Vehicle to Grid Integration: Opportunities and Challenges

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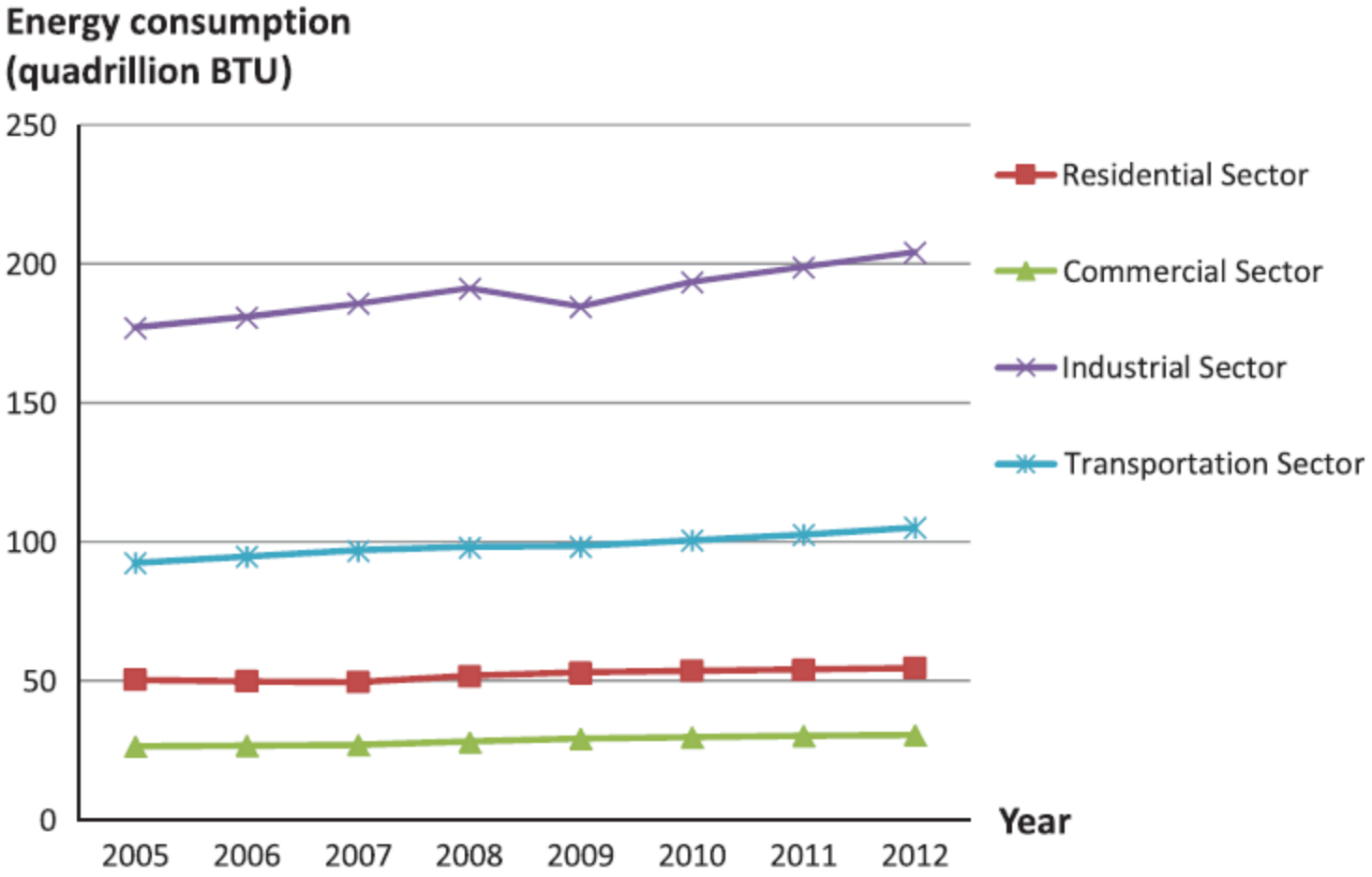
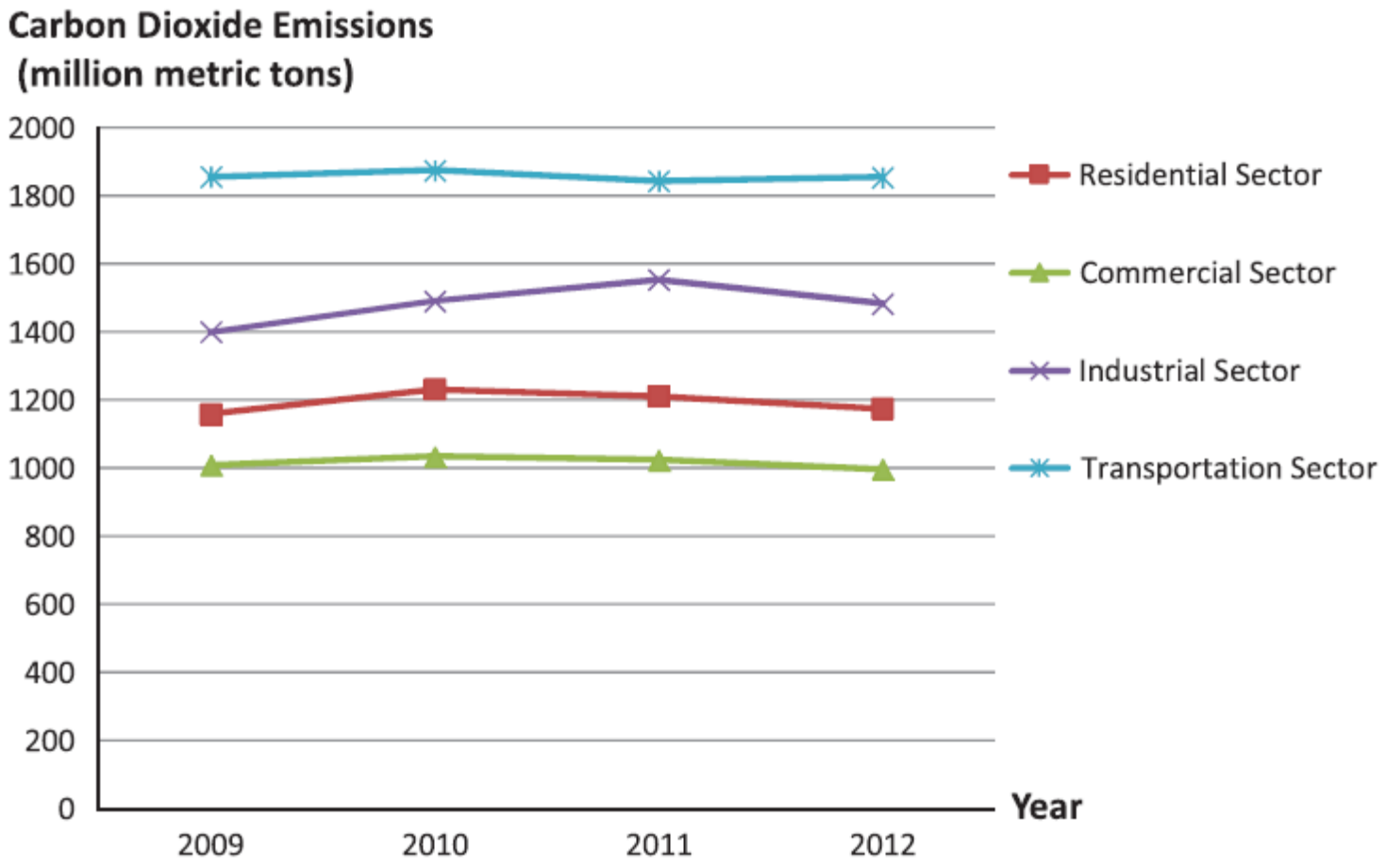
Background



