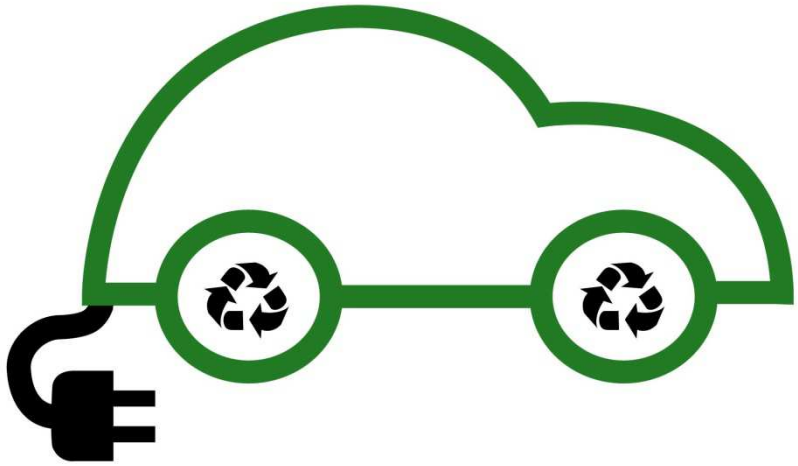
# Electric Vehicle Battery Re-use in Stationary Applications



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# Overview

**Electric Vehicles**

Vehicle types

**Battery Technologies**

Chemistry type

**Stationary Applications**

Building Integrated Photovoltaic's (BIPV)

# Vehicle Types

Class I

**Conventional (ICE)**

No electrification

**Start-stop**

ICE shuts down under braking and rest

Class II

**Micro/mild hybrid**

Start-stop combined with regenerative braking used to boost vehicles acceleration

# Vehicle Types

**Class II**

**Full-hybrid (HEV)**

Start-stop combined with regenerative braking used for electric driving

**Class III**

**Plug-in hybrid (PHEV)**

Charged off the grid and used for Electric driving (20-50km)

