determine net cost/value of EV charging options on electricity system

The majority of EVs are expected to charge at home during the night

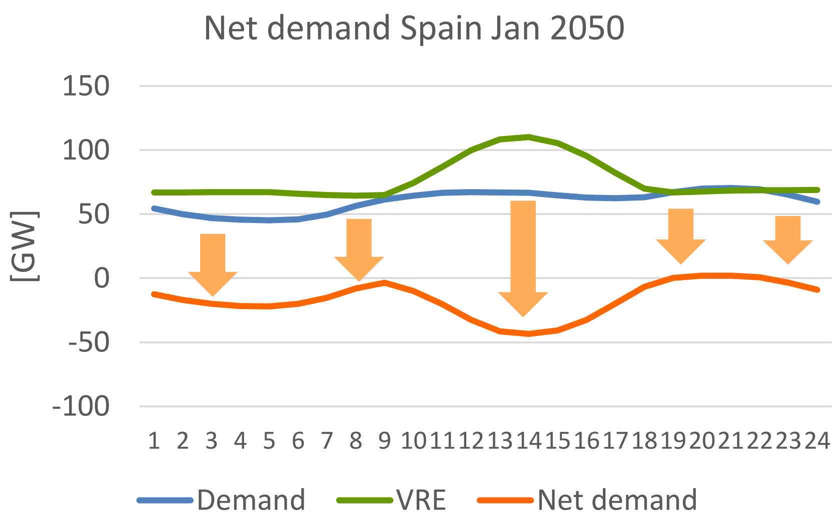
EV demand is divided into different categories depending on timing and location

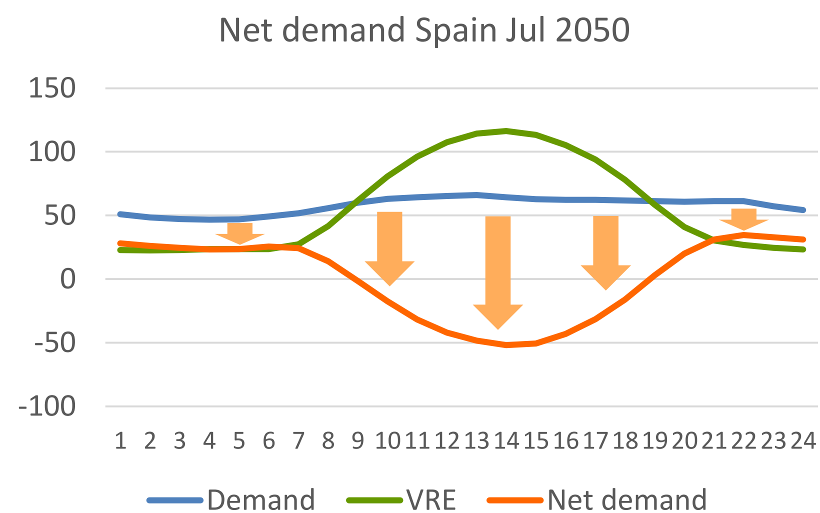


- Modelled EV demand consists of home/work and public charging
- Public EV demand is considered inflexible
- Home and work demand is considered flexible within constraints: Each EV has a charging window at the end of which it has to be fully charged
- Graph above shows the composition of the passive charging profile

2050 Capacity Assumptions: Renewable energy leads to negative net demand for much of the year

Baseline demand, less Variable Renewable Energy output determine Net Demand





- Future dispatchable generation must to respond to “Net Demand” – residual demand after Renewable Generation.
- Strong seasonal variation in renewable output: wind high in winter, solar high in summer.
- Net demand is negative throughout the day in winter, but significant amounts of positive net demand remain in summer during the evening and night time

