Energy Storage: A Key Enabler for the Decarbonisation of the Transport Sector

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Table of Contents

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EXECUTIVE SUMMARY

The transport sector is the only EU sector in which greenhouse gas emissions have risen since 1990. To reduce these emissions and meet its long-term decarbonisation goals, the EU is focusing on electrifying the transport sector, based on renewable energy sources, through Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs).

Electrifying the transport sector will create new consumption patterns and business models but could also impose significant stress and costs on the electricity system if left unmanaged. EASE's position paper on energy storage and mobility introduces general principles that should be implemented at EU level to support the roll-out of Electric Vehicles (EVs). It also explains how energy storage systems can reduce the cost of this roll-out by coupling the energy and transport sectors.

The first chapter of this paper explains which principles need to be respected to ensure a smooth and rapid deployment of sustainable mobility in Europe:

- The contribution of EVs to reducing greenhouse gas (GHG) emissions should be fully recognised: fair and efficient tools based on the polluter/user pays principle should steer users to move towards more sustainable transport choices with positive impacts on emissions.
- The higher efficiency of EV technologies compared to conventional vehicles should be recognised: the penetration of EVs in the transport sector should be considered as an energy efficiency measure.
- There should be no discrimination against the form of renewable energy used in transport. Specific targets for the use of biofuels have been set, and those targets should also be allowed to be reached via renewable energy in electric, liquid or gaseous form.
- Charging infrastructures should be rapidly and efficiently deployed to support the roll-out of EVs: free market should establish the charging price (charge for the service, the cost of electricity, etc...) and anyone should be free to install and access a charging point following market principles in a competitive environment. In case there is a market failure and in order to ensure minimum geographical coverage when developing charging infrastructure (e.g. no viable

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business case), local or national authorities should be responsible to solve it first and foremost by e.g. proposing incentives to engage market parties in developing such infrastructure, depending on pre-defined market tests. In case market tests are negative, EASE endorses the approach laid out in Article 33 of the recast Electricity Directive, allowing DSOs to own and operate recharging points under certain conditions with the oversight of the national regulatory authority.

The paper also describes how energy storage couples the energy and transport sectors by presenting three specific use cases:

- EV batteries can be repurposed for other applications than their original one, thereby maximising the value of the battery and providing new applications such as stationary storage applications to the grid. For this use case to be economically viable, R&D, development of new business models, and standards must be promoted. The EU legislative framework must also specifically enable the repurposing of EV batteries (e.g. waste legislation).
- Energy storage technologies can support the development of charging infrastructures by alleviating their impact on the grid, providing additional revenues to the charging facility operator and enabling greater penetration of variable renewable energy sources in the transport sector by coupling RES plants and charging infrastructures. Currently, fiscal rules, energy taxes create a lack of revenue certainty for storage facilities coupled with charging infrastructures. EU funding programmes and a coordinated approach to defining grid connection conditions and electricity pricing configurations could solve these problems.
- Vehicle-to-grid integration technologies and processes, including smart charging, will enable mitigating peaks created by a high number of EVs charging simultaneously. EV batteries could actively work as storage systems and solve this issue by managing electricity loads across infrastructure assets and time. In order to do so, network tariffs should be designed to incentivise EVs to recharge when it is most efficient for the system. Appropriate taxes, grid fees, and levies placed on energy storage facilities are key to allow for a robust storage business case. In particular, double charging of storage facilities should be avoided.

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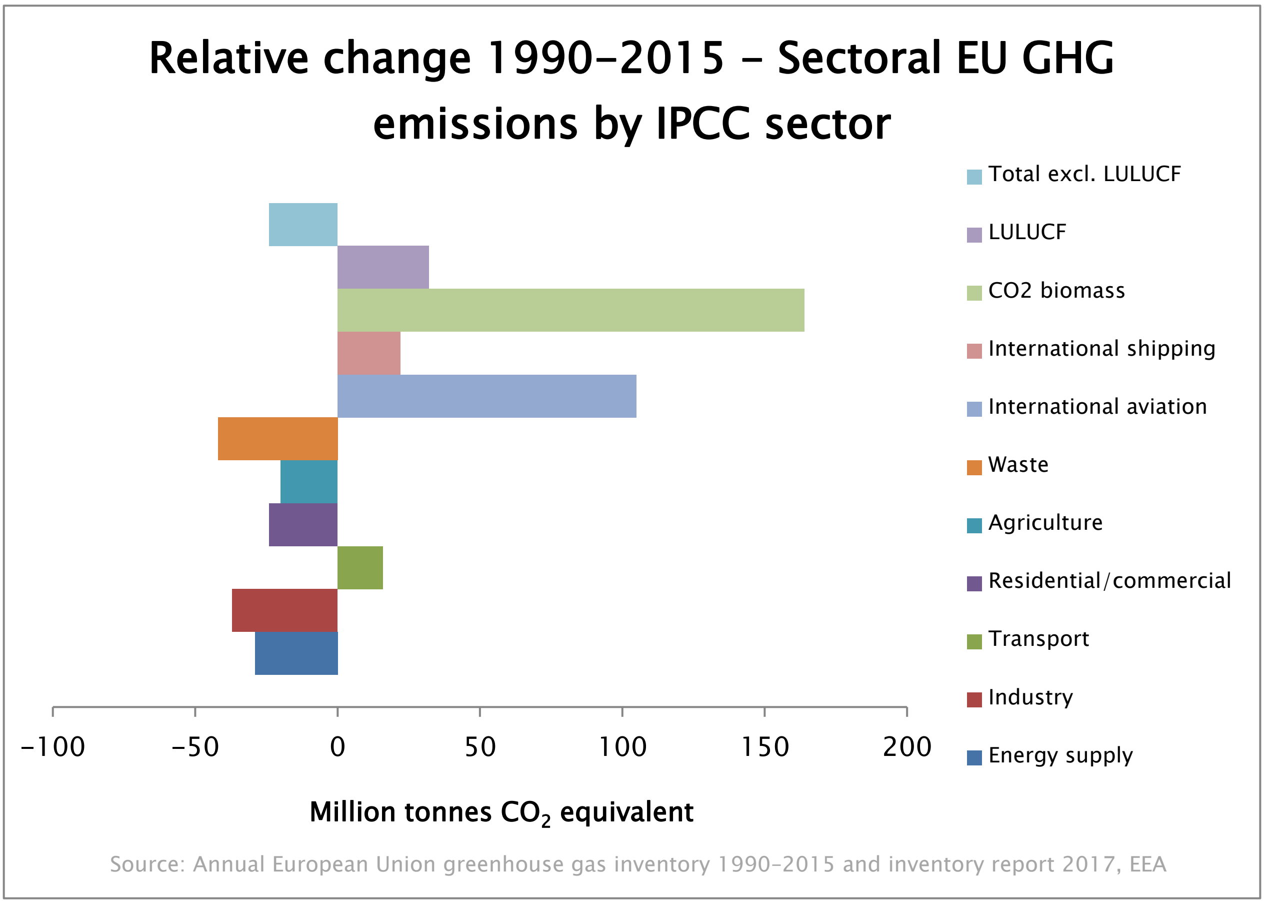
I. Overview and general recommendations to decarbonise the EU transport sector