**Battery Electric Vehicles (BEV)**

Battery is the vehicles only energy source

# Electric Vehicles (Batteries)

**Class I**

Traditional and advanced lead based batteries

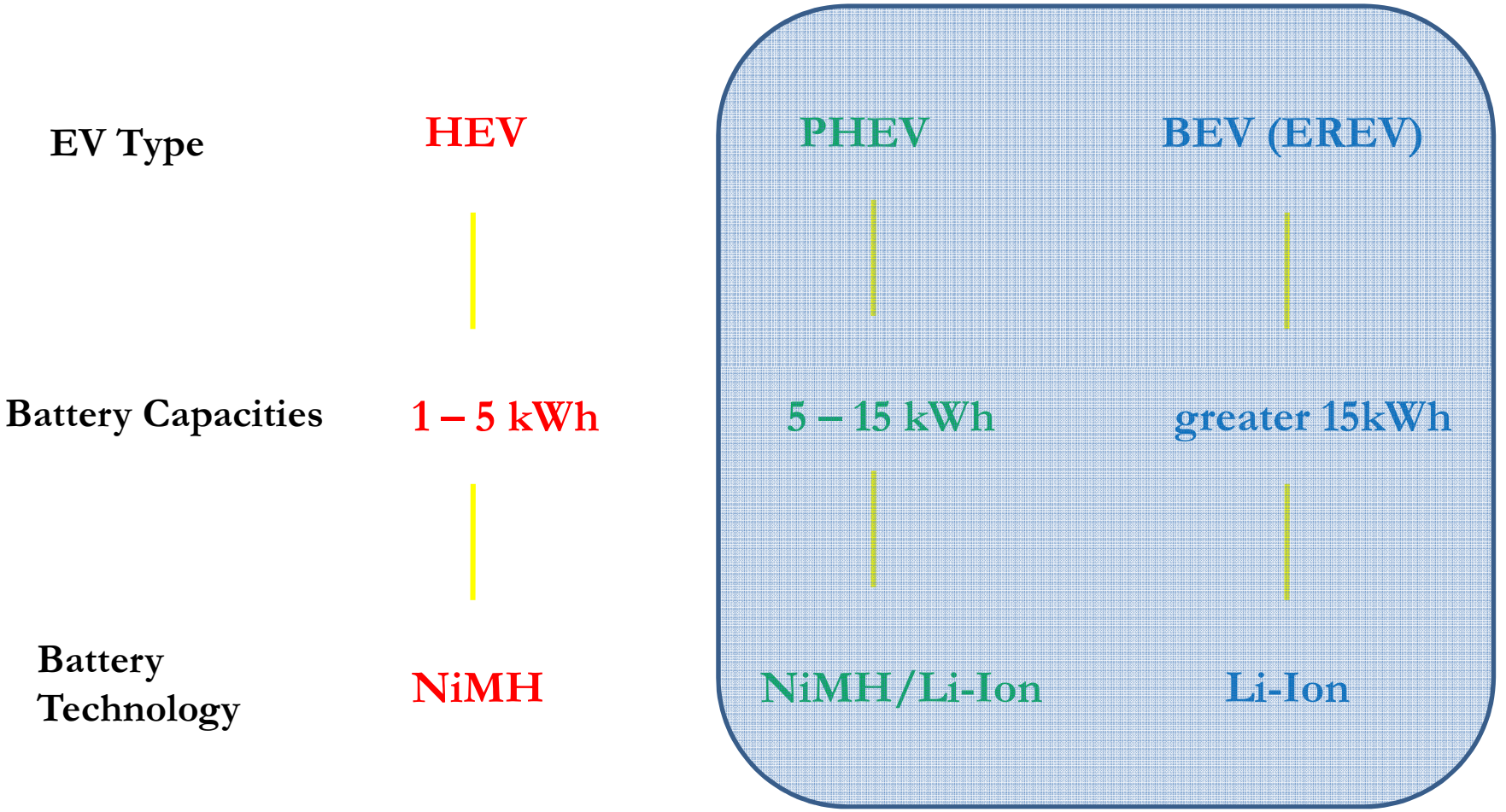
**Class II**

Nickel-Metal Hydride (NiMH) and Lithium Ion (Li-Ion)