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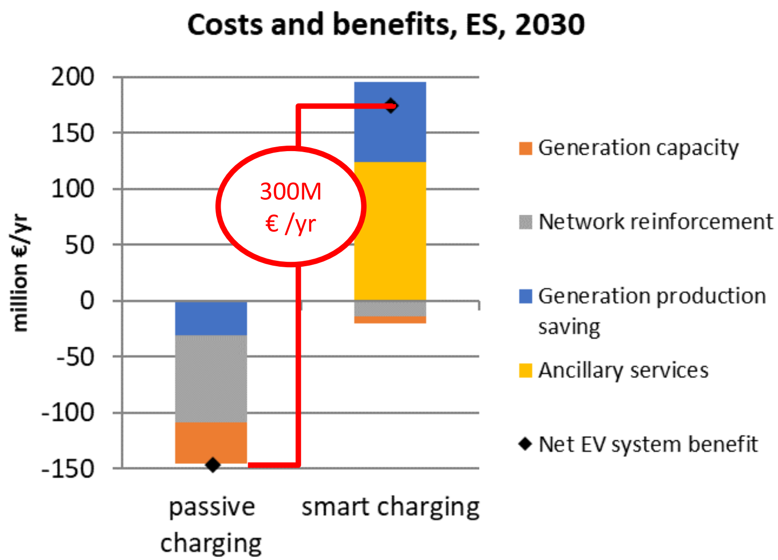
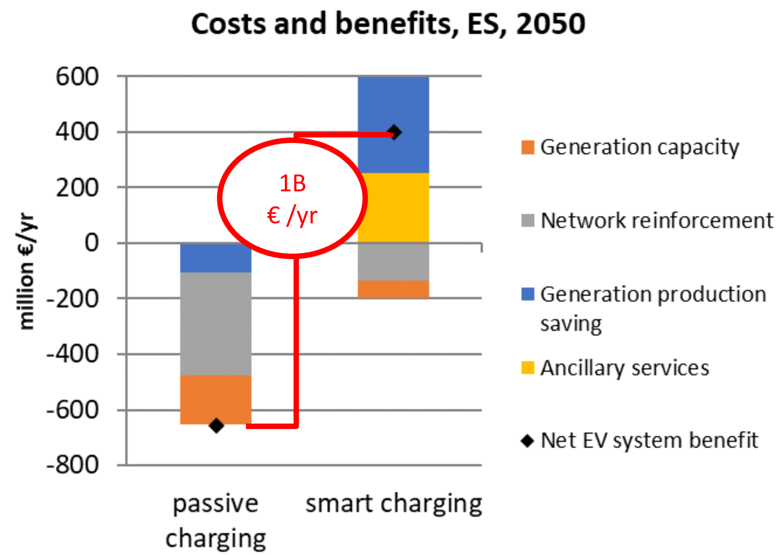
Significant net benefit through smart charging – also avoids investments throughout the electricity system

2030: 300M€/year net benefits



2050: 1B€/year net benefits



Passive charging: relative to baseline, the increase in EV peak load requires:

- additional fossil fuel; investment in peaking power plant capacity and distribution networks

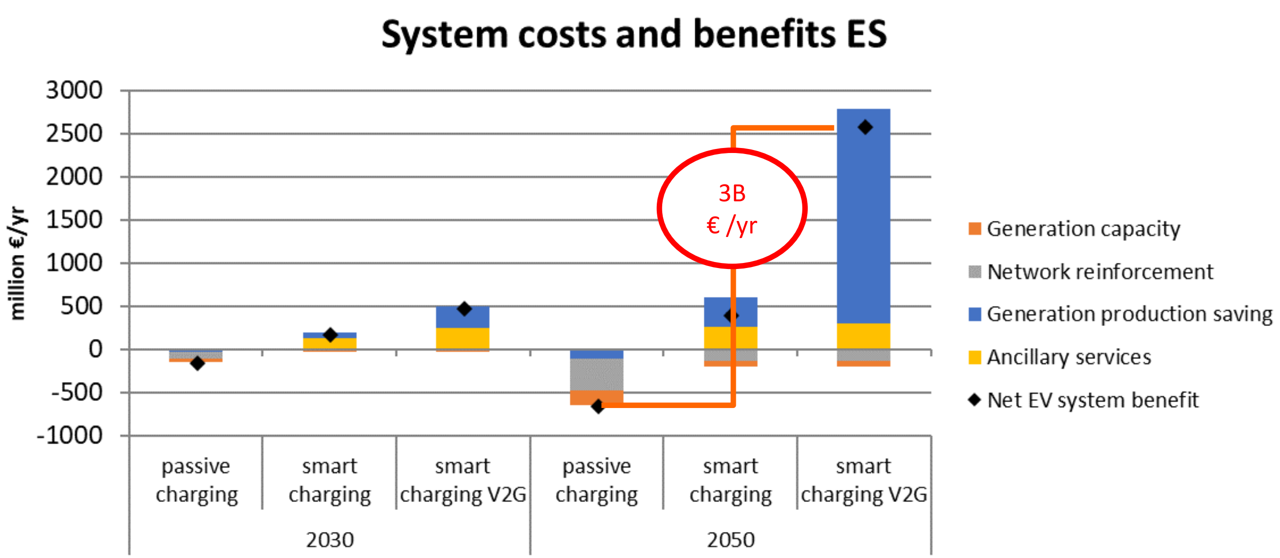
Smart charging: peaking generator & distribution network investments significantly reduced.