Source: Tie and Tan, 2013

Background



Source: Tie and Tan, 2013

Background

- Other harmful emissions from this sector:
  - Hydrocarbons,
  - Carbon monoxide,
  - Nitrogen oxides, and
  - Various compounds of lead
- Why????
- These issues are mainly associated with the traditional vehicle technology of internal combustion engines (ICE) which operate on fossil fuels
- **Solution: Electric Vehicles**

Introduction

- Electric Vehicles (EV); vehicles which consume electrical power for operation of their engine.
- Two types of technologies;

❖Plug-in Hybrid Vehicle (PHEV), and

❖Battery Electric Vehicle (BEV)

- The term hybrid refers to the fact that these vehicles are provided with both electric motor system as well as an ICE or hydrogen cell for their operation

Introduction

- Vehicle to grid (V2G) was first coined by Kempton and Letendre (1997)
- EVs remain idle for more than 90% of the times
- These vehicles can serve as energy storage (for battery operated) or as power generation sources (for hybrid and fuel cell) by the utilities
- The vehicles used with this technology are also referred to as Gridable vehicles

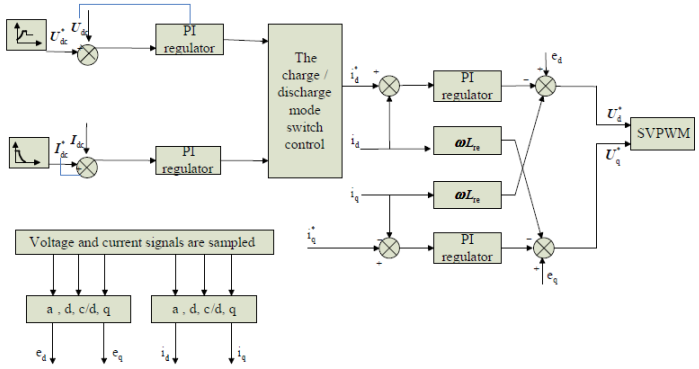
- Two-way charging and discharging mechanism comprising of 4 parts;

✓ Three phase AC power supply,

✓ Converter module,

✓ Circuits and

✓ Batteries

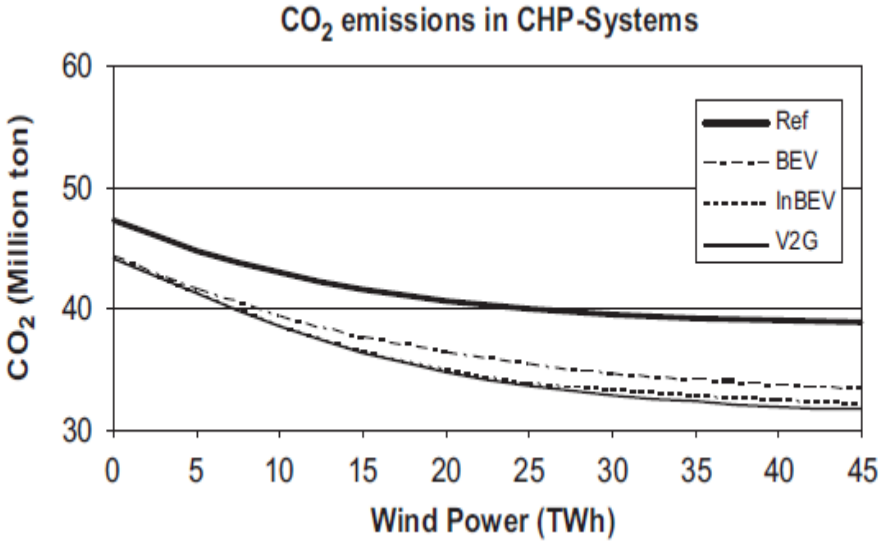


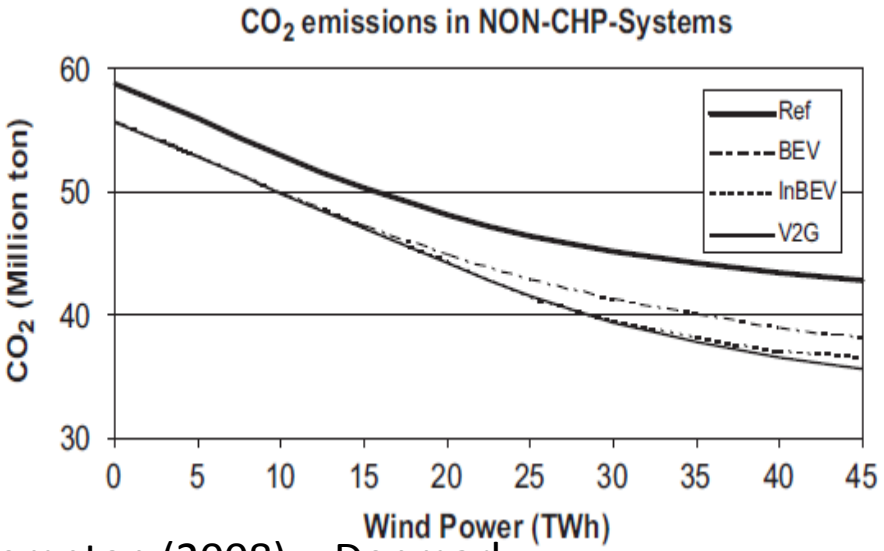
Zhou et al., 2014

Opportunities

Reduction in Emissions

- Kempton and Tomić (2005); Anderson et al. (2009), Saber and Venayagamoorthy (2010 and 2011)
- Situation till 2009: 95% ICE operated vehicles; 50% contribution in overall emissions
- Reduction by conversion to EVs: 20%
- Further reduction: 40% if the electric power is generated through RES (Anderson et al., 2009)