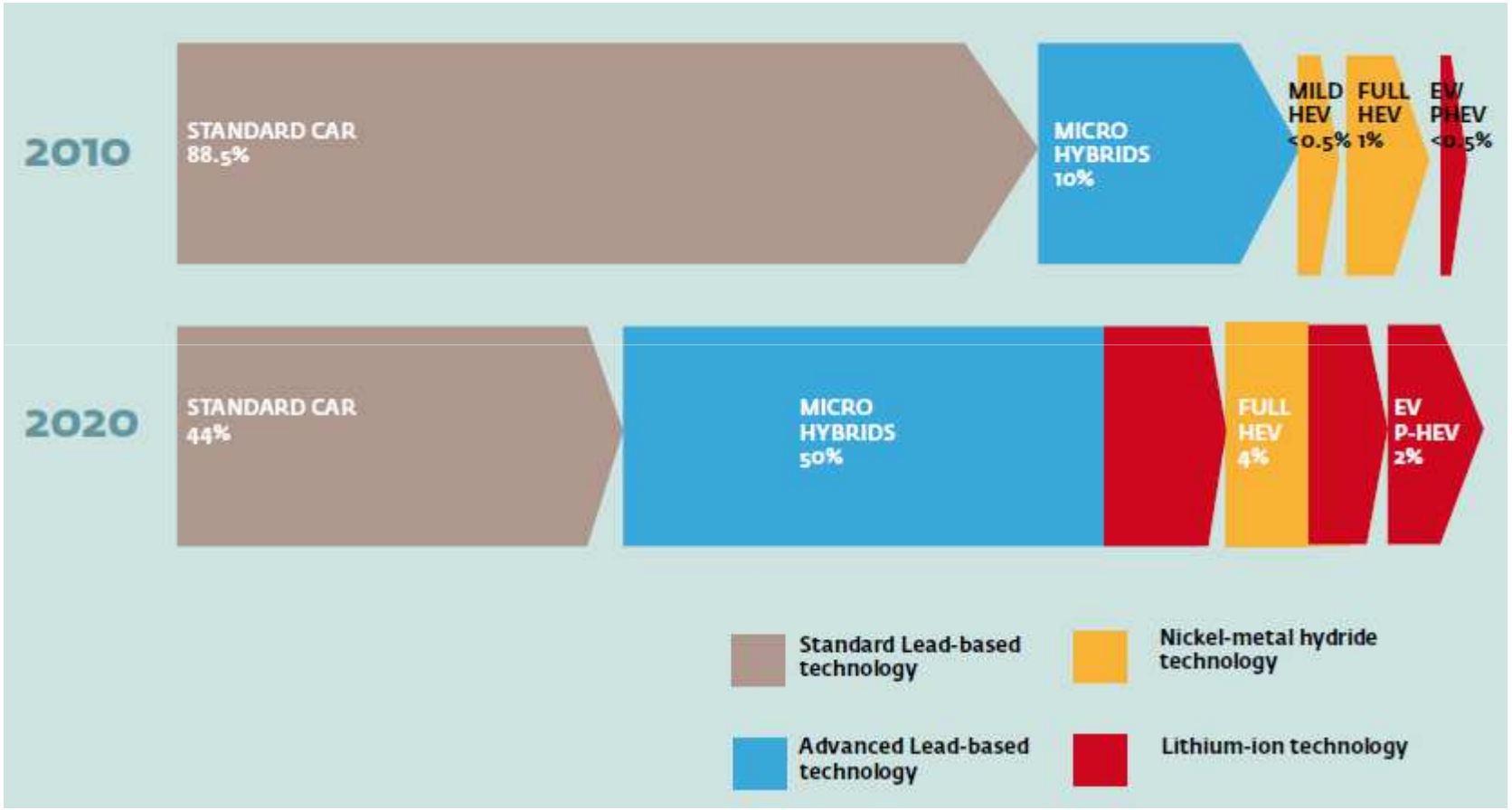
**Class III**

Li-Ion or Sodium Nickel Chloride (NaNiCl2) for heavy duty vehicles

# Electric Vehicles (Batteries)

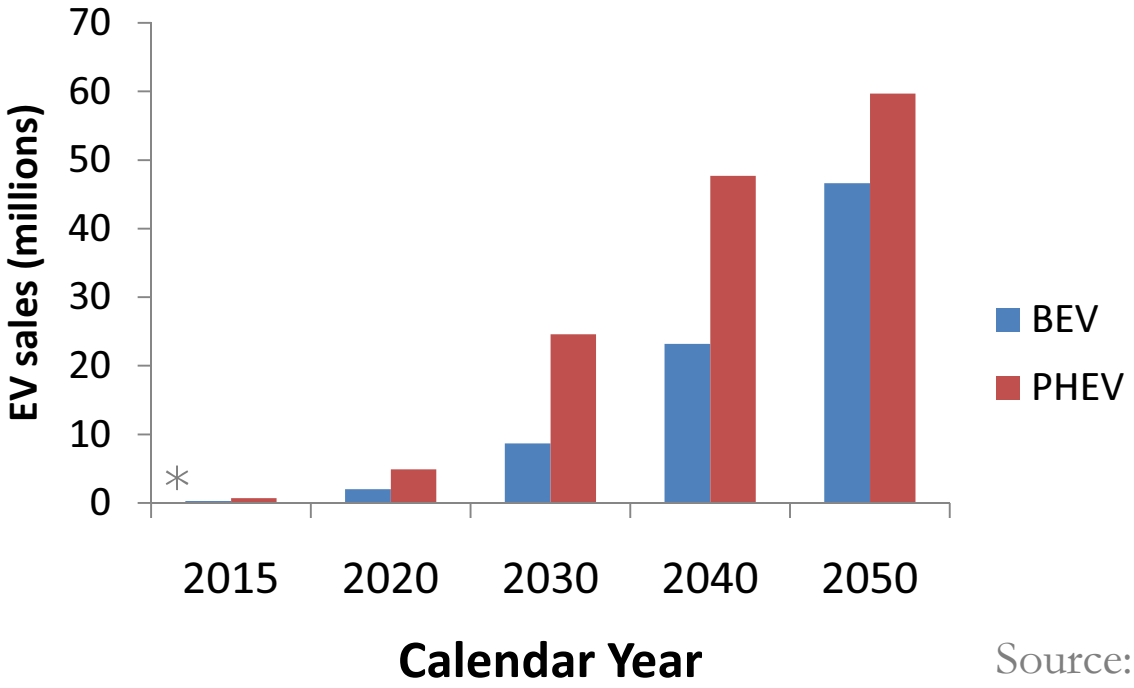


# Projected worldwide market penetration for battery technology by vehicle type




Source: EUROBAT, “A review of battery technologies for automotive applications” , 2014.

# EV Type




Source: IEA

* 405,000 BEV and PHEV on the road globally in early 2014

# Battery (characteristics)

**Energy Density**

Specific energy (Wh/kg) and Specific power (W/kg)