- Also curtailment of renewables is reduced, inefficient fossil generation avoided.

Revenues from providing ancillary services are estimated based on current prices.

Vehicle-to-Grid: €2.6 bn per year net benefit to the electricity system - Grid CO2 reduced by 28%

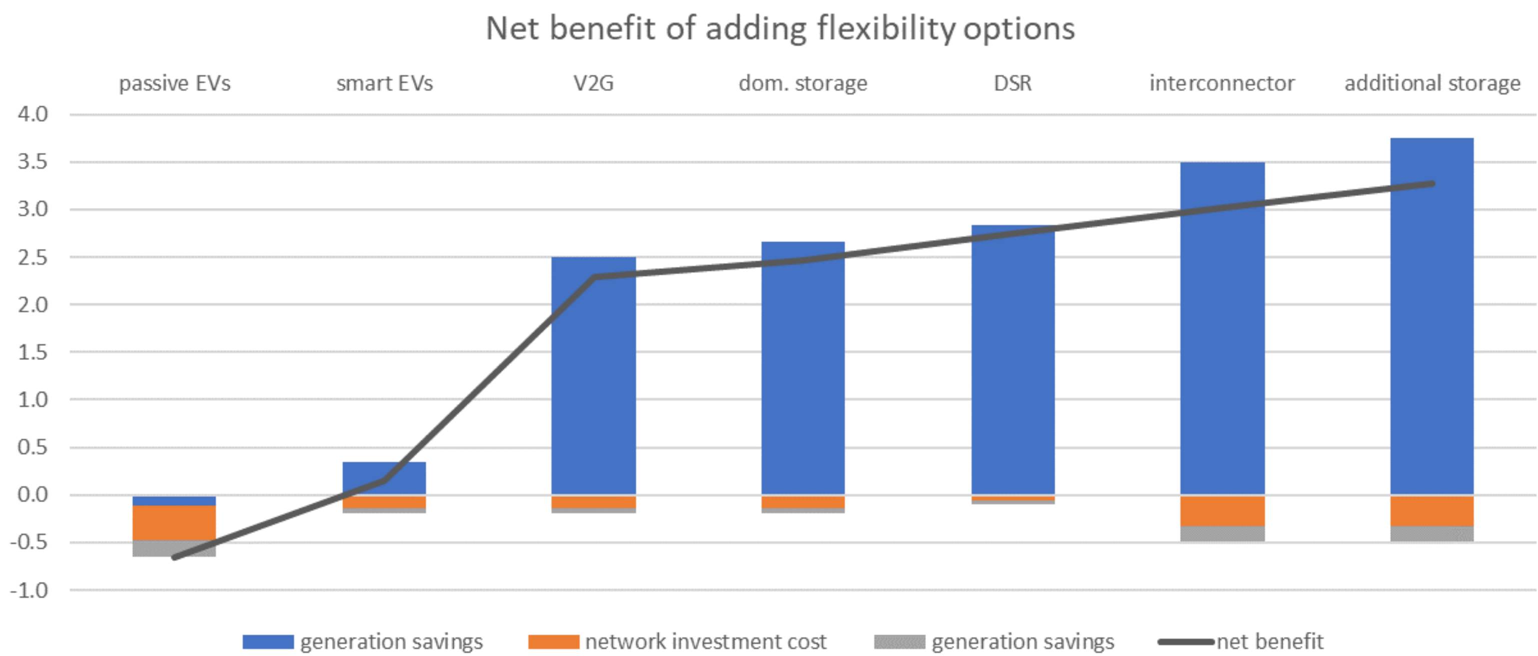
Vehicle to Grid: System costs and benefits



- The (combined) battery capacity in the 2050 EV fleet is very large, ca. 239 GWh
- V2G allows EV to absorb excess PV energy during the day, released to the grid in evening
- Using EV batteries as grid storage device would allow the absorption of about 26TWh additional VRE output (5% of annual demand).
- Relative to smart charging, the increased use of renewable energy displaces fossil fuel and reduces carbon intensity by 28%

