Cover

1 Project Statement: Utilizing unused renewable Energy

References

Current Situation

Each year the electricity generated by using renewable energies like solar and wind makes up a bigger part in the energy-mix [1]of Germany. But the amount varies because of seasonal or just daily fluctuations. This is especially true for wind. In 2018 wind energy was the main renewable source with about 48%, which made up around 19% of the overall consumption.

1 Source: `https://strom-report.de/strom`

Need

Because of the significant mismatch in grid power demand, the need for a solution is becoming more acute. It's a well-established problem for the industry, and there are a number of energy management and storage systems in the pipeline today, which could solve this problem. But few offer a complete solution allowing wind energy to be seamlessly plugged into the grid.

Problem

Today, the importance of transitioning into a sustainable and cost-effective energy sector is more important than ever. Fossil fuels won't last for ever and are straining the environment too much. The state will on the long-term ban or at least heavily restrict the usage to meet its own agendas therefore the solution for efficiently using renewables is of utmost importance.

Energy production by wind power is intermittent and fluctuates. Currently one of the main challenges is the adaptability of different energy storage or management systems to daily and annual fluctuations as well. This paper will investigate which is the best solution to those problems.

Method and Criteria

The new solution must be more cost-efficient than just shutting the wind turbines off, or buying energy from other countries. It has to be able to be integrated into the current grid of wind turbines. The factors to rate our solution therefore include:

- **Costs** Must be equal or lower than 21.82 billion €over 10 years: including investment, maintenance and operating costs. Otherwise, it is cheaper to than just shut the wind turbines off, or buy energy from other countries.
- **Efficiency** Must be equal or higher than70 %: including kwh lost while transforming and lost while saving over one year.
- **Safety** in %: failure rate per year must be lower than 1 ppm (part per million)
- **Scaling** yes or no: Is it reasonable for an input of 1,495 GW per hour and saving 36 GWh?
- **Technical Feasibility** yes or no: Implementable in the next 5 years? Is the technology viable or is something better obtainable in the next years? Is it possible in the geographic area?

Aspects covered

The most promising Solutions are covered in this analysis:

- **Storage systems made out of batteries**
  Written by CFO Annabelle. See section IV page ???
- **Storage systems made out of Pump storage**
  Written b COO Lennart. See section IV page ???

- **Power to Gas**

  Written by CAO Christian. See Section IV page ???

- **Storage systems made out of hydrogen**

  Written by CEO Moritz. See section IV page ???

- **Storage systems made out electric vehicles**

  Wtitten by CTO Kai. See section IV page ???

References and Informations

[energy-mix] Der deutsche Strommix: Stromerzeugung in Deutschland.
https://strom-report.de/strom/.
Last accessed 21.11.19

2 ExecutiveSummary

ExecutiveSummary

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4 The Working Papers

4.1 Section IV Vehicle to Grid

Definition

A solution to utilize unused renewable energy, which does not rely on building additional storage systems is using EVs (Electric vehicles) and PHEVs (Plug in Hybird) as Storage system. When the power output of the grid/the offshore parks is low the EVs can throttle their charging rate or even return power to the grid. The EVs could also delay their charge and use the peaks in the power output of offshore parks to charge their batteries. There are two fundamental ideas in Vehical to Grid. Bidirectional Vehical to Grid where the EVs also return power to the grid or unidirectional Vehical to Grid where the EVs only store the power but do not return power to the grid. Bidirectional Vehicle to Grid requires special hardware. This results in a system, that is far more complex and expensive than unidirectional Vehicle to Grid. It also results in a lot of additional wear in the EVs batteries. It would therefore be a lot more difficult to convince customers to use bidirectional Vehicle to Grid. At the same time multiple studies showed, that the profit is not significantly higher than with unidirectional Vehicle to Grid. Because of this unidirectional Vehicle to Grid is superior and will therefore be the object of the following calculations.

https://en.wikipedia.org/wiki/Vehicle-to-grid

https://www.isi.fraunhofer.de/content/dam/isi/dokumente/sustainability-innovation/2010/WP4-2010_V2G-Valuation.pdf

https://www.erneuerbar-mobil.de/sites/default/files/publications/anhang-optum-ap6_1.pdf