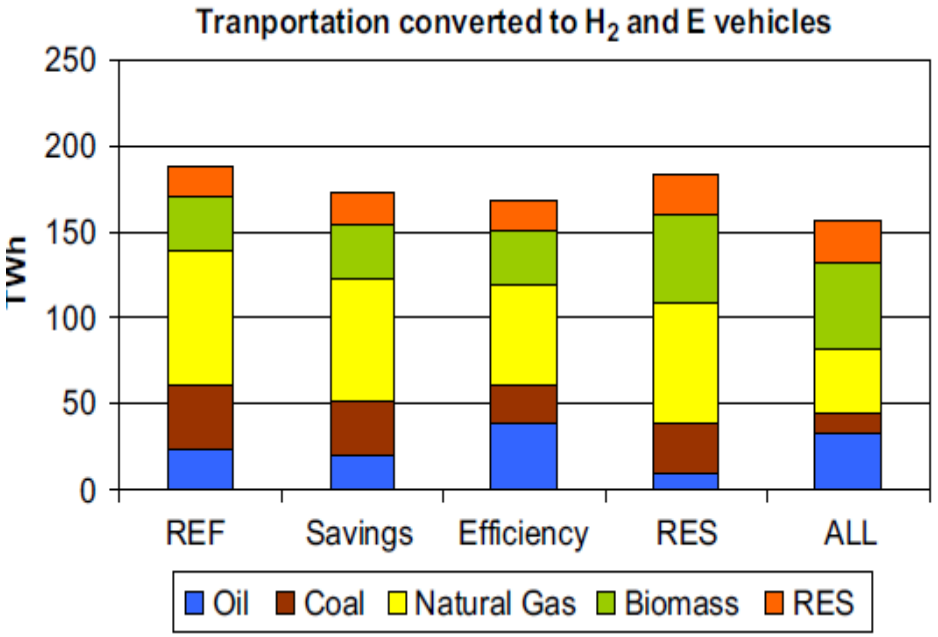
Source; Lund and Kempton (2008) – Denmark

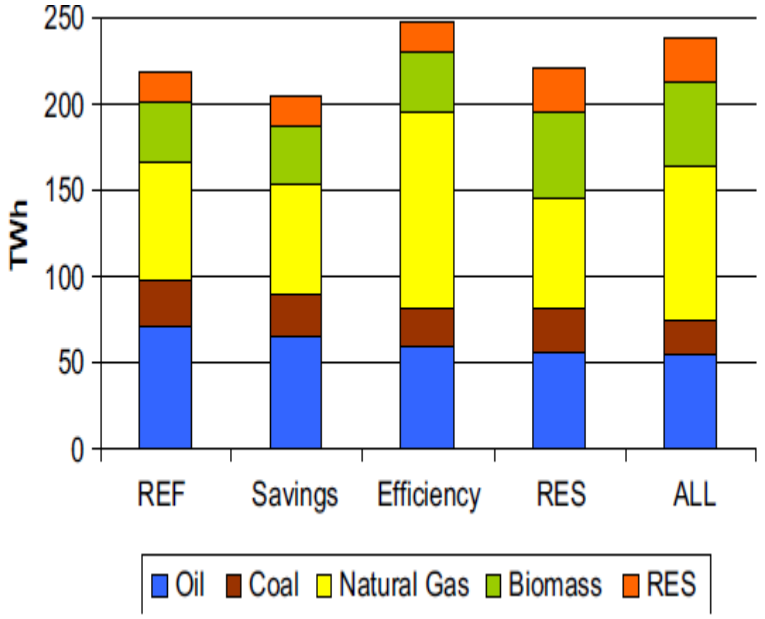
- According to Electric Power Research Institute (EPRI) study (Saber and Venayagamoorthy, 2010)

	Emission reduction per year using smart grid
Emission reduction from power plants with 50,000 EVs in V2G	450,259.985 tons
Emission reduction from power plants and transport sector with 50,000 EVs in V2G	776,938.751 tons

Energy Independence

- Lund (2007); Richardson (2013); Richardson (2013); Chukwu et al. (2014); Kempton et al. (2014)