EVs will have to compete with other technologies for flexibility

EVs are one of several flexibility options in a future decarbonised grid

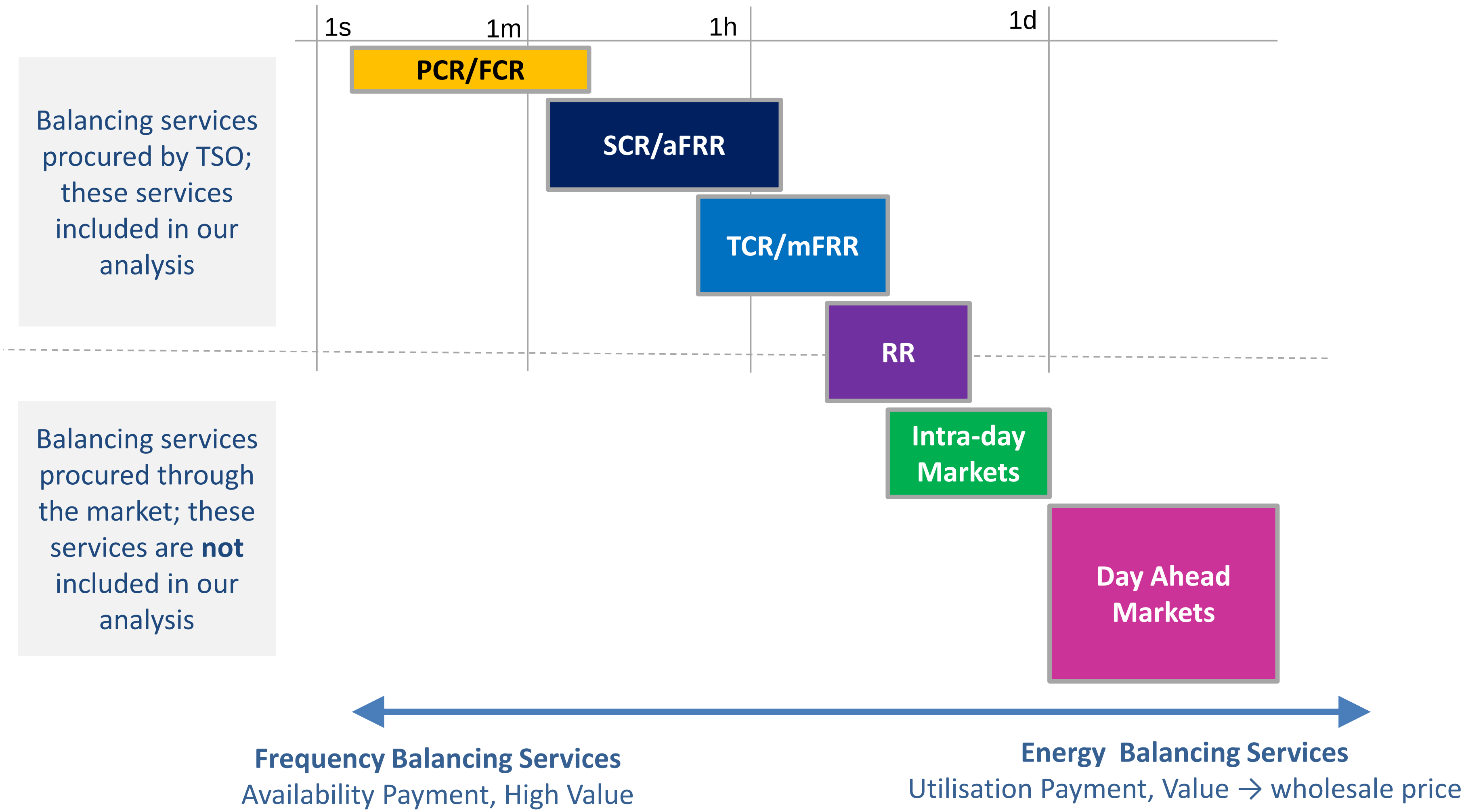


- Adding flexibility options to the system increases generation savings due to more zero marginal cost VRE being absorbed and avoided fossil output
- However some operational savings come at a cost of infrastructure reinforcement
- Flexibility options will compete for the “low hanging fruit” of curtailed VRE generation