❖ *Importance of decarbonisation/electrification of the transport sector*

In order to achieve Europe's long-term decarbonisation goals, a substantial and efficient reduction of greenhouse gas (GHG) emissions in transport is required.

As today, transport accounts for 25% of EU GHG emissions[1]. This share is growing, with transport being the only EU sector in which GHG emissions have risen since 1990 while overall emissions in Europe decreased by 23% between 1990 and 2016.[2]



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[1] European Commission, *Electrification of the Transport System – Expert Group Report*, 2017: https://ec.europa.eu/programmes/horizon2020/en/news/electrification-transport-system-expert-group-report

[2] European Commission, *Progress made in cutting* emissions: https://ec.europa.eu/clima/policies/strategies/progress_en

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This is why electrification of transport based on low carbon and renewable energy sources will play a pivotal role in decarbonising the transport sector. It will also contribute to fight against air and noise pollution thanks to battery electric vehicles (BEVs) and fuel cell electric vehicles' (FCEVs) electric drivetrains and lack of fossil fuel combustion.

However, the electrification of transport could impose significant stress and costs on the electricity system if managed poorly. Energy storage systems will be key to mitigate these effects and to support decarbonisation efforts by coupling the energy and transport sectors. For instance, vehicle-to-grid integration technologies, including smart charging, will support electrification of road transport while also limiting negative impacts on the electricity grid. Power-to-Hydrogen and Power-to-Fuel technologies will also be crucial to decarbonise longer-distance light duty vehicles but also trucks, ships, trains or planes.

❖ *Energy storage in EU policies for zero and low-emission mobility*

The European Strategy for Low-Emission Mobility, published in July 2016, set the groundwork for the EU's actions in the framework of zero and low-emission mobility. With the set of policy measures proposed in this Strategy, the share of low-emission energy could increase and thereby provide about 15-17% of transport energy demand in 2030 while also replacing oil products[3]. The roll-out of electric vehicles has become a key EU policy, and this rapid shift towards decarbonised mobility can be expected to have a significant impact on the energy storage sector.

While the recasts of the Batteries Directive and the End-of-life Vehicles Directive impact the development of energy storage technologies in the framework of sustainable mobility, two sets of legislation place zero and low-emission mobility in the spotlight in the EU agenda:

- The Clean Mobility Package (Europe on the Move)
- The Clean Energy for all Europeans Package (CEP)

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[3] European Commission, *Fact Sheet: A European Strategy for low-emission mobility*, 2016: http://europa.eu/rapid/press-release_MEMO-16-2497_en.htm

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The discussions on these sets of legislative and non-legislative proposals offer a unique opportunity to reduce the economic and regulatory barriers that currently hamper the deployment of EVs, and therefore also the deployment of storage technologies. The following general principles should be taken up to ensure a rapid and efficient deployment of BEVs and FCEVs, with energy storage as a key enabling technology:

- **The high efficiency of EV technologies compared to conventional vehicles should be recognised.**

Compared to EV technologies, conventional vehicles are inefficient, with only about 18 to 25% of the energy available from the fuel used to move them on the road[4]. Despite the technological improvements in internal combustion engines, EVs are generally more efficient.

This difference in energy efficiency should be addressed at EU level: the penetration of EVs in the transport sector should be considered as an energy efficiency measure supporting Europe's long-term renewables and decarbonisation objectives. Consequently, the costs of charging infrastructures in the EU should be covered by Energy Efficiency Funds available for energy efficiency projects.

- **No discrimination against the form of renewable energy used in transport.**

As advocated by the European Strategy for Low-Emission Mobility, Europe's answer to the challenge of decarbonising the transport sector is an 'irreversible shift to low-emission mobility in terms of carbon and air pollutants'. This means among others scaling-up the use of low-emission alternative energy for transport through renewable electricity, gas and fuels. All these renewable energy sources will be heavily needed to accelerate the decarbonisation of the transport sector (cars, trucks, planes…) and must therefore be promoted on level-playing field with each other.