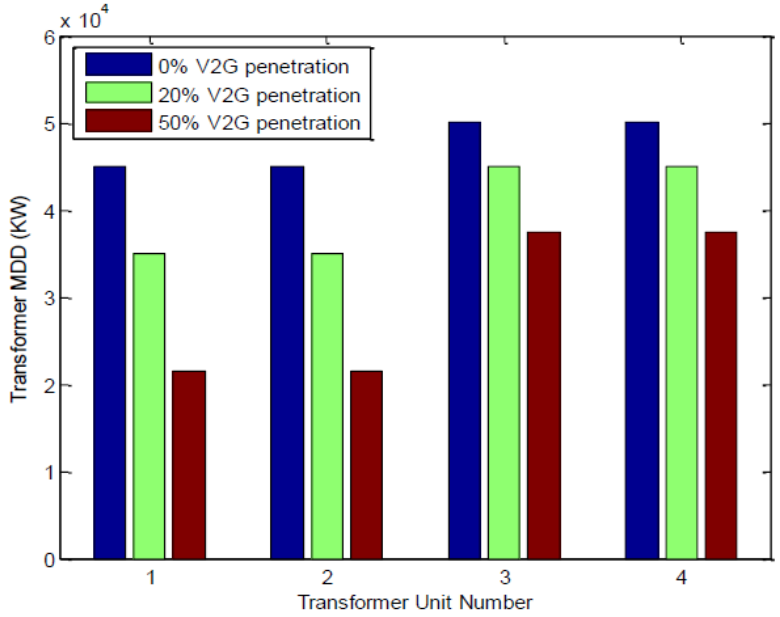


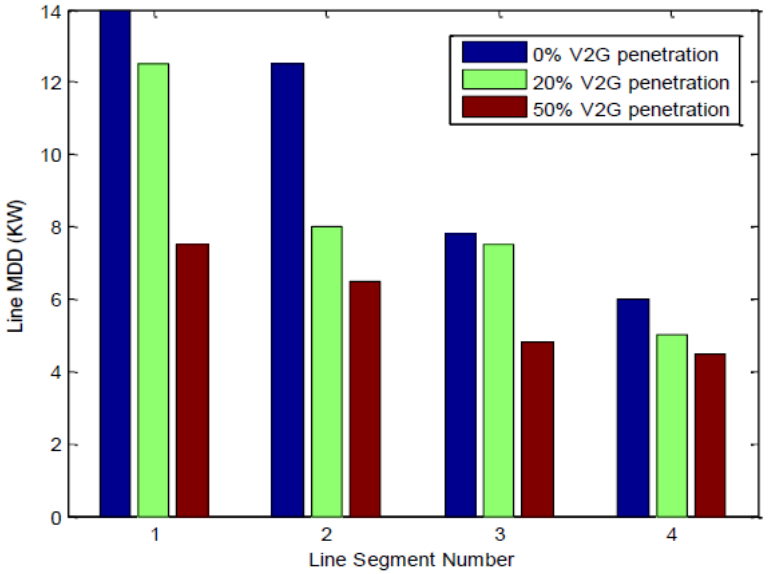


Source: Lund (2007) - Denmark

Energy Independence

- EVs can be completely operated with renewables if charged with renewable electricity from the grid (Richardson, 2013)