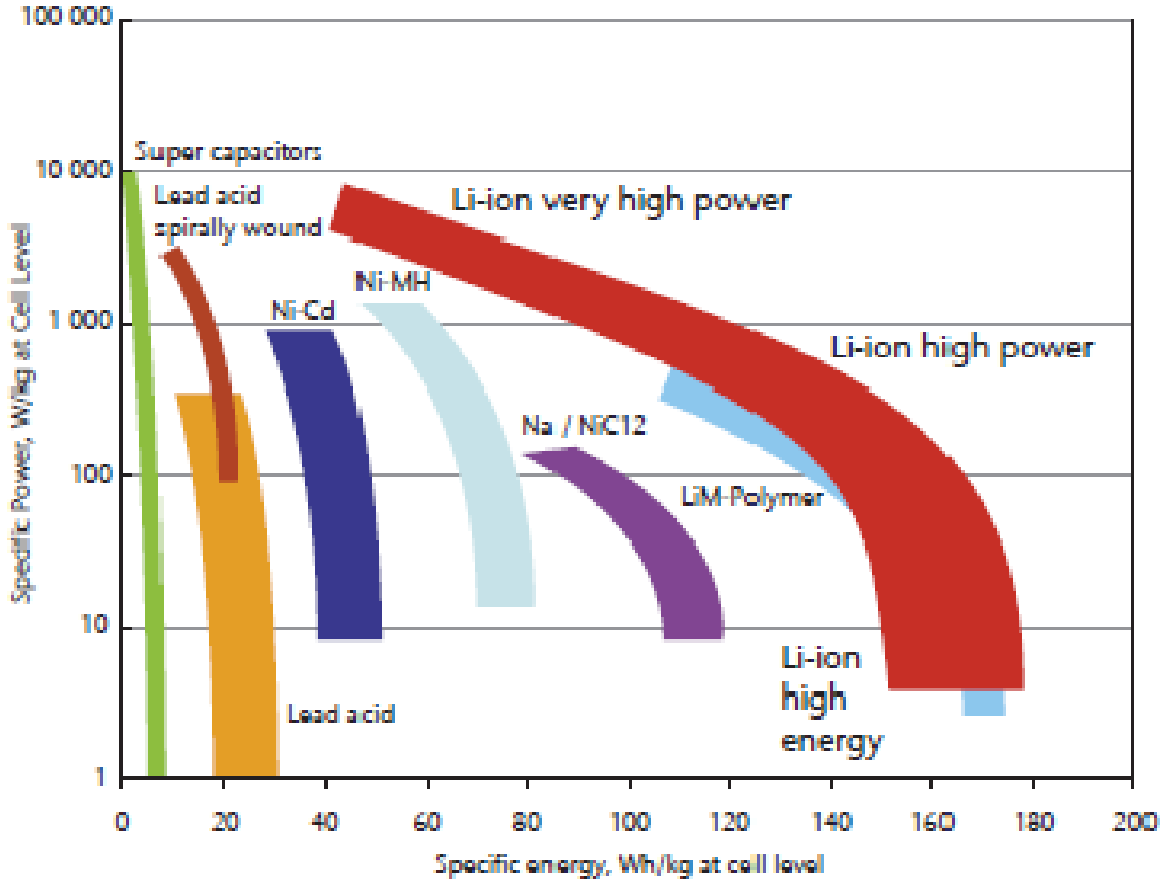
**Cost**

€/kWh and €/kW

**Lifetime**

Chemistry type

# Battery specific energy & power




International Energy Agency (IEA), "Technology Roadmap - Electric and plug-in hybrid electric vehicles," Paris, France, 2011

# Battery (characteristics)

**Energy Density**

Specific energy (Wh/kg) and Specific power (W/kg)

**Cost**

€/kWh and €/kW

**Lifetime**

Chemistry type

# Battery cost

| | Cost | |
|---|---|---|
| | €/kWh | €/kW |
| Lead based | 100 - 250 | 10 - 25 |
| NiMH | 400 - 500 | 910 - 1140 |
| Li-Ion | 300 - 450 | 100 - 200 |

Source: EUROBAT, “A review of battery technologies for automotive applications” , 2014.

# Battery (characteristics)

**Energy Density**

Specific energy (Wh/kg) and Specific power (W/kg)

**Cost**

€/kWh and €/kW

**Lifetime**

Chemistry type

# Battery lifetime

| | Lifetime |
|---|---|
| Lead based | 3 – 8 years |
| NiMH | 8 – 10 years |
| Li-Ion | 10 years* |

* Can be significantly less if operated under high DoD > 80%

Source: EUROBAT, “A review of battery technologies for automotive applications” , 2014.

# Other important battery characteristics

**Self-discharge**

Dependent on temperature and SOC

**Temperature range**

During charging & discharging

**Recharge power (C-rate)**

Vehicle types

# Self discharge

| | Discharge rate (%) |
|---|---|
| Lead based | ~ 3% |
| NiMH | ~ 15% - 20% |
| Li-Ion | ~ 5% |

Source: EUROBAT, “A review of battery technologies for automotive applications” , 2014.

# Other important battery characteristics

**Self-discharge**

Dependent on temperature and SOC

**Temperature range**

Affects charging & discharging

**Recharge power (C-rate)**

Vehicle types

# Temperature range

| | Temperature Range |
|---|---|
| Lead based | -30 to +75˚C |
| NiMH | -10 to +45˚C |
| Li-Ion | -25 to +55˚C |

Source: EUROBAT, “A review of battery technologies for automotive applications” , 2014.

# Other important battery characteristics

**Self-discharge**

Dependent on temperature and SOC

**Temperature range**

Affects charging & discharging

**Recharge power (C-rate)**

Vehicle types

# Re-charge power (C-Rate)

| | kW/kWh |
|---|---|
| Lead based | 0.35 |
| NiMH | 1[ab] |
| Li-Ion | 0.5 – 2C[a] |

[a] Charge must be managed by an active cooling system

[b] Charge must be managed by an adequate electronic and electric control system

Source: EUROBAT, “A review of battery technologies for automotive applications” , 2014.

# So why recycle batteries from electric vehicles??

**Specific Energy**

EV can no longer sustain minimum travel distance

**Specific Power**

A minimum acceleration velocity is no longer attainable

These points are generally accepted to occur when storage capacity has reduced by 20% or when available peak power has decreased by 25% of its maximum

However between 70 – 80% of original battery capacity still remains and can be considered for re-use in other applications