[4] European Environment Agency, Electric vehicles in Europe, 2016. https://www.eea.europa.eu/publications/electric-vehicles-in-europe

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In order to be technologically neutral and boost the uptake of low-emission mobility, the following measures would be welcome:

- A mandatory and gradually increasing percentage of renewable energy from renewable electricity should be introduced for the transport sector, as it has been introduced for biofuels. The new Renewable Energy Directive includes a blending mandate on fuel suppliers to ensure that the share of renewable energy supplied for final consumption in the transport sector is at least 14% by 2030. 3.5% of this must come from advanced biofuels. A similar type of requirement should be introduced for renewable electricity.

- A mandate on vehicle manufacturers to ensure that a proportion of their car sales produced between 2025 and 2030 is made up of electric vehicles. This would give a great boost to early deployment, offering investors and value chains a clear signal on the direction Europe is taking. The proposal for a recast Directive 2009/33/EC on the promotion of clean and energy-efficient road vehicles in public procurement (so-called Clean Vehicles Directive) introduces series of targets for the procurement of clean vehicles by public authorities in 2025 and 2030 but this is not enough: vehicle manufacturers should also have targets to produce electric vehicles. This specific measure could be included in the ongoing CO_2 standards negotiations, notably in the proposal for a recast Regulation on emission performance standards for new passenger cars and for new light commercial vehicles.

➢ **Charging infrastructures should be rapidly and efficiently deployed to support the roll-out of EVs.**

In order to ensure a rapid and efficient deployment of charging infrastructures, the following recommendations should be carefully taken into account:

- EV charging offers need to be considered as a service led by market operators. The free market should establish the charging price (charge for the service, the cost of electricity, etc…).

- Anyone should be free to install and operate a charging point, and the process for installation should follow market principles in a competitive environment.

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- Deployment and promotion of urban/motorway charging points, including fast-charging points, are necessary to increase customer confidence and therefore EV demand. In the short term, however, business models may not be balanced on the sole end-customer revenues due to high CAPEX and OPEX levels while there is a need to create a minimum local or regional coverage. In order to ensure long-lasting involvement of operators, investment risks will have to be shared by the stakeholders (operators, original equipment manufacturers, energy suppliers, DSOs, local, national and European authorities). In cases of market failure and in order to avoid a delay in the investments required, EASE supports the approach laid out in Article 33 of the recast Electricity Directive:

  1a. Distribution system operators shall not be allowed to own, develop, manage or operate recharging points for electric vehicles, with the exception of those cases where distribution system operators own private recharging points solely for their own use.

  2. By way of derogation from paragraph 1a, Member States may allow distribution system operators to own, develop, manage or operate recharging points for electric vehicles only if all of the following conditions are fulfilled:

  (a) other parties, following an open and transparent and non-discriminatory tendering procedure, subject to review and approval by the regulatory authority, have not been awarded with a right to own, develop, manage or operate recharging points for electric vehicles or could not deliver those services at a reasonable cost and in a timely manner. Regulatory authorities may draw up guidelines or procurement clauses to help distribution system operators ensure a fair tendering procedure;

  (b) the regulatory authority has carried out an ex-ante review of the conditions of the tendering procedure under subparagraph (a) and has granted its approval;

  (ba) the distribution system operator must operate the recharging points on the basis of third party access and must not discriminate

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between system users or classes of system users, particularly in favour of its related undertakings.

- Customers should be granted fair and non-discriminatory access to any publicly available electric charging infrastructure and hydrogen refuelling stations (with or without a supplier contract), as it happened with petrol stations. The deployment of publicly available charging infrastructure must be incentivised by local, national or European-level organisations to guarantee a minimum coverage in all regions of the EU while taking into account the need for grid stability.

- Public funding should be strengthened to support the deployment of charging infrastructures, especially in non-profitability cases or in the early deployment of fast and ultra-fast recharging points with a low EV market share penetration. This could be done through Energy Efficiency Funds as described above but also through the Connecting Europe Facility in the Ten-T Corridor funding programme.

- Existing regulatory and technical barriers hampering the development of private/domestic charging points (at homes or in business premises, shopping centres...) should be removed: e.g. need for dedicated supply connections, approval to be given by all members of a neighbourhood...

- There should be a mandatory and gradually increasing percentage of pre-equipment for EV charging points in car parks of business premises, shopping centres, new buildings, and not only a minimum requirement as proposed in the revised Energy Performance of Buildings Directive (EU) 2018/844.

- Some non-supply related costs, such as policy costs, are included in many cases in the consumer tariff. This price structure creates distortions among different energies and consequently, electricity customers are highly discriminated against for their energy choice. This inequality has already been recognised by the European regulator ACER (Agency for the Cooperation of

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Energy Regulators)[5] as a problem that needs to be fixed by tariff redesign, with reallocation of externalities away from the cost of electricity.

- All stakeholders, including stakeholders from the electricity sector, should be invited to work together on charging infrastructure deployment and identify solutions that are most cost-efficient and useful to the community and that would avoid stressing the distribution and transmission grid. This would help solve uncertainty surrounding the type and number of charging stations deployed created by the amount and variety of actors involved in deploying charging infrastructures.