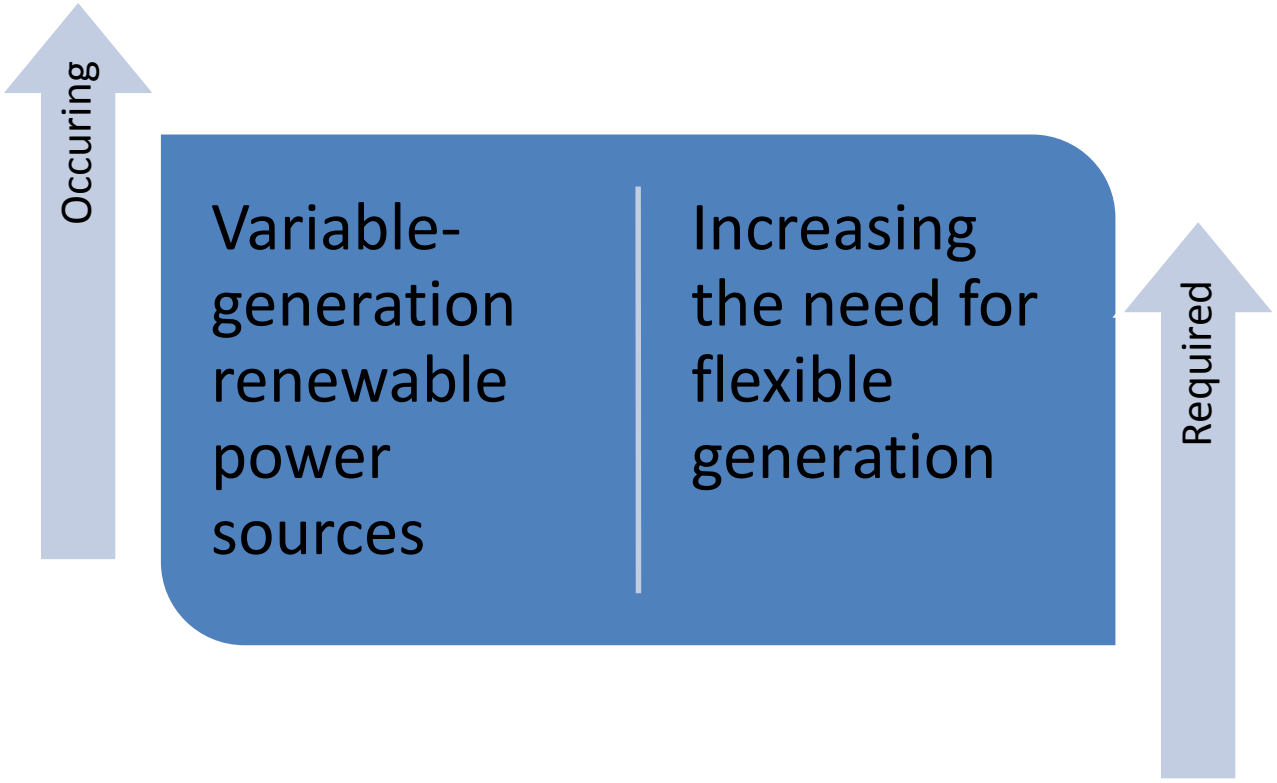


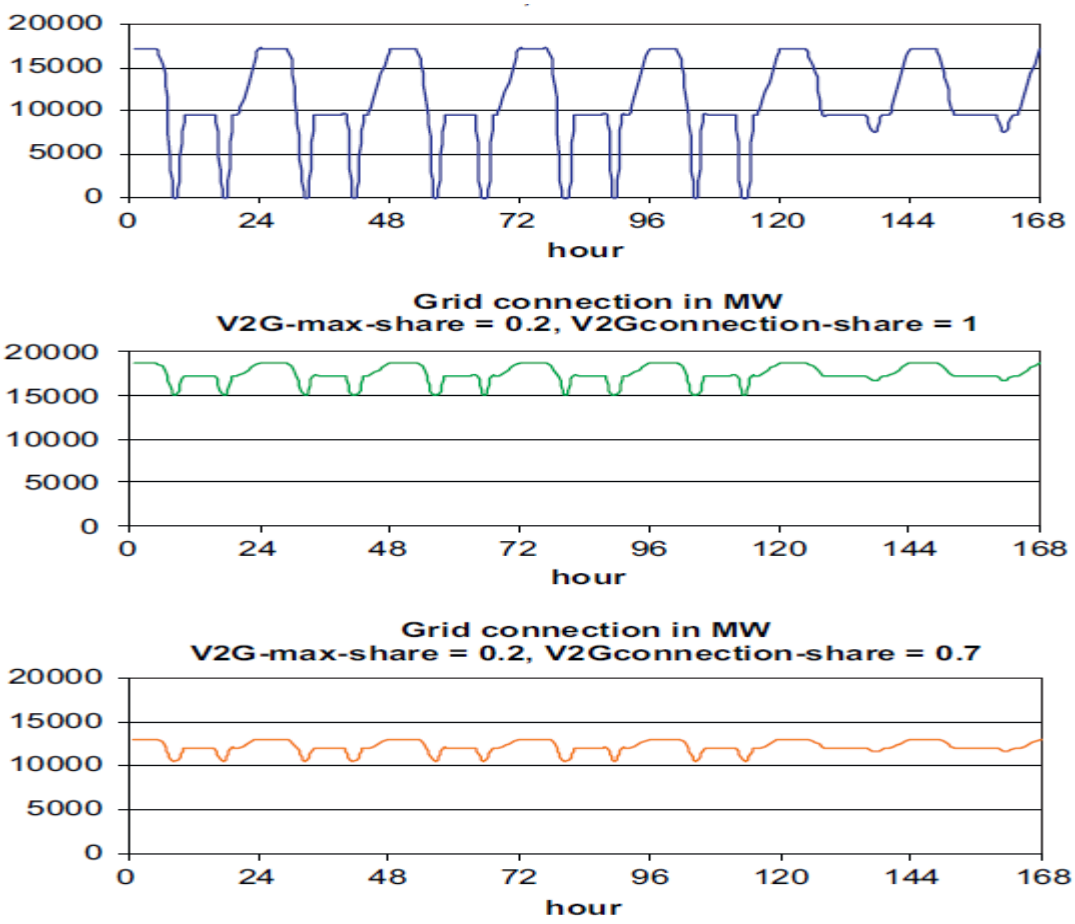


Source: Chukwu et al. 2014 – V2G in supply mode

Cover the Fluctuations of RES

- Lund and Kempton (2008); Richardson (2013); Kempton et al. (2014)

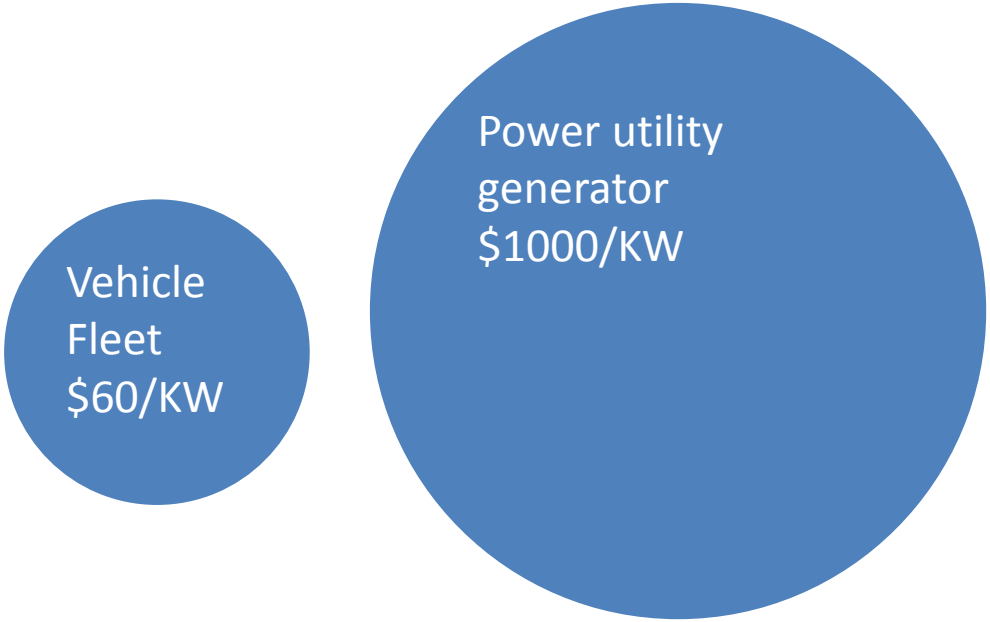




Source: Lund and Kempton (2008)

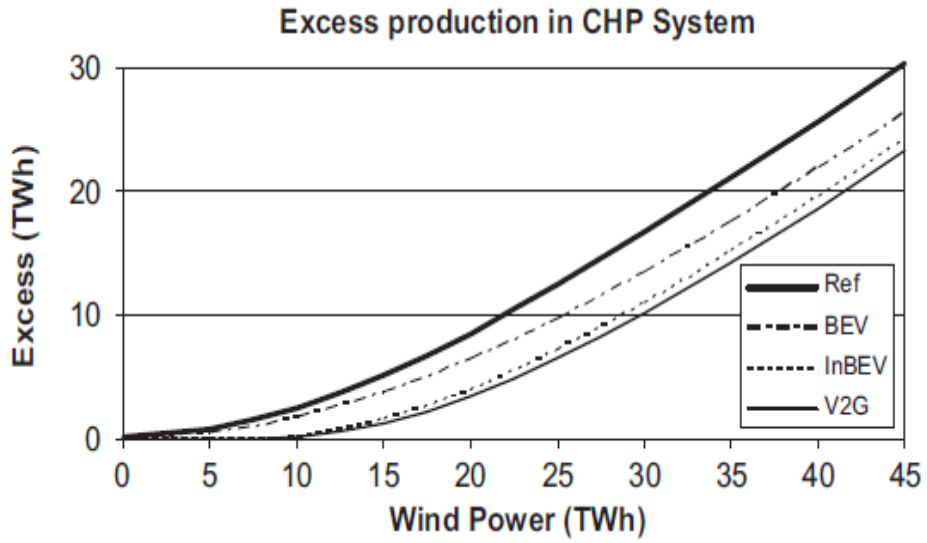
Low Capital Cost Than Generation Systems