Appendix

Energy markets are balanced on timescales from a few seconds to several days ahead; the more rapid services are procured by the TSO[1]

Power Market Balancing Services by Timescale and Customer



1) Transmission System Operator

In Spain, balancing service provision by EVs provides medium revenues, compared other European markets

Service provision and value per Vehicle

Service	Type of reserve	Daily service volume (kW)				Availability price (€/MW/h)	Utilisation rate	Utilisation price (€/MWh)	Annual revenue (€/year)			
		Unidirectional		V2G					Unidirectional		V2G	
		3kW	7kW	3kW	7kW				3kW	7kW	3kW	7kW
PCR	symmetric	6	6	24	64	10	4.3%	0	23	23	87	233
SCR	negative	24	64	24	64	0	10.0%	32.4	28	75	28	75
	positive	6	6	36	76	0	12.0%	43	12	12	68	144
TCR*	negative	20	20	20	20	0	5.0%	19.4	7	7	7	7
	positive	6	6	21	53	0	8.0%	50.4	9	9	31	78
Total									79	126	221	537

- Currently PCR is procured as mandatory service by large thermal generators but this could change in the future given lower opportunity costs of batteries vs. thermal generators
- We assume a PCR availability price of €10/MW/h informed by recent price reductions in this segment in European markets
- 0 availability payments lead to reduced revenues compared to other European markets such as DE and the UK

*In fact there is a small availability payment, but it is not possible to separate this from the ENTSO-E data.

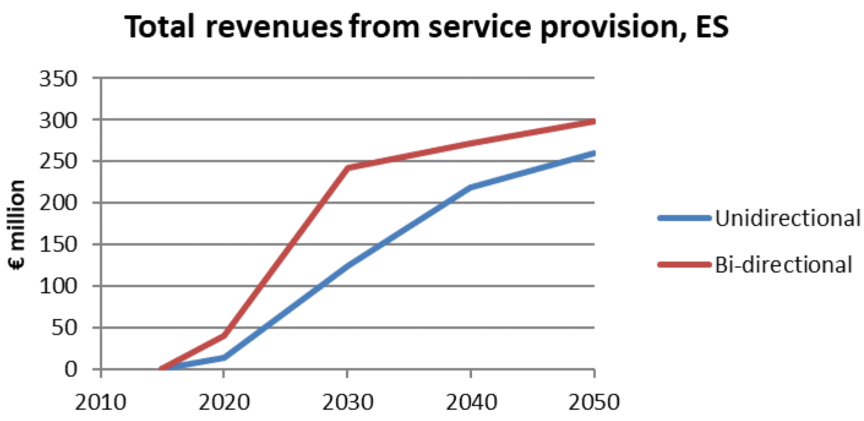
Grid service revenues in Spain are low compared to EU average, since PCR is procured through mandation of generator headroom

Charge Management Value by Vehicle

- EV charging provides significant negative (demand-up) service, but this has a lower price.
- Aggregators could combine EV loads with other load types to increase value across their portfolio.
- Spain provides all its ENTSO-E demand PCR through mandatory headroom in thermal plant; this increases wholesale power prices by 6% - around €3/MWh.
- Secondary and tertiary revenues are not as large as in DE, though as in Spain they are rewarded through a clearing cost, rather than pay-as-bid auction, it may be possible to access greater value through DSM by determining and bidding the true SRMC of charge management.

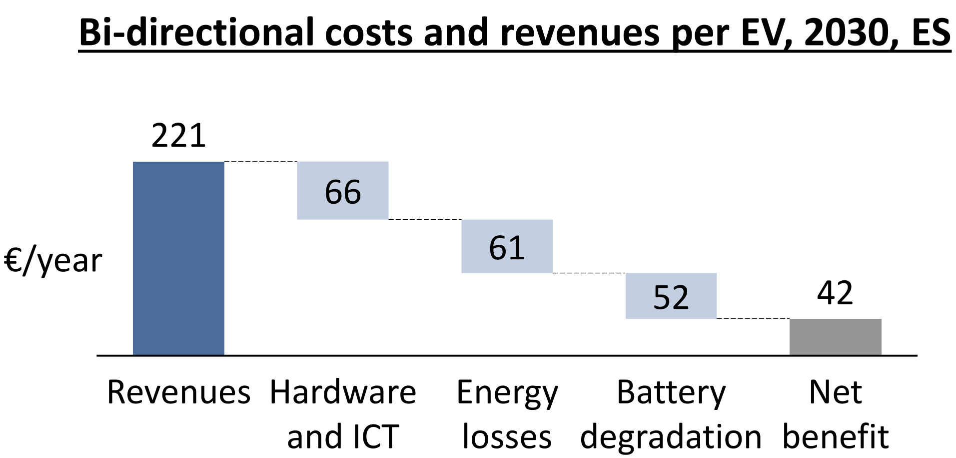
Ancillary service provision by EVs represents a total value of approximately €240m in Spain in 2030