Given the importance of energy storage to decarbonise the transport sector, a coherent, ambitious and long-term strategy for the deployment of these technologies is required in the EU. EASE identified, described and issued recommendations for the development and deployment of three use cases illustrating how energy storage can decarbonise the transport sector:

- Second-life batteries
- Energy storage as support of (fast) charging infrastructures
- Vehicle-grid integration

[5] ACER/CEER, *Annual Report on the Results of Monitoring the Internal Electricity and Gas Markets in 2015*, 2016: http://www.acer.europa.eu/official_documents/acts_of_the_agency/publication/acer%20market%20monitoring%20report%202015%20-%20key%20insights%20and%20recommendations.pdf

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II. Energy storage and mobility use cases

❖ *Second-life batteries*

a. Description of the use case

The electric vehicle (EV) market will experience a very strong growth in the coming years. The International Energy Agency predicts that worldwide between 100 and 200 million EVs will be on the road by 2030.[6] A first consequence of this transition towards electro-mobility will be the fast development of the EV lithium-ion battery market, which will reach the TWh scale by 2030 according to forecasts by BNEF.[7] A second consequence will be the proliferation of used EV batteries.

Since recycling EV batteries is not yet economically viable, car manufacturers – in charge of battery collecting and recycling – try to find opportunities to give EV batteries a second life, i.e., by repurposing EV batteries for other applications than their initial one. The stationary energy storage market is one of these applications. End-of-life EV batteries may maintain between 70 and 80% of their initial capacity and may therefore be suitable for energy storage applications, in various use cases such as utility scale, commercial, residential or off-grid.

This use of second-life batteries would be a significant opportunity for car and battery manufacturers but also EV owners who would be able to reclaim a part of their initial investment in the EV battery, thereby reducing its cost.

It could also be an opportunity for storage developers to access batteries at a lower price, reducing not only CAPEX but also environmental costs. Second-life batteries could provide services, among which the following services are seen as very promising[8]:

- Transmission and distribution investment deferral, reducing needs for locally reinforcing the electricity grid

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[6] Internal Energy Agency, *Global EV outlook*, 2018

[7] BNEF, *Lithium-ion battery costs and market*, 2017

[8] DOE Energy Storage Systems Program, *Technical and Economic Feasibility of Applying Used EV Batteries in Stationary Applications*, 2003

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- Ancillary services: frequency regulation, voltage support…
- Local renewables curtailment minimisation[9]
- Continuity of energy supply or Uninterruptible Power Supply (UPS): storage to be substituted to the network in case of interruption

More generally, the profitability of a repurposed EV storage system will depend on various criteria, including:

- The cost of repurposing the storage system compared to the cost of a new storage system. If battery prices continue to fall, it could be comparatively more expensive to re-purpose EV batteries as stationary storage than buying a new battery.
- The performance, lifetime, and operating costs of a second-life battery system compared to that of a new storage system.
- The distribution of second-life batteries recycling costs between the EV and energy storage sectors.

Several car manufacturers are currently exploring business cases related to second life batteries:

- Renault has partnered with Powervault for repurposing EV batteries in residential energy storage;[10]
- 4R Energy Corporation, a joint venture between Nissan and Sumitomo, has set up a plant in Japan specialised in the reuse and the recycling of EV batteries;[11]

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[9] ADEME, *Etude de la seconde vie des batteries des véhicules électriques et hybrides* rechargeables, 2011 : https://www.ademe.fr/sites/default/files/assets/documents/79604_synthese_seconde_vie_des_batteries-anglais.pdf

[10] Renault Group, *Renault and Powervault Give EV Batteries a "second-life" in Smart Energy Deal,* 2017 : https://media.group.renault.com/global/en-gb/media/pressreleases/92203/renault-et-powervault-donnent-une-seconde-vie-aux-batteries-des-vehicules-electriques1

[11] Sumitomo Corporation, *Nissan, Sumitomo Corporation and 4R set up plant to recycle electric-car batteries,* 2018 : https://www.sumitomocorp.com/en/jp/news/release/2018/group/20180326_01

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4R Energy Corporation has also recently launched “The Reborn Light”, a street lamp combining a used EV battery, a solar panel and a LED lighting system;[12]

- Enel has partnered with Nissan to directly use both used and new EV packs in a stationary energy storage system integrated into a power plant located in the city of Melilla, which has an energetically isolated system. The solution will improve guaranteed energy supply in Melilla, notably when the failure of one of the generation assets could cause load shedding events and blackout due to dynamics of the other gensets.[13]

Other industrial initiatives have also recently been announced, such as the multiannual plan (2018-2022) of SNAM to invest about 25 M€ to set up a factory for remanufacturing end-of-life EV batteries in France and repurposing them for stationary energy storage applications, following a R&D project in collaboration with CEA.[14]

b. Recommendations on the use of second-life batteries

While the above examples show how promising second-life batteries are for car and battery manufacturers but also storage developers, a clear EU regulatory framework is necessary to enable EV batteries to be repurposed as stationary storage. In order to do so, the following actions should be undertaken:

1. Developing or improving standards, preferably compatible with global standards:
   - For testing and grading processes of EV battery packs, modules, and cells that are intended for a repurposed use application, such as stationary energy storage.

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[12] CleanTechnica, *Nissan Pushes Into Energy Storage With Second-Life Battery Initiative,* 2018 : https://cleantechnica.com/2018/03/24/nissan-pushes-energy-storage-second-life-battery-initiative/

[13] Endesa, *Endesa gets the green light for a pioneering system for large scale energy storage with electric cars batteries,* 2018: https://www.endesa.com/en/press/news/d201811-endesa-gets-the-green-light-for-a-pioneering-system-for-large-scale-energy-storage-with-electric-car-batteries.html

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- To implement specific processes to repurpose and remanufacture batteries.
- To ensure and simplify/harmonise market compliance at EU level.