# Stationary application

**Building integrated Photovoltaic's (BIPV)**

Growing market of BIPV installations

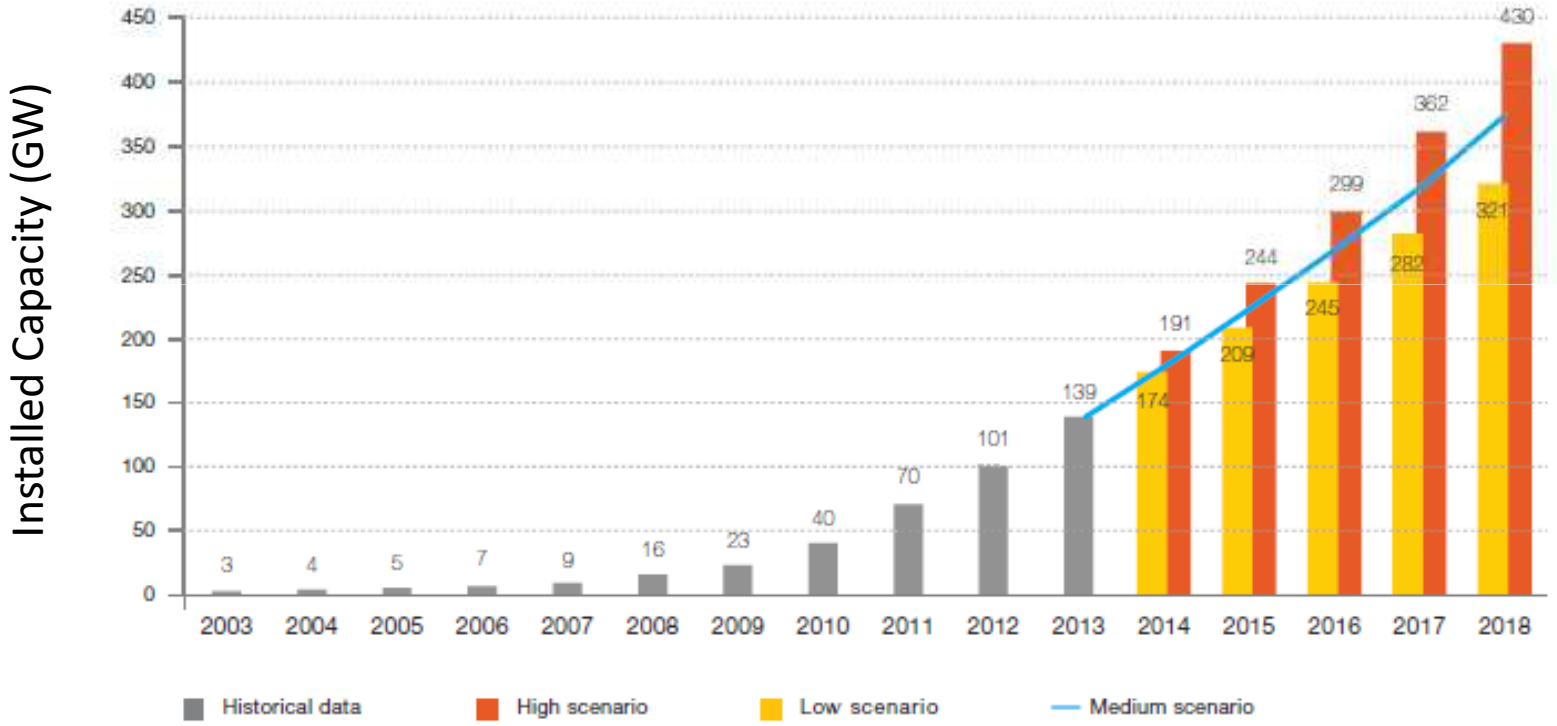
**Operational control strategies**

High penetrations of PV & excess capacity is causing network stability problems on grid such as voltage and frequency disturbances

**Battery storage**

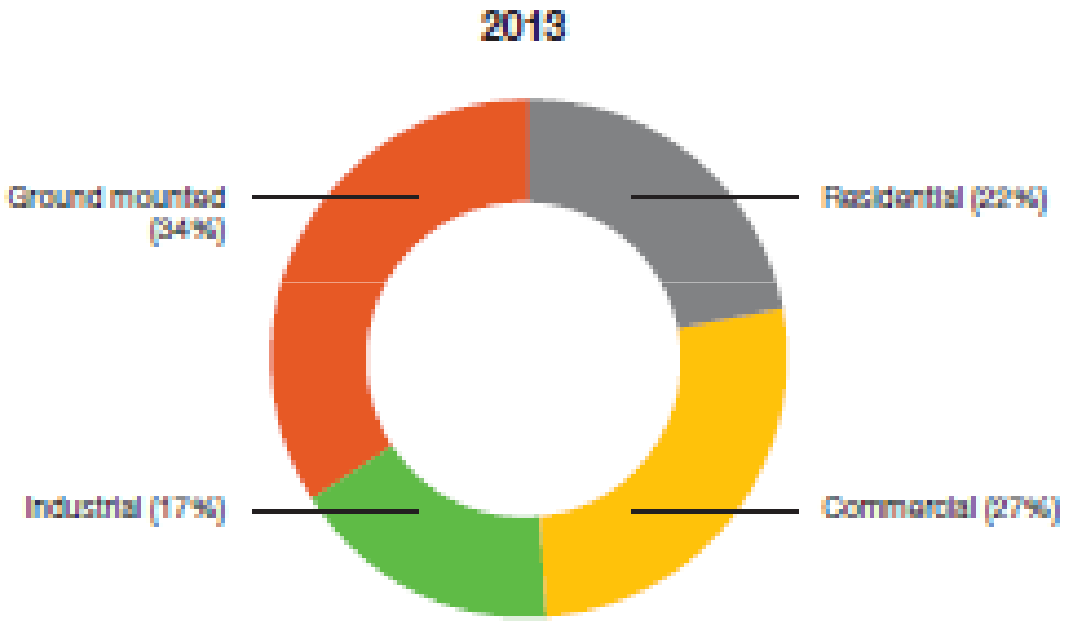
A need to balance supply and demand at a local level

# Global grid connected PV installed capacity projections




Source: European Photovoltaic Industry Association (EPIA), "Global Market Outlook for Photovoltaics 2014 – 2018", June 2014.