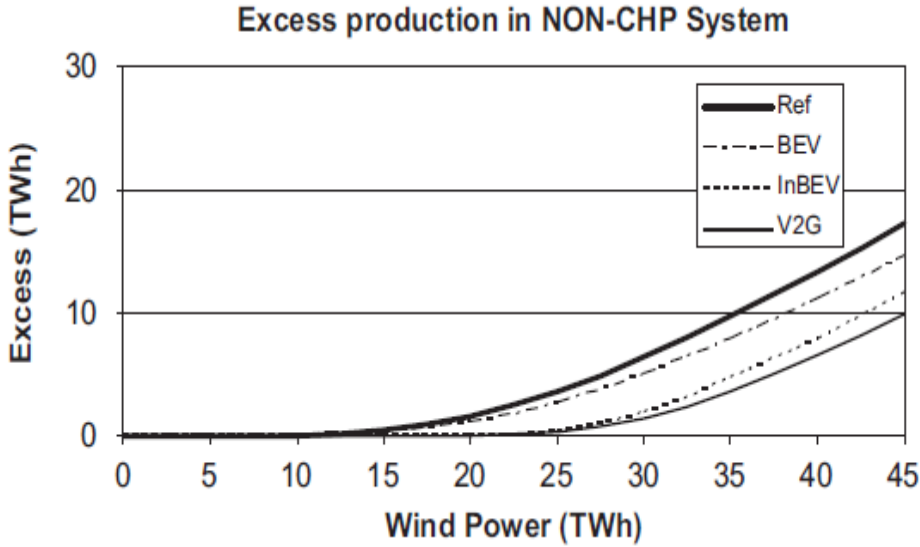
- Kempton and Letendre (1997); Kempton and Tomić (2005)



Reducing Cost on Excess Power Generation and System Upgradation

- Lund and Kempton (2008); Richardson (2013); Chukwu et al. (2014)



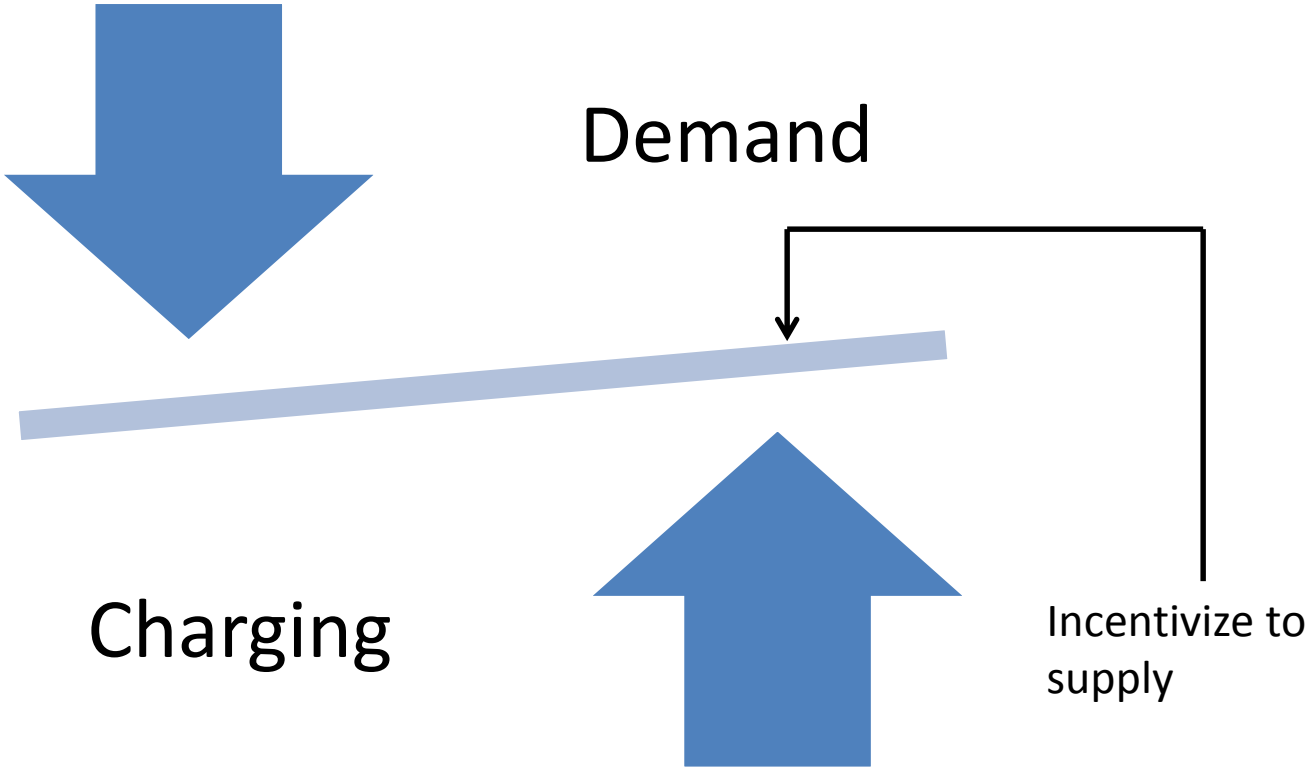


Lund and Kempton (2008)

- At higher penetration levels (50% or more), the system can be relieved from any upgrades due to these hikes in power demand: Source: Chukwu et al. (2014)

Variable Charging Rates

- Dallinger and Wietschel (2012) highlighted that vehicles have variable charging rates