➢ These standardised processes would help determine the state of health of batteries and other parameters to identify viability for continued use. It would also help reduce repurposing costs, and provide guarantees on the performance and lifetime of the second-life batteries.

2. Ensuring that the EU regulatory framework specifically enables EV batteries to be repurposed. Currently, the Battery Directive categorises EV batteries at the end of their first life as waste. The recast Battery Directive, under discussion, should therefore tackle this problem and introduce a clear definition and a legal framework for second-life batteries, without:

   - Hampering innovation in the stationary battery storage sector;

   - Making it more difficult for new stationary battery storage products to be developed and put on the market when more suitable than second-life EV batteries.

3. Ensuring that original equipment manufacturers (OEMs) cover, at least in part, the cost of recycling the batteries at end-of-life, including when EV batteries have been repurposed for energy storage purposes. The absence of legal clarity for second life batteries raises the issue of how to apply the extended producer responsibility to those batteries.

4. Ensuring that second-life batteries comply with environmental policies. Second-life batteries must not have a larger footprint in their second-life than when directly recycled and must alleviate environmental concerns.

5. Supporting RD&D in the fields of battery testing, battery repurposing, and battery management systems for second-life applications which could be used for a better assessment of the state-of-health of battery cells or modules.

6. Supporting the development of new business models, including product-service systems (PSS), for second-life batteries.

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7. Promoting data collection and dissemination on second-life battery projects in an EU Energy Storage Observatory that would set up a database of all storage facilities across Europe to gain a clearer understanding of the current deployed capacity and planned developments.

❖ *Energy storage as a support for (fast) charging infrastructures*

a. Description of the use case

Several millions of Electric Vehicles (EVs) are expected to be sold in Europe by 2025. Most EVs are and will be mainly recharged at home or at work, but charging stations open to the public will be necessary to avoid present range anxiety and to offer new services that will help EV market share penetration and extend EV trips.

Hundreds of thousands of charging infrastructure points have been rolled out throughout Europe, including thousands of 50 kW fast chargers[15]. In order to prepare for the short term arrival of very high range EVs on the market, brand-new high power fast charging infrastructures are being designed and deployed: power levels ranging from 150 kW to 350 kW per EV charging point will be requested to rapidly charge these new generations of EVs.

The total power demand at the grid interface will spread from 350 kW to 1 MW or more depending on the station configuration. The impact of the charging infrastructure development on the electrical grid will be very substantial, both in terms of power demand and grid investment[16].

Energy storage systems can be used to mitigate the impact of such EV development on the electricity network and to increase RES penetration levels in the transport sector by being connected to charging points (see figure 1, below)[17]:

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[15] Examples : European projects Corri-Door, RCN, UNITe …

[16] In France, main household power subscriptions are around 6 kW, 1 MW corresponds to a city quarter power demand.

[17] Examples : European projects Corri-Door, RCN, UNITe …

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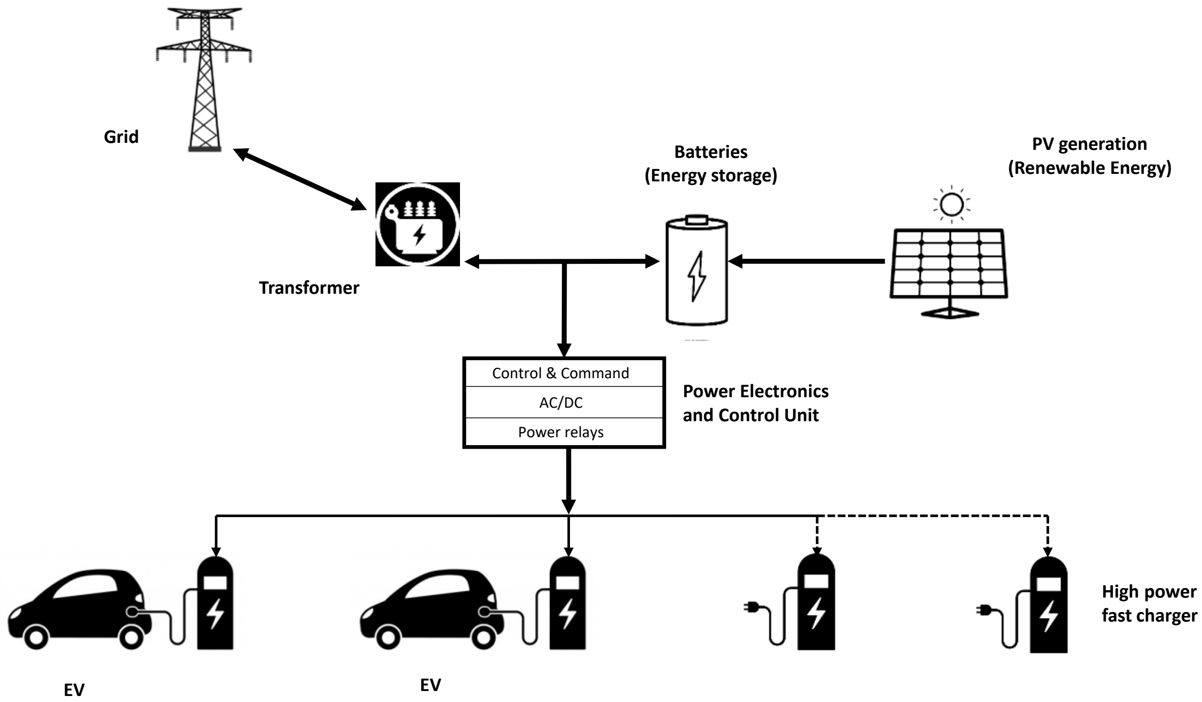
- Energy storage systems can charge electricity from the grid at times of low demand and discharge at times of high demand. They can also avoid/defer costly grid reinforcements for DSOs and TSOs especially in remote locations such as rural areas[18].
- Energy storage systems increase RES penetration levels in the transport sector, with minimised curtailment and at optimised system cost, by storing renewable energy when there will be excess of sun or wind power and by discharging at times where sun will not shine and wind will not blow.