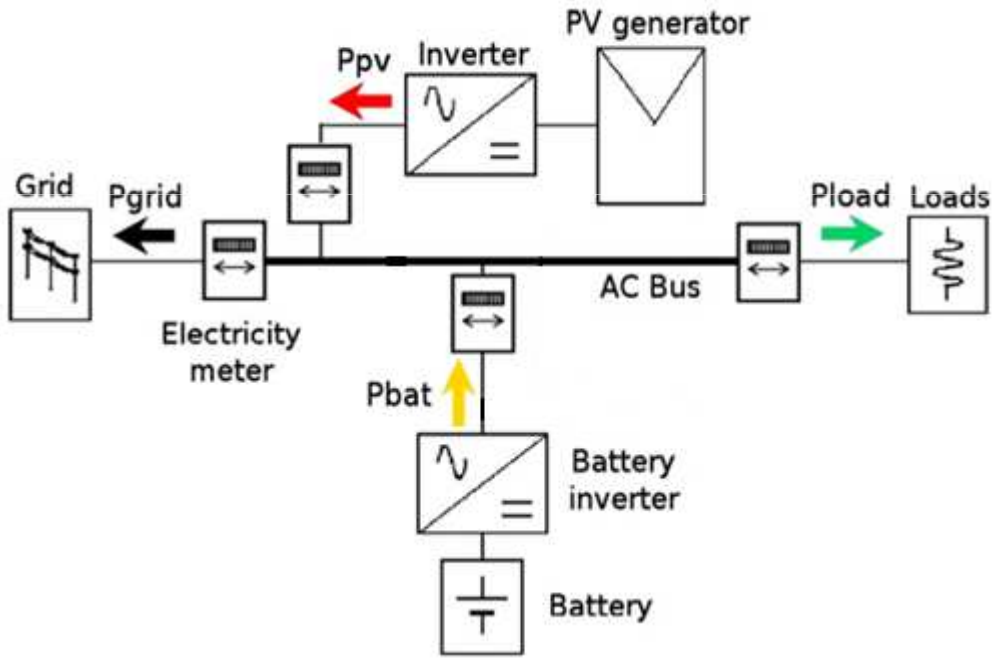
# Global grid connected PV by sector




Source: European Photovoltaic Industry Association (EPIA), “Global Market Outlook for Photovoltaics 2014 – 2018”, June 2014.