Total potential revenues for EVs providing services



- The total potential revenue for EVs for bi-directional service provision is approximately €240m in 2030, rising to €300m in 2050
- (based on technical potential)
- Demand for services (SCR, TCR) is expected to grow due to increase of wind capacity

Costs and revenues per EV for bidirectional service provision (providing all ancillary services)

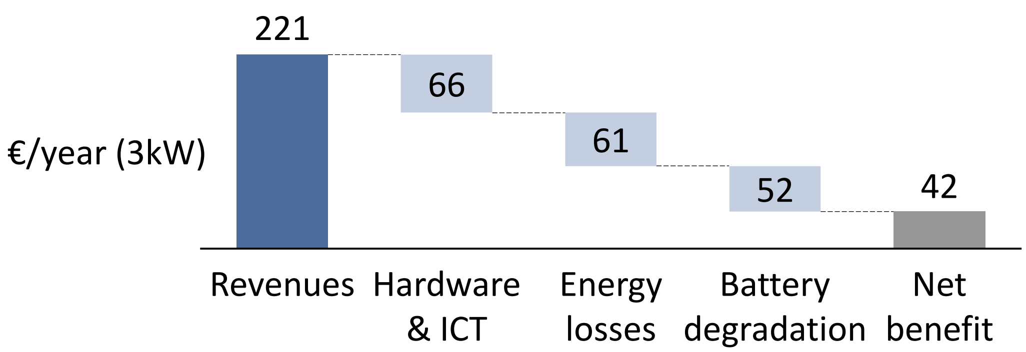


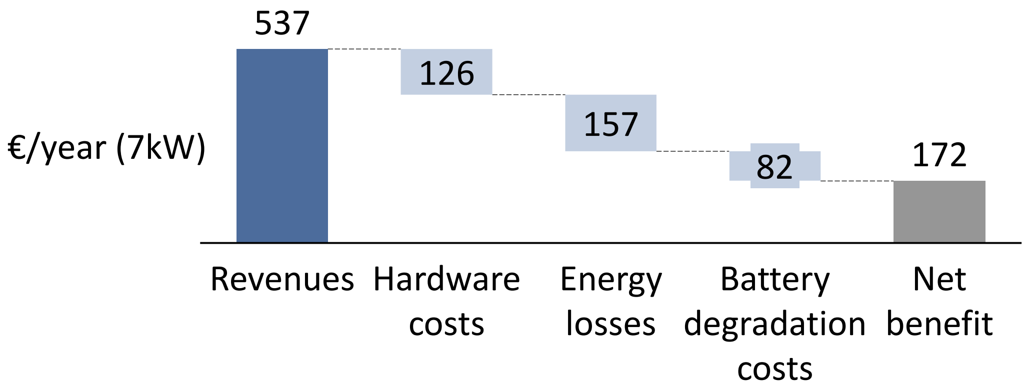
- We assume a price of 10€/MW/h PCR provision, informed by recently observed price reductions in this segment in EU markets
- Services in Spain are capacity and energy related (the latter have a utilisation duration of 2h+)
- Utilisation rates are relatively high (up to 12%, cp. to up to 6% in the UK) leading to higher degradation and losses in Spain
- Low or 0 availability payments reduce the attractivity of ES ancillary markets for EVs

Higher revenues with higher power V2G chargers: But net benefit very sensitive to future service values

Bi-directional charging – costs and revenues per EV for ancillary services provision, 2030

3kW bi-directional residential vs charger7kW bi-directional residential charger, DE