Energy storage technologies coupled to EV chargers would also enable multiple vehicles to be charged at the same time, with power being supplied both by the grid and local RES.



High power fast charging station with battery storage and PV generation

[18] Example: it is not always economical to bring high voltage to site and in Norway, the solution to solve this problem was to have an electric ferry being charged from batteries; Corvus Energy, *Ampere, Ferry: World's First All-Electric Car Ferry – Vessel and Shore Charging Stations*, 2018: https://corvusenergy.com/marine-project/mf-ampere-ferry/

Various energy storage solutions such as batteries or flywheels might be coupled to EV charging infrastructure. In 2018, main projects coupling storage to EV charging infrastructures use battery storage, notably because battery prices have been decreasing quickly. For instance, Pivot Power and National Grid announced the upcoming creation of a nationwide network of EV fast charging stations and 50 MW battery storage facilities in the UK.[19] Energy storage could also be used as a buffer for grid-independent and mobile fast chargers to satisfy the need for fast charging without major risky infrastructure investment.

In centralised approaches - which will be far more common than decentralised approaches – the decision on whether or not to couple a stationary storage solution with a charging station will be made based on two criteria: the limitation of the impact on the electrical grid for DSOs & TSOs and the actual reduction of the total cost of ownership (TCO) for the charging facility operator:

- The CAPEX and OPEX must be reduced with the installation of a storage solution, both in terms of initial grid connection costs[20] and yearly energy and maintenance expenditure or recycling.
  Considering that cost breakdowns in terms of grid connection and electricity supply costs are highly dependent on national situations (grid connection rules, tariffs: power level, electricity consumption, off-peak periods…), a case-by-case approach needs to be followed to decide whether to integrate a storage facility or not.
- Additional benefits must be captured such as the possibility to:
  - Install a charging site in areas where grid extension is not technically feasible or unaffordable

[19] Pivot Power, *Pivot Power to work with national grid to future-proof energy system and accelerate electric vehicle revolution,* 2018: https://www.pivot-power.co.uk/pivot-power-work-national-grid-future-proof-energy-system-accelerate-electric-vehicle-revolution/

[20] Grid connection costs highly depend on station locations and national situations. In some countries, expensive initial grid connection expenses and high yearly power subscription fees are charged pro rata the power demand (e.g. 200 €/kW initial flat fee for grid connection under 400 V in Austria).

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- Benefit from attractive local PV generation and self-consumption schemes
- Generate extra revenues via the aggregation of the flexibility of the battery charging on the energy and ancillary service markets

Prosumers could also be interested in coupling a storage device to a charging point in the future. Indeed, they could store the energy produced from solar panels on their roof, and use it at times when there is no sun anymore or when the electricity price is high to charge their EV. They could therefore maximise their energy autonomy. Storage costs must however continue to decrease to see attractive offers for solar+storage+EV charging appear.[21]

Table 1: Examples of fast charging infrastructures with battery support

Example 1: 50 kW fast charger with a low-capacity battery		
	+	–
• 36 kVA grid connection and subscription • Up to 20 kW extra power delivered by the battery to the fast charger • Battery fully discharged during the 1st half of the EV charging cycle and fully recharged during the second half of the EV charging cycle. • 50 kW charging power is immediately available after the end of the previous charge	• Lower grid connection costs (depending on national grid rules) • Lower power subscription fees • ROI < 3 years	• Extra CAPEX and OPEX: low-capacity battery investment and maintenance costs ex. Corri-Door in France: too expensive compared to direct grid connection (average cost = 6 k€)

[21] Yorick Ligen, Heron Vrubel & Hubert H. Grant, "Mobility from Renewable Electricity : Infrastructure comparison for Battery and Hydrogen Fuel Cell Vehicles", World Electric Journal, Volume 9(1), 3, 2018

Example 2: High power 350 kW charging points with batteries		
	+	–
• 250 kVA grid connection and subscription • Up to 150 kW extra power delivered by the battery to the fast charger • Battery partially discharged during the EV charging cycle and recharged during off-peak tariff periods Example: • A battery capacity with a minimum of 150 kW/160 kWh buffer allows 2 charging points sharing 350 kW with a 250 kVA grid connection to be fully available after each charge.	• Lower MV/HV grid connection costs (depending on national grid rules) • Lower power subscription and supply expenditure (off-peak tariffs) • Aggregation of flexibility (energy market, ancillary services)	• Extra CAPEX and OPEX: high-capacity battery investment and maintenance costs • Bidirectional charging equipment costs

b. Recommendations

EASE recommends the following actions to accelerate the development and deployment of storage as a support to (fast) charging infrastructure:

- An evolution of fiscal rules and energy taxes for consumption/injection has to be considered in order to facilitate the provision of ancillary and flexibility services by energy storage, on a level playing field with other technologies. Currently, fiscal rules and energy taxes create a lack of revenue certainty and are a burden for storage developers.