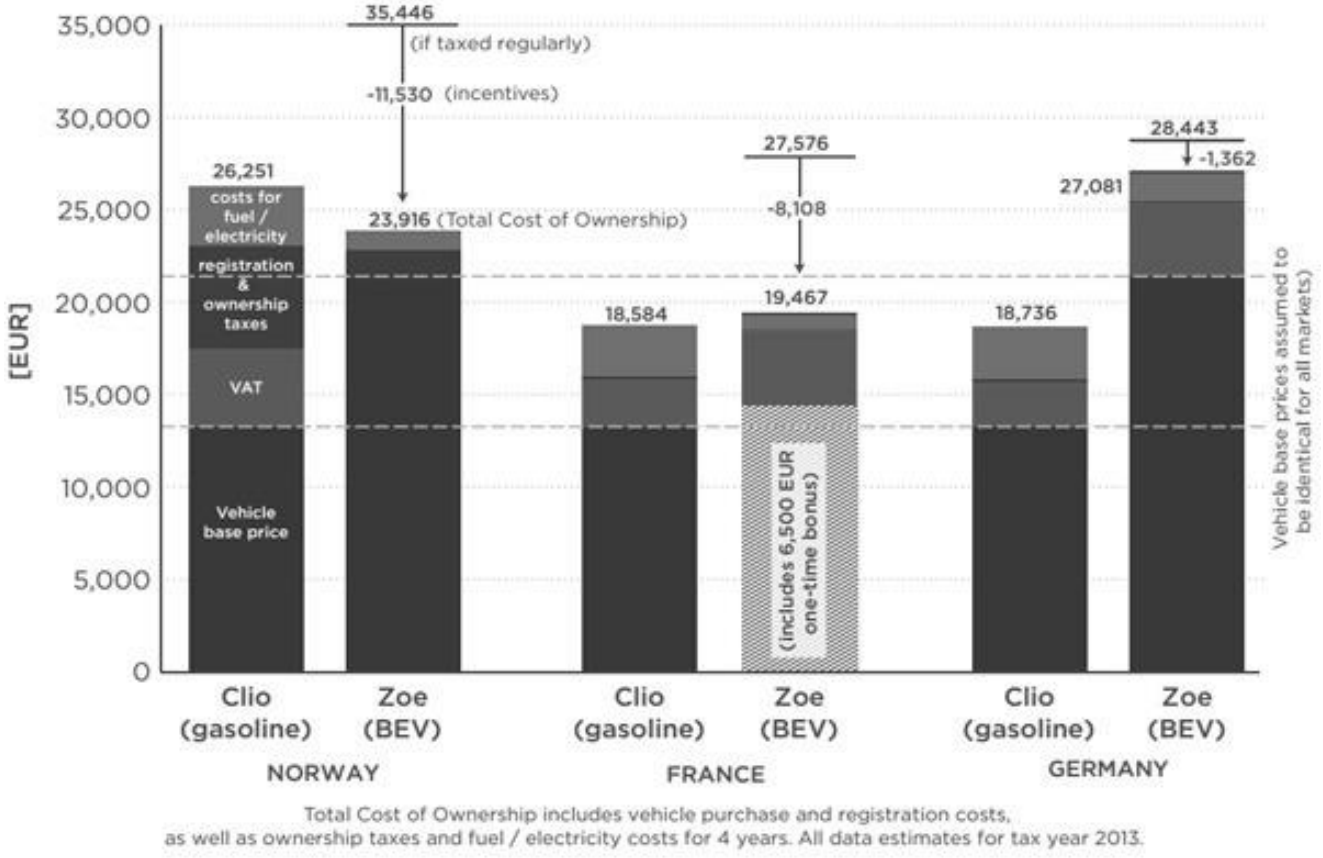
Other Opportunities

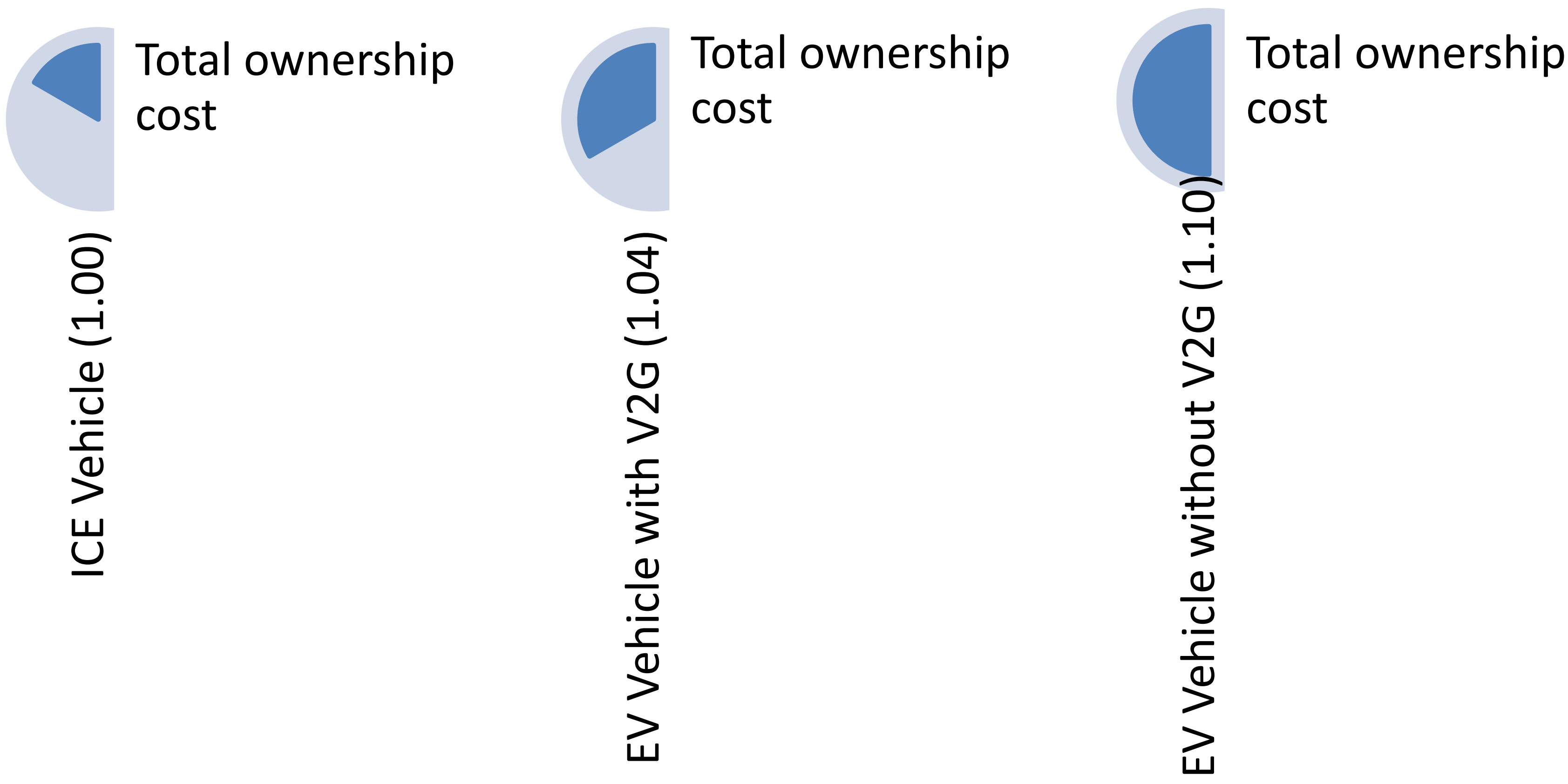
- Kempton and Letendre (1997) and Kempton and Tomić (2005) proposed that subsidies must be given to the EV drivers who contribute to the system
- Passenger cars:
  - Highest proportion in traffic
  - Low capital cost
  - Maximum number of recharges
  - Maximum storage capacity