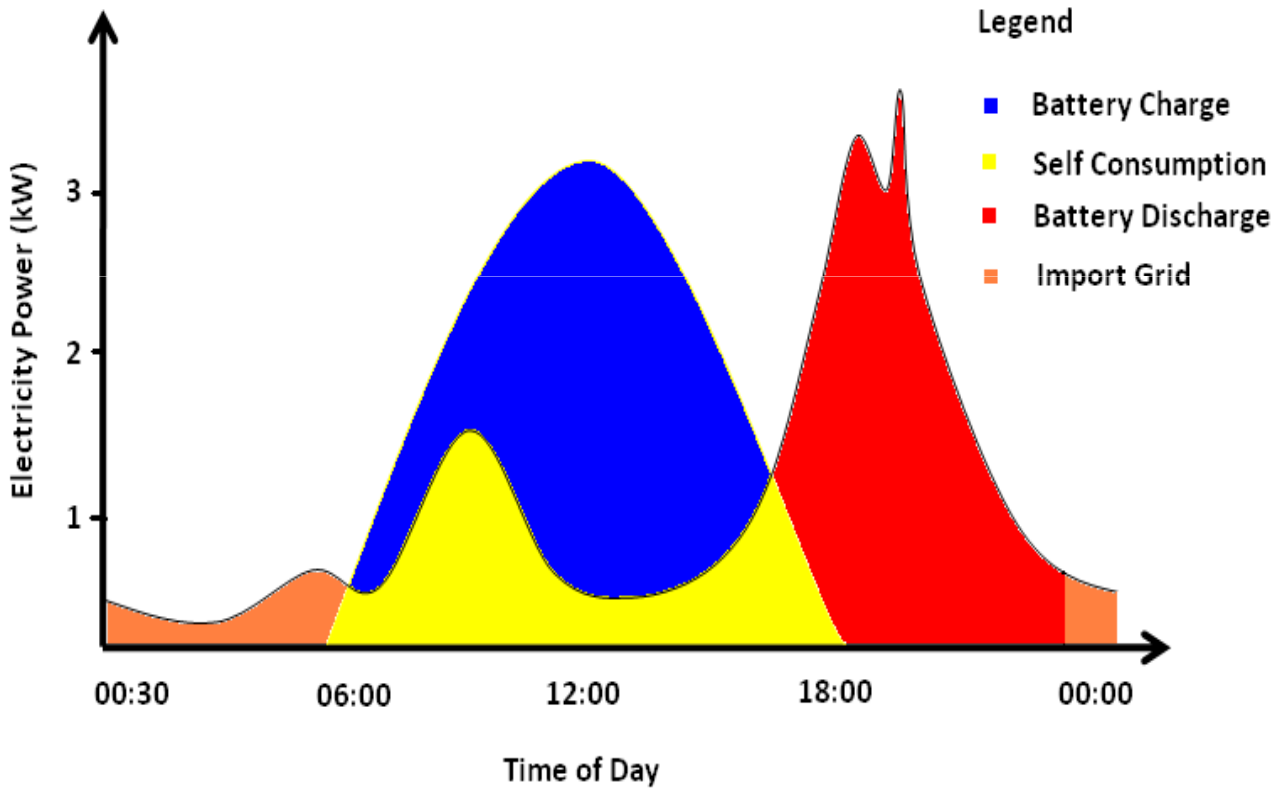
# BIPV operation

General configuration of a grid connected PV system with battery storage

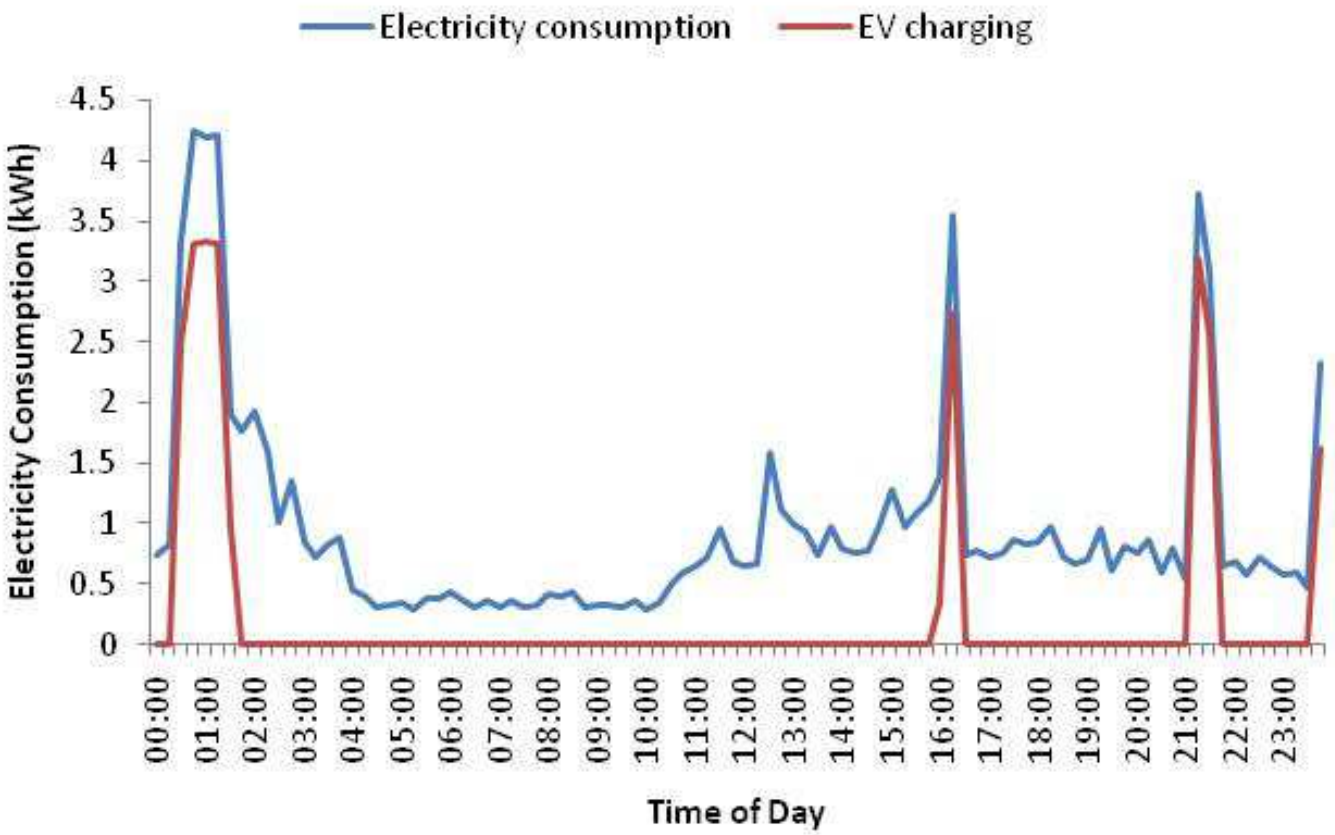



Source: M. Castillo-Cagigal, E. Caamaño-Martín, E. Matallanas, D. Masa-Bote, a. Gutiérrez, F. Monasterio-Huelin, and J. Jiménez-Leube, "PV self-consumption optimization with storage and Active DSM for the residential sector," *Sol. Energy*, vol. 85, no. 9, pp. 2338–2348, Sep. 2011.