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- Energy storage should access more easily the energy and ancillary markets.[22] For instance, only storage facilities with a capacity above 1MW are eligible for primary reserve, which forces storage developers to aggregate different storage systems to offer this service. The complexity of the energy and ancillary markets are also a barrier to storage deployment.
- The EU must adopt a coordinated approach to defining grid connection conditions and electricity pricing configurations. Today, fragmented local and national approaches create undue barriers for storage developers who have to assess the feasibility and profitability of storage projects case by case.
- EU funding programmes such as TEN-T or Connected Europe Facility (CEF) should provide support to the deployment of charging infrastructures coupled with energy storage. Solutions enabling risk-sharing for CAPEX/OPEX on the long run should also be investigated.
- Safety rules for indoor/outdoor stationary storage installations for charging infrastructures should be clarified.

❖ *Vehicle-Grid Integration*

a. Description of the use case

Large-scale electrification of transport could impose significant stress and costs on the electricity system if left unmanaged. If all EV owners charge when they arrive at home in the evening, there will be very high peaks compared to situations without EVs. For instance, peak demand could reach 122 GW in Germany in 2050 with EV owners all charging during peak times compared to 80 GW without EVs.[23]

Vehicle-Grid Integration through smart charging and vehicle-to-grid services is a crucial strategy that can help reduce future grid reliability problems as EVs penetrate

[22] Other energy storage configurations could also be used for acting on the energy market or for ancillary services : stationary batteries directly connected to DOS' facilities, V2G …

[23] Harrison P, "Fuelling Europe's Future: How the transition from oil strengthens the economy", 2018

the vehicle market.[24] EV batteries can indeed provide different services, depending on business solutions and the level of involvement of the consumer:

- Implicit demand-side management (or price-based flexibility):
    - Time-of-use-based charging: defined by the preferred charging during prior specified, static low price periods given by so-called time-of-use tariffs (ToU).
    - Real-Time Price: the optimisation can be based on a price signal, such as the hourly market price being reflected via an hourly real-time price for EVs (e.g. with flexible tariffs or dynamic pricing). Real-time Pricing optimisation and previous described ToU-based charging are applicable wherever implicit demand side management mechanism are in place, to avoid congestion and smooth demand profile at system level.
- Explicit demand-side management (or 'incentive-driven' flexibility):
    - Unidirectional flows or V1G services: consist in charging smartly the EV to provide the following services to the grid: demand-response, RES curtailment minimisation, and ancillary services.
    - Bidirectional flows or vehicle-2-grid (V2G) services: cover V1G services but also explicit management of local loads and participation in energy market value streams through the possibility to release electricity and feed it back to the grid (e.g. arbitrage).

EV batteries can actively work as storage systems and solve grid management issues by providing V1G and V2G services, thereby managing electricity loads across infrastructure assets and time.

[24] Smart charging of an EV is when the charging cycle can be altered by external events, allowing for adaptive charging habits, providing the EV with the ability to integrate into the whole power system in a grid- and user-friendly way; CEN-CENELEC-ETSI, *Smart Grid Coordination Group: Smart Charging of electric vehicles in relation to smart grid*, 2015

The Vehicle-to-Grid Hub

The Danish Vehicle-to-Grid hub is the Europe's first fully commercial vehicle-to-grid hub. The utility Frederiksberg Forsyning installed ten Enel V2G units and purchased 10 electric Nissan e-NV200 vans to connect them together and to turn them into small power plants and micro distribution grids. The California-based company Nuvve provides the aggregation platform that controls the power flow to and from the car.

The zero-emission vans can charge or discharge (sell) energy to the national electricity grid, thereby offering the below services:

- Balancing energy loads during generation peaks, thereby reducing RES curtailment.
- Storing surplus electricity that will be fed back into the network when necessary.

For this solution to be replicated:

- EVs must be equipped with the capability to allow bidirectional flows of electricity between the vehicle and the grid.
- The V2G system's price, set by both the vehicle and charger manufacturers, should be affordable enough to attract customers.
- The EV owner must be remunerated by the aggregator for providing grid services to the grid operator and must be assured that the vehicle will be available for personal use when needed.
- The aggregator must derive enough benefit from the availability of vehicles to compensate for the additional cost of monitoring and controlling the vehicle-grid interactions, remunerating EV owners, and administering the system.

The total capacity made available by the Vehicle-to-Grid hub increases the stability of the Danish National electricity grid. It provides frequency containment reserve (FCR) services through low voltage aggregated resources to the Danish network operator Energinet.dk. FCR remuneration can generate up to €1,000 per EV per year.