Challenges

Higher Capital Cost for Car Users

- Kempton et al. (2014); Kim and Li (2015)





Kim and Li (2015) - Korea

Optimization of Charging Mechanism

Study	Optimization algorithm	Application
Saber and Venayagamoorthy (2010 and 2011)	Particle swarm optimization	Cyber-physical energy system (CPES) which works on the concept of smart grid systems
Dallinger and Wietschel (2012)	Agent-based electricity market equilibrium model	Scheduling of EVs and incentivizing the use of electricity
Fazelpour et al. (2014)	Genetic algorithm	Time-dependent charging optimization
Jin et al. (2014)	Lyapunov optimization	Minimize the delay of EV charging and the cost of non-renewable energy systems
Su et al. (2014)	Stochastic and deterministic optimization	Micro-grid stations to cater the issue of variability of renewable energy resources

Integration with Other Existing Resources

- Natural monopoly of electric supply systems (Kempton et al. 2014)
- The understanding of dynamic behavior of electrical systems with the integration of renewable energy sources and V2G is important (Mwasilu et al. 2014)
- Integration of V2G with wind is more prominent than solar energy systems (Richardson 2013)
- Mathiesen et al. (2015) stated focusing on single sector of energy are sub-optimal and V2G must be the heating and thermal, gas and fuel grid systems

Increasing Efficiency of EVs

- The vehicle technology is still growing in this sector to improve the battery capacity under frequent charging and discharging cycles (Mwasilu et al. 2014)
- Tie and Tan (2013) argued that the present hybrid EV should be converted to EV with low level component control and high level control algorithm to attain maximum efficiency.
- Pulse-width modulation (PWM) can be used to suppress the harmonic interference and consequently improve operational quality and energy savings (Zhou et al. 2014)

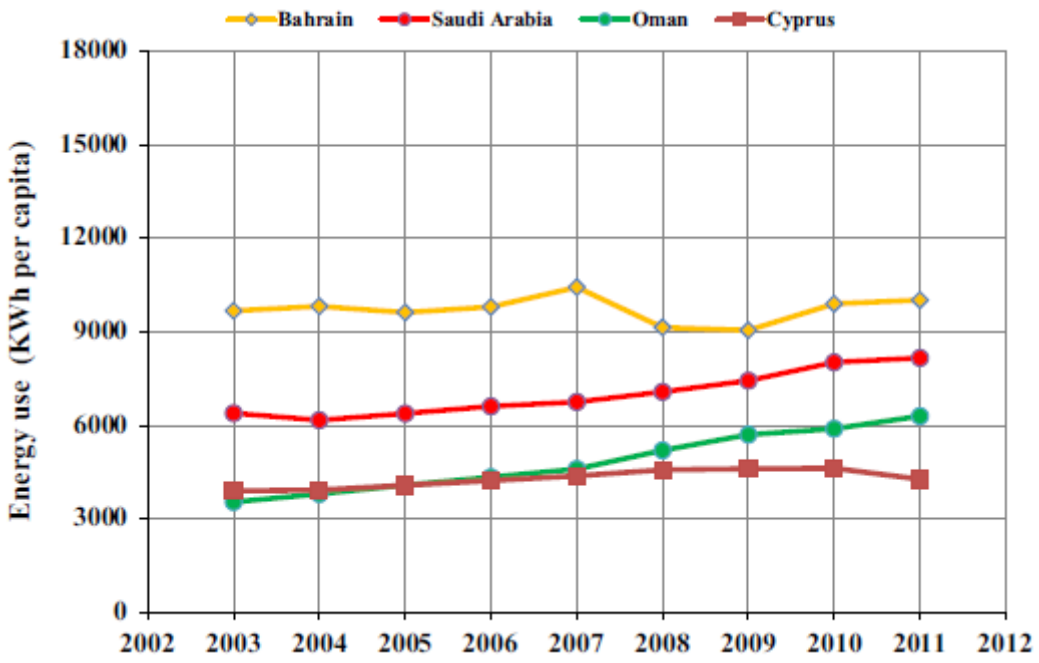
Other Challenges

- Potential over-loading of the system (Kempton et al. 2014)
- Lack of studies on operational configurations for the system with V2G integration (Chukwu et al. 2014; Mathiesen et al. 2015)
- Design of smart grid system to minimize utilization of non-renewable sources and cost to the renewable systems (Mwasilu et al. 2014)
- Development of smart control, communication and metering system (Saber and Venayagamoorthy 2010 and 2011; Fazelpour et al. 2014)
- V2G integration would improve the voltage profile which may result in over-utilization of energy resources (Nworgu et al. 2016)

Case of Bahrain

https://www.pinterest.com/explore/bahrain-map/

Increasing Electrical Energy Demand



Source: Nematollahi et al. 2016

Reliance on Fossil Fuels

- 3GW of electricity generating capacity, more than 12 billion kWh of annual electricity.

More than 90% is derived from the combustion of fossil fuels

http://www.steamenginerevolution.com/wp-content/uploads/2015/05/Coal-Fired-Power-Plant_in-USA_Kentucky.jpg

Potential for Renewable Energy Resources

- Daily available solar energy in Bahrain = 2.6 million bbl of oil or from 43.2 million m^3 of natural gas: Alnaser et al. 2014
- The wind turbines in the World Trade Center in Manama can generate wind energy from 1000 up to 1300 kW
- The wind energy generation is limited
- PV electricity generation used more widely (Al-Maamary et al. 2016)

Increase in Private Vehicles

- Average increase in private vehicles 7.3% per year
- Average increase in fuel consumption 5.7 % per year on average: Al-Sabbagh et al. 2016

https://www.tradearabia.com/source/2014/09/05/traffic.jpg

V2G Adaptation

- These facts make adaptation of the V2G technologies feasible for Bahrain to complement the shift to solar energy systems.
- The shift in technology can happen in a short time horizon with the small area and low population in Bahrain.

Challenges

- Create awareness among the general public and administration towards the potential benefits of V2G
- Low prices of electricity and fuel in spite of decline in fossil fuels and associated emissions
- Planning and design duration (if adopted)
- Present lack of renewable energy resource usage and EV