Findings

For the purpose of a large scale storage system for unused wind energy unidirectional Vehicle to Grid is not a resalable option. The necessary system should have a regulating power of 1495 MW and a capacity of 36 GWh is needed. This equals the average unused power in the

https://www.bdew.de/presse/presseinformationen/zahl-der-woche-gut-32-mr first months of 2019. The capacity equals the amount of this power over 24 hours. Since the system is not only storing power but also constantly using it to drive the vehicles this should be enough capacity. The unidirectional Vehicle to Grid system necessary to achieve this size would need over 10 million EVs or PHEVs. The Problem is not the power. The necessary power output would only require a little more than 1.7 million EVs or PHEVs. But the storage to power ratio in Vehicle to Grid is a lot smaller than the necessary ratio. This results in a system with the necessary 36 GWh of storage capacity but 9000 MW of regulating power. This system needs over 10 million vehicles. It is unlikely that this amount of EVs and PHEVs will be available in the next five years. And even if we assume 10 million EVs and PHEVs in the year 2025 in the necessary infrastructure for a system this large would take a lot longer than five years to be built. In order to include 10 million vehicles in the system more than 10 million chargingstations would be necessary (not including the chargers at home). This can not be implemented in the next five years. But assuming that we could built the charging and communication infrastructure in 5 years the cost would be 47.7 billion euros in investment cost and 4.8 billion euros a year in running cost. Over five years this adds up to 71.7 billion euros.

Scaling

On average a vehicle spends over 90 percent of the day not driving. Given the infrastructure a EV could be connected to the grid and function as a storage system in this time. In Germany are over 83000 EVs and almost 67000 PHEVs (01 Jan 2019) and this number is

https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/b_jahresbilanz.

growing exponentially. The Government has the goal to increase this number to 1 million by 2022. A study by the Frauenhofer institute from 2010 showed with simulations, that a Vehicle to Grid System could provide up to 3.5 kWh of capacity and 0.875 kW of regulation power per Vehicle. This study is now almost 10 years old and the capacities for batteries in EVs have increased a lot since then. But this study uses a very complex simulation which does not just use averages but accounts for different driving behavior at weekends, battery degeneration, dispatch time, different charges at day and night, and a whole lot more. Because of this its results are still viable today but it should be clear that the numbers will increase with improved batteries. This would mean that today the system would have a theoretical capacity of 525 MWh and a regulation power of 131.25 MW. This numbers a relatively low but the number of EVs and PHEVs in Germany is growing. With 1 million vehicles in the system it would have a theoretical capacity of 3.5 GWh and a regulation power of 875 MW. Assuming that 90 percent of germanys vehicles (42 million vehicles) would be EVs or PHEVs it would result in a theoretical capacity of 147 GWh and a regulation power of 36.75 GW.

html

https://www.isi.fraunhofer.de/content/dam/isi/dokumente/sustainability-innovation/2010/WP4-2010_V2G-Valuation.pdf

Cost

In order to operate such a system additional infrastructure is needed. Wherever the EV is parked it needs a connection to the grid via a chargingstation. This means that we need additional to our fast charging gird on the highway a lot more charchingstations in the cities, at work and everywhere a car might get parked. These charchingstations also need to communicate with the

https://de.statista.com/

gird in order to make the regulation and storage system work. At the moment there are 17500 charchingstations in Germany, but 83000 EVs and 67000 PHEVs (01 Jan 2019). With the help of numbers provided by Volkswagen we can calculate the costs. Assuming that every owner of an EV or and PHEV already has a charchingstaion at home we only need to install additional ones at workplaces, car parks and public places. But the ones at home still need a connection for the load management. Using the example given by Volkswagen a charchingstation, which provides place for 22 vehicles would have an investment of about 105000 Euro and 250 Euro upkeep every month. The connection for the charger at home would cost about 350 Euro a year. To ensure that the EVs and PHEVs can connect almost everywhere they park we would need about 9100 charchingstations from the example. The cost would then add up to about 960 million Euros of investment cost and 27.5 million per year to run them. And an additionally 52.5 million per year to run the charginstations at home. If we assume 1 million vehicles in the system the cost would add up to 6.4 billion in investment cost and 532 million per year to run all the charchingstations.

statistik/daten/studie/460234/umfrage/ladestationen-fuer-elektroauto

https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/b_jahresbilanz.html

https://www.volkswagenag.com/presence/konzern/group-fleet/dokumente/Compendium_Electric_charging_for_fleets_DE.pdf