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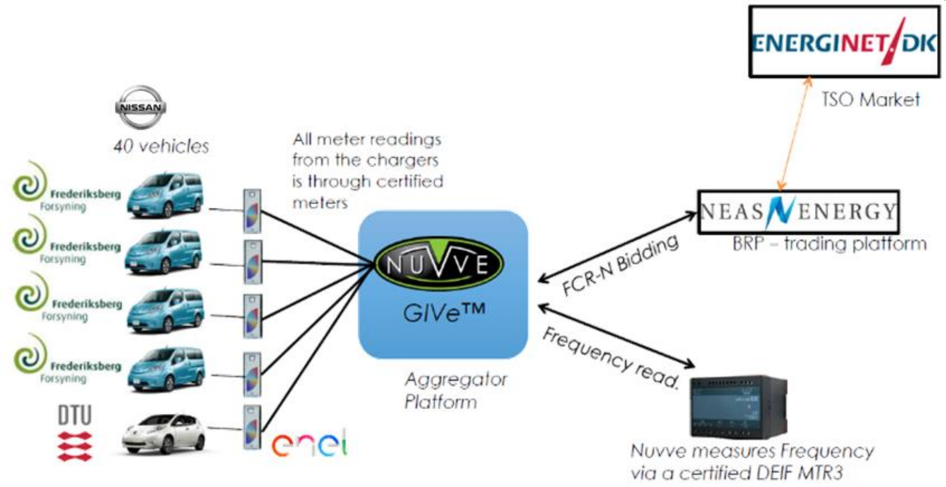

Vehicle-to-Grid hub structure

b. Policy and regulatory recommendations

V1G and V2G technologies are crucial assets to manage the future energy system to empower customers, as advocated by the 'Clean Energy for All Europeans' package. However, they are not regulated yet at EU level even though they support greater integration of RES in the system and provide numerous grid services, both at transmission and distribution level, including grid investment deferral.

Apart from Denmark, all V2G projects have been deployed in the form of trials and pilots over the last years[25] due to several barriers:

- Energy tariffs and pricing structures
- Access to the electricity market by aggregators
- Lack of charging infrastructure allowing V2G schemes in residential and non-residential buildings
- Lack of clarity on business and aggregation models enabling V2G to capture the greatest economic value
- Lack of charging standards/protocols necessary to deliver grid services across different car brands

[25] DELTA-EE, *V2G: The journey to commercialisation Report: EVs & Electricity Research Service*, 2018

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- EV battery owners' concerns about:
    - The loss of range or availability of their vehicles if engaged in V2G schemes
    - Battery degradation: operating in a V2G mode could increase battery wear and shorten battery life[26] but new studies tend to show that it could maximise battery life if for instance specific operating regimes are respected. In the future, the negative effect of V2G on the battery life could indeed be mitigated by defining suitable ranges of V2G applications, e.g. limiting the depth of discharge to a percentage of the battery's capacity thanks to control algorithms.[27]
- Technical barriers: technical costs (AC/DC, software, hardware) could hamper the deployment of mass market for EVs participating in V2G services.

In order to enable the deployment of vehicle-grid integration:

- Interoperability, harmonised protocols, and standards among the infrastructures and systems should be implemented to enable seamless communication: technical standards for charging processes are mostly defined but there is currently no formal procedure to ensure the compliance between these standards and the vehicles coming into the EU market from abroad. These standards are crucial to ensure consumer engagement and the provision of vehicle grid integration services over Europe while avoiding over-investment. Furthermore, with regards to charging stations management system communication, as well as electric vehicle communication, standards such IEC 63110 will be of paramount importance as well as the upcoming ISO 15118 standard.

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[26] Matthieu Dubarry, George Baure, and Arnaud Devie, "Durability and Reliability of EV Batteries under Electric Utility Grid Operations: Path Dependence of Battery Degradation", Journal of The Electrochemical Society, Volume 165 (5) A773-A783, 2018

[27] Uddin Kotub, Tim Jackson, Widanalage D. Widanage, Gael Chouchelamane, Paul A. Jennings, "On the possibility of extending the lifetime of lithium-ion batteries through optimal V2G facilitated by an integrated vehicle and smartgrid system", James Marco Energy, Volume 133, 2017, Pages 710-722;
Uddin Kotubm Matthieu Dubarry Mark B. Glick, "The viability of vehicle-to-grid operations from a battery technology and policy perspective", Energy Policy, Volume 113, February 2018, Pages 342-347

- Energy tariffs and pricing structures should be smart and enable vehicle vehicle-grid integration. EV owners must pay a proper charging price, based on time-differentiated tariffs. Dynamic pricing for the energy part of the bill is necessary to provide effective price signals. Similarly, network tariffs should be designed to incentivise EVs to recharge when and where it is most efficient for the system. This may require an adequate mix between fixed, capacity and volumetric components of the charges and a time and spatial-differentiated approach.

- Double-charging of taxes and levies on electricity generated from storage facilities should be avoided: owners pay once when charging their storage asset (EV battery) and should not pay again when they feed electricity back into the grid.

- Aggregated EVs should be able to participate in all electricity markets, including balancing and capacity markets. To remove potential entry barriers, they should be subject to proportionate administrative processes. Appropriate regulatory frameworks should support the use of smart solutions which can defer costly investments.

- Open markets should also be developed for non-frequency ancillary services: e.g. voltage control or synthetic inertia. These services can provide further revenue and value for aggregated EV sources and EV owners.

- An output based regulation for network operators is needed to create new markets for non-wire grid expansion solutions, e.g. investment deferral thanks to flexibility procurement from network operators.

- Access to energy consumption data should be ensured. Availability of charging patterns to the EV energy supplier or EV aggregator is crucial for consumers to be offered the right tariffs. This should include protection of consumer privacy and security and the consumers' access to their own data, notably in case of switching of service provider.

- Ambitious requirements in public as well as private charging infrastructures to promote Vehicle-Grid Integration need to be set.

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- Building codes need to be revised to be more e-mobility friendly and ensure the “right to charge” for building owners and tenants to help overcome non-financial barriers.
- Customers need to be well informed and incentivised to participate with fair reward in Vehicle Grid Integration schemes.

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