# BIPV operation

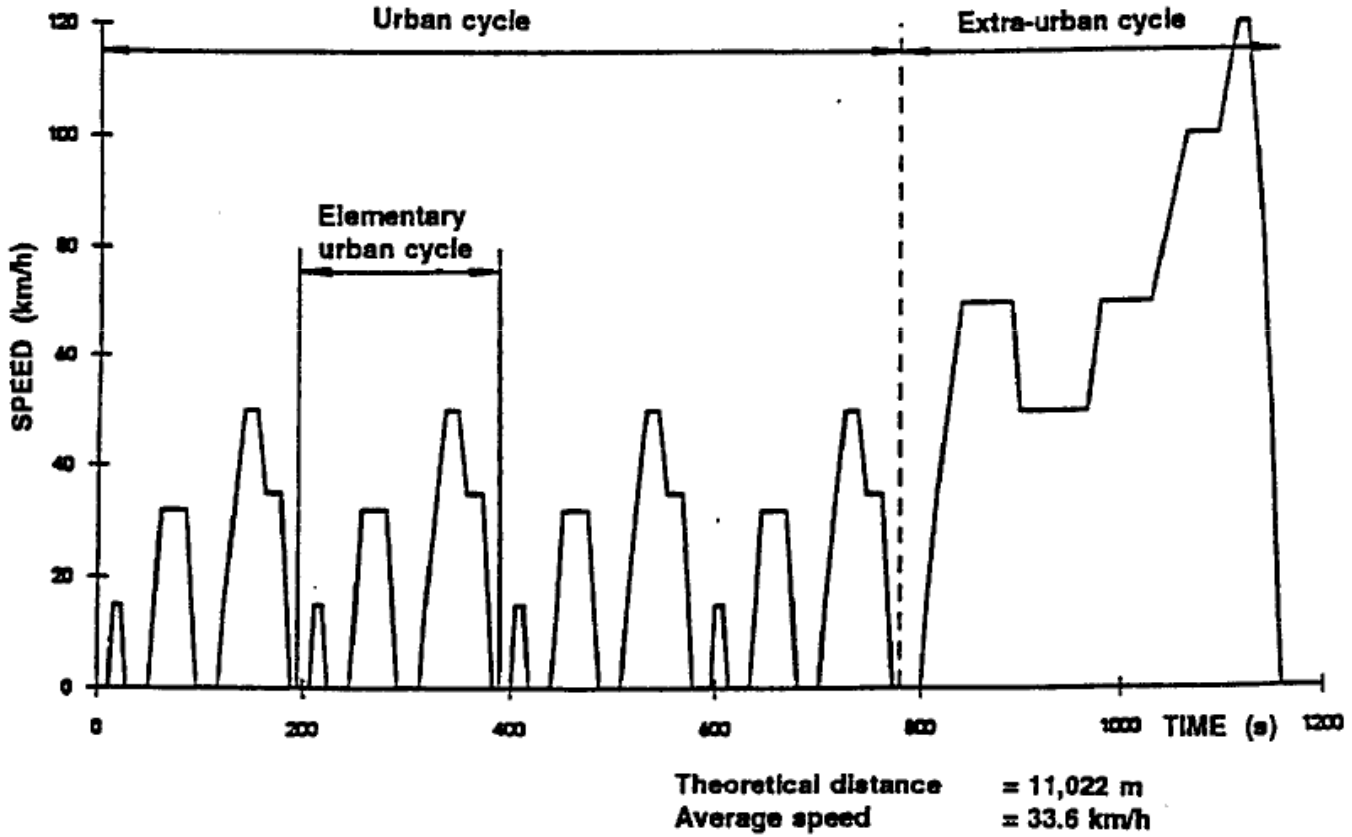


# EV charging profile




Source: Electric Vehicle Behaviors: Adoption and Charge Times
http://wiki-energy.org/

# EV discharging profile (speed proxy)




Source: UN ECE 101 (see http://www.unece.org/trans/main/wp29/wp29regs/r101r2e.pdf - See more at: http://www.seai.ie/Grants/Electric_Vehicle_Grant_Scheme/I_am_a_consumer/EV_Range_and_Fuel_Efficiency/#sthash.ozHL6DuQ.dpuf

# how will battery perform subjected to building load profiles???

**Building profiles**

Building load profiles are very different to EV profiles

**BIPV control strategies**

Control strategies may be necessary to limit battery cycle use

# Conclusions

**EV and battery availability**

Currently it is estimated that there are 405,000 PHEV & BEV's on the road and projected 20 million by 2020

**PV penetration**

BIPV market penetration is growing worldwide and a means of storing excess electricity capacity will be required to avoid overloading network grid infrastructure.

**EV battery re-use**

Reusing EV batteries for BIPV can provide a "cheap" method of providing storage as between 70-80% of capacity still remains after being retired from the automotive industry.

# Questions ?

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