BENEFITS OF ELECTRIC VEHICLE INTEGRATED INTO THE ELECTRICITY NETWORK

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Objectives

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- Looking at current electricity grid structure
- Weaknesses with current grid and need for smart grid
- Electric vehicle is becoming a new component of the grid
- Benefits of electric vehicle as part of the grid
- The research questions

Sources

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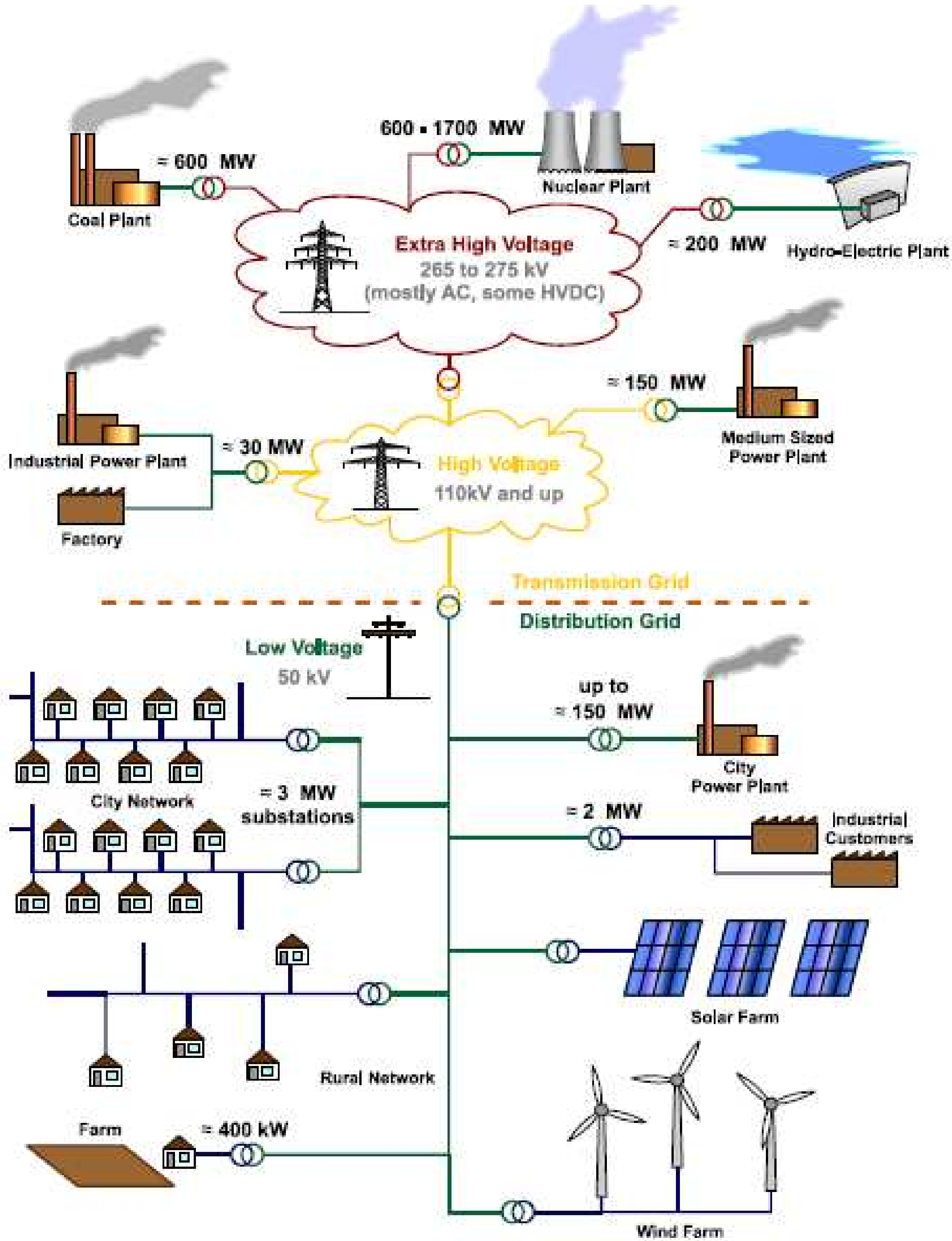
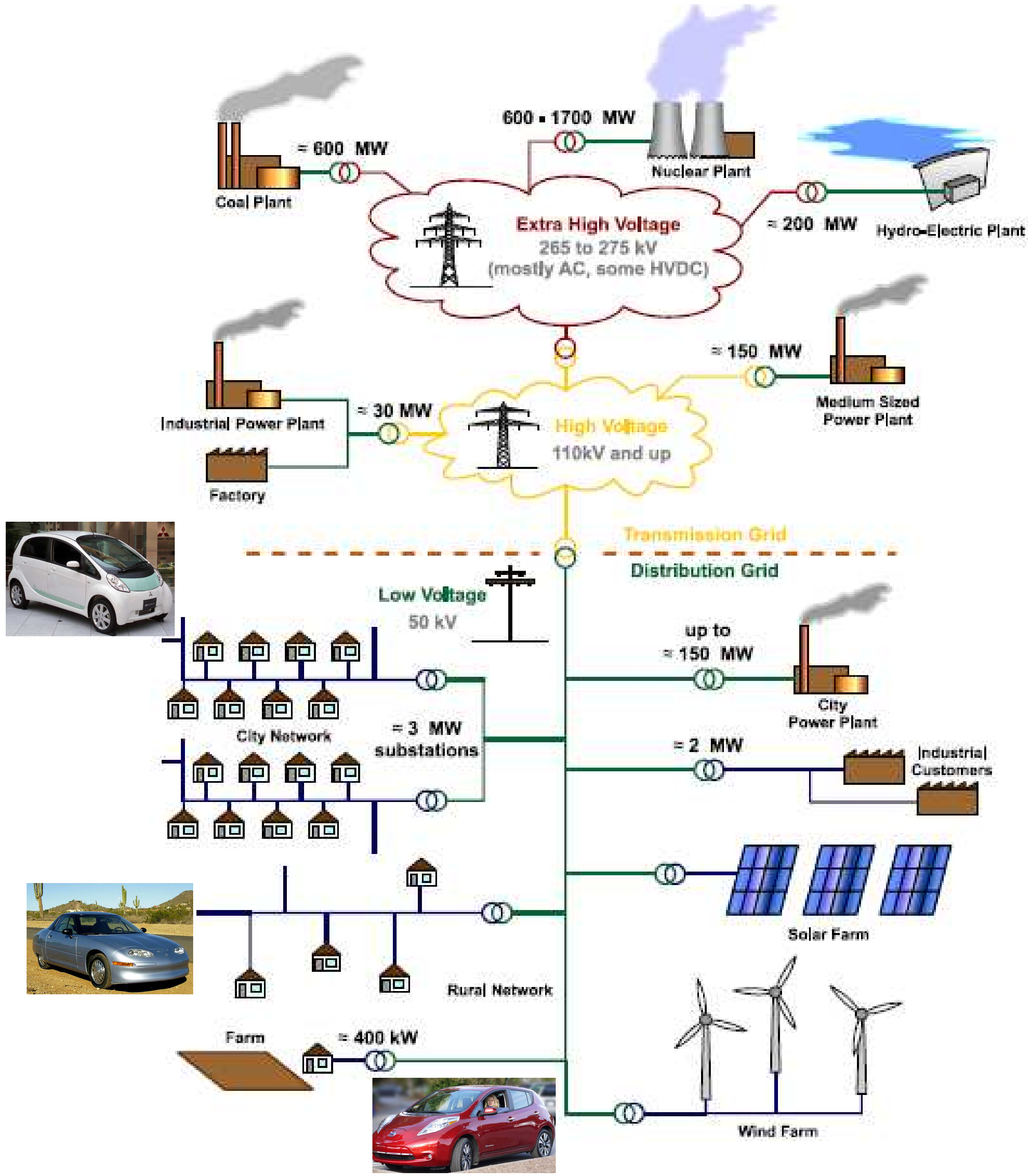
Objectives



≈ 600 MW
Coal Plant
600 - 1700 MW
Nuclear Plant
≈ 200 MW
Hydro-Electric Plant
Extra High Voltage
265 to 275 kV
(mostly AC, some HVDC)
≈ 150 MW
Medium Sized
Power Plant
Industrial Power Plant
≈ 30 MW
Factory
High Voltage
110kV and up
Transmission Grid
Distribution Grid
Low Voltage
50 kV
up to
≈ 150 MW
City
Power Plant
City Network
≈ 3 MW
substations
≈ 2 MW
Industrial
Customers
Solar Farm
Rural Network
Farm
≈ 400 kW
Wind Farm

Objectives



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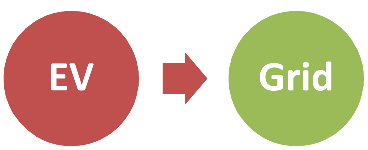