Technical Feasibility

The time needed to build all this new chargingstations is comparable to the construction of the Tesla Superchargers. Since 2012 Tesla built almost 15000 individual superchargers at 1650 locations and an additional 24000 destination chargers at hotels worldwide. This would mean for less than 40000 charchingstations it took almost eight years. The superchargers have a power output higher than the ones needed for Vehicle to Grid.

https://en.wikipedia.org/wiki/Tesla_Supercharger

Furthermore, the stations are created worldwide. A Charchingsolution in Germany with less powerful chargers would be quicker to realize. The numbers we used form the volkswagenag suggest a time of less than 5 months from planing to finishing the construction of one of the charchingstions from our example. When we keep all this in mind it becomes clear, that it would take approximatly ten years to built all the chargingstions needed for the EVs and PHEVs today. This does not take into account, that the number of EVs and PHEVs is rising exponentially.

Effciency Unidirectional Vehicle to Grid does not require multiple conversions form AC to DC and vice versa like bidirectional Vehicle to Grid would. The efficiency is comparable to the normal charching efficiency which is on average 65 – 75 percent. This loss efficiency is explained by the different design criteria of the converters. When the charger and the cars converter design match each other, efficiency can be as high as 90 percent. Since the EVs and PHEVs constantly use their charge to drive it is not necessary to include the efficiency losses by holding the charge.

https://backend.orbit.dtu.dk/ws/portalfiles/portal/137328554/efficiency_paper.pdf

Substainability The environmental effects of Vehicle to Grid are hard to calculate, since it mostly relies on hardware, that already exist. With unidirectional Vehicle to Gird the additional wear on the battery is negligible. There are no numbers to be found how much Co2 and water the construction of a chargingstation consumes. But with the high amount of chargers needed it should not be ignored.

Safety The safety of this system is comparable to the safety of an EV or PHEV charging on a normal chargingstaion. This already controlled and regulated by German law and can therefore be regard as safe.

https://www.bmwi.de/Redaktion/DE/Downloads/V/verordnung-ladeeinrichtungen-e pdf?__blob=publicationFile&v=3

Conclusion Vehicle to Grid is not viable for a system this big and should not be implemented. It is to expensive and requires to much new infrastructure to function properly. On a small scale there may be cases where Vehicle to grid makes sense. For example a small city, that already has lot of EVs or PHEVs could use a Vehicle to grid system to for its local wind or solar power plants. Or an owner of an owner of a small solar power plant on the rove of its house could use his EV as a storage system for its own power production. But on a large scale Vehicle to Grid can not be recommended.

Personal Comments At first glans Vehicle to Grid seems like a brilliant idea. But as this analysis showed it is neither economical nor technical feasible. It also comes with a social problem, that has not been described in the analysis yet. All calculations assume that the owner of an EV or PHEV has no problem with a software deciding when to charge his car. This could come with problems such as People having an important meeting and not having enough charge, just because the software assumed that the driver wasn't going to work this early. The drivers of PHEVs could end up driving with gasoline most of the time, because the software can completely discharge them. Other than EVs PHEVs can drive with an empty battery, but this does not mean, that the driver is willing to drive with an empty battery.

Kai Braungardt

Revised: 08 Jan 2020

5 AnalysisSummary

AnalysisSummary

6 Resources

Resources

Section VI -A

Personnel Qualifications List

A. Education:

since October 2018	Karlsruher Institute of Technology (KIT) Electrical Engineering and Information Technology, Bachelor studies
	Secondary Education (A-levels)
2015 – 2018	Armin-Knab-Gymnasium in Kitzingen
2009 - 2015	Jakob-Stoll-Realschule in Würzburg

B. Work Experience:

since October 2019	Math tutor at Studienkreis Karlsruhe-Mühlburg – teaching Students up until the 12/13 grade in Math and physics
August 2018 - September 2018	Summer Job at Service and ElectroMechanical Devices (semd) Rottendorf – built wireless switches – used laser engraving machine
2016 – 2018	Math tutor at Schülerhilfe Ochsenfurt – teached Students up until 10 grade in Math and physics

C. Special Skills and Awards:

August 2018	Prize of the German Physics Association (DPG)
March 2018	Cambridge Certificate
	Programming skills (C++)
	Language skills: German = Native Speaker English = C1 - proficient Spanish = B1 - Independent

7 Glosary

Glossary

8 Evaluation

Evaluation

9 ReferenceList

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10 Other

10.1 Presentation

Presentation