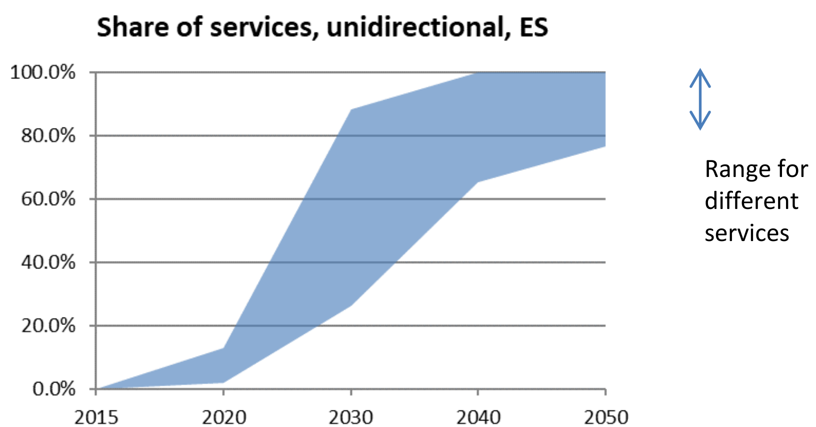


Key insights

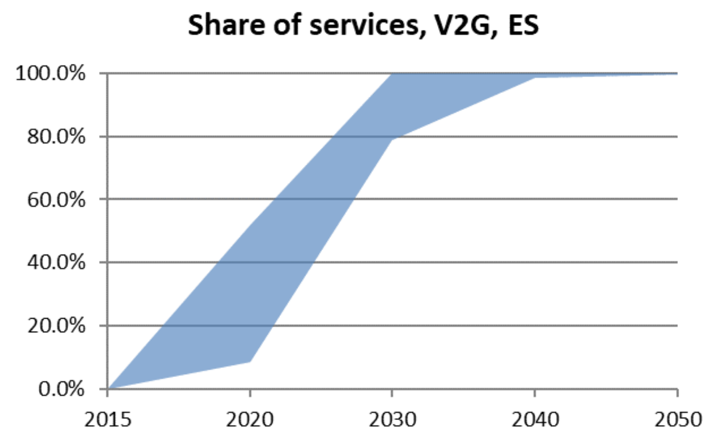
- Net metering assumed: energy fed back to grid is subtracted of electricity consumption
- Losses occur in inverters and due to roundtrip efficiency of battery
- Low residential electricity price prevents even higher costs of losses due to high utilisation rates
- Sensitivity analysis: halving of revenues (due to saturation of ancillary market by batteries) would wipe out net benefit.

EVs have the potential to provide a large fraction of Spanish ancillary service requirements from 2030 on, with V2G the fraction is even bigger

Proportion of services that managed unidirectional and bidirectional EV charging can provide based on technical potential in ES



Share of services requirements that EVs can supply with unidirectional charging based on their technical potential



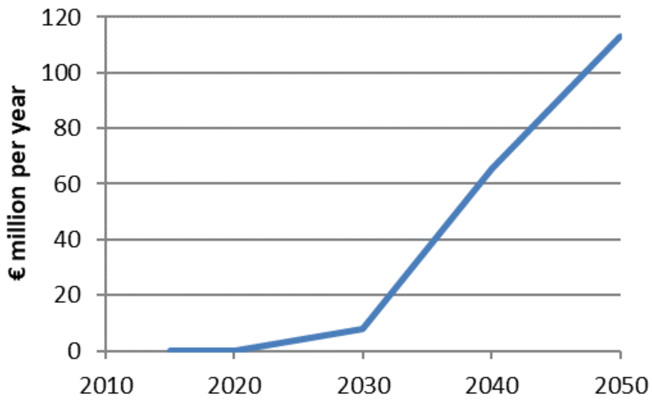
Share of services requirements that EVs can supply with V2G based on their technical potential

- With increasing EV uptake, EVs can provide a large proportion of ancillary service requirements in Spain through managing unidirectional charging.
- By 2050, the 16m EVs in Spain, can provide on average 90% of all services requirements (left)
- With V2G EVs could provide 85% of all requirements already in 2030
- Theses shares are based on the EV fleet’s technical potential. Due to commercial arrangements (e.g. a fixed capacity has to be offered for a service for several hours), the fraction can be lower

Service provision by electrolysers could capture €110m in revenues in 2050, corresponding to €76/year per FCEV

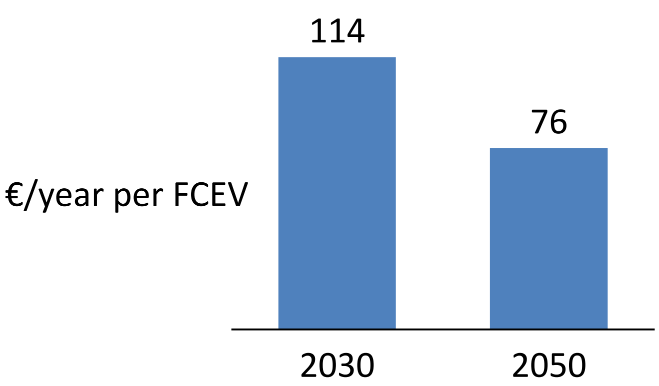
Total electrolyser potential revenues for ancillary service provision

Total revenues for all electrolysers, ES



- The total potential electrolyser for car transport revenues for service provision is approximately €10m in 2030, rising to €110m in 2050

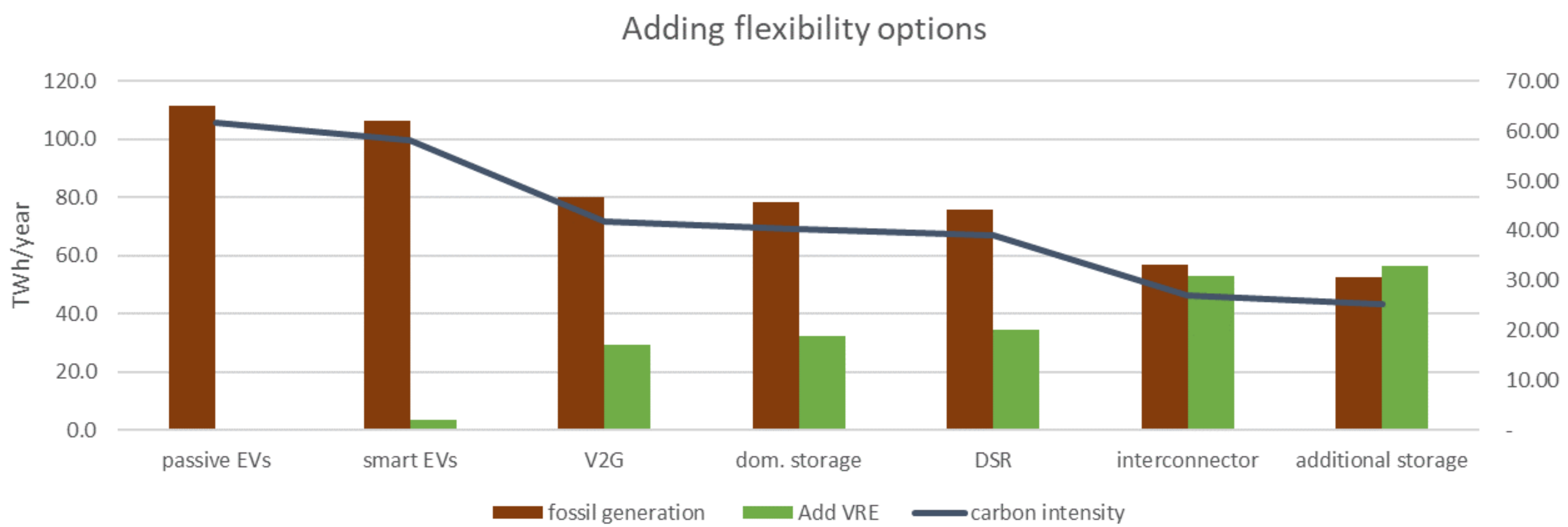
Potential revenue per FCEV for provision of ancillary services in ES



- Electrolyser service provision has the potential to capture €1.09 per kg of hydrogen produced
- This corresponds to annual revenues per FCEV of €114 in 2030 and €76 in 2050 (as hydrogen consumption per FCEV declines).
- These revenues are based on unsaturated service provision, and will be lower if large numbers of EVs or FCEVs are providing services

Flexibility is key to achieving carbon reductions

A high degree of flexibility in the power system is necessary to achieve decarbonisation



- Without a high degree of flexibility, a large amount of VRE output cannot be absorbed and fossil plant still supply significant amount of generation
- Adding flexibility options reduces the carbon intensity from about 60g/kWh in the inflexible case to 20g/kWh in the most flexible modelled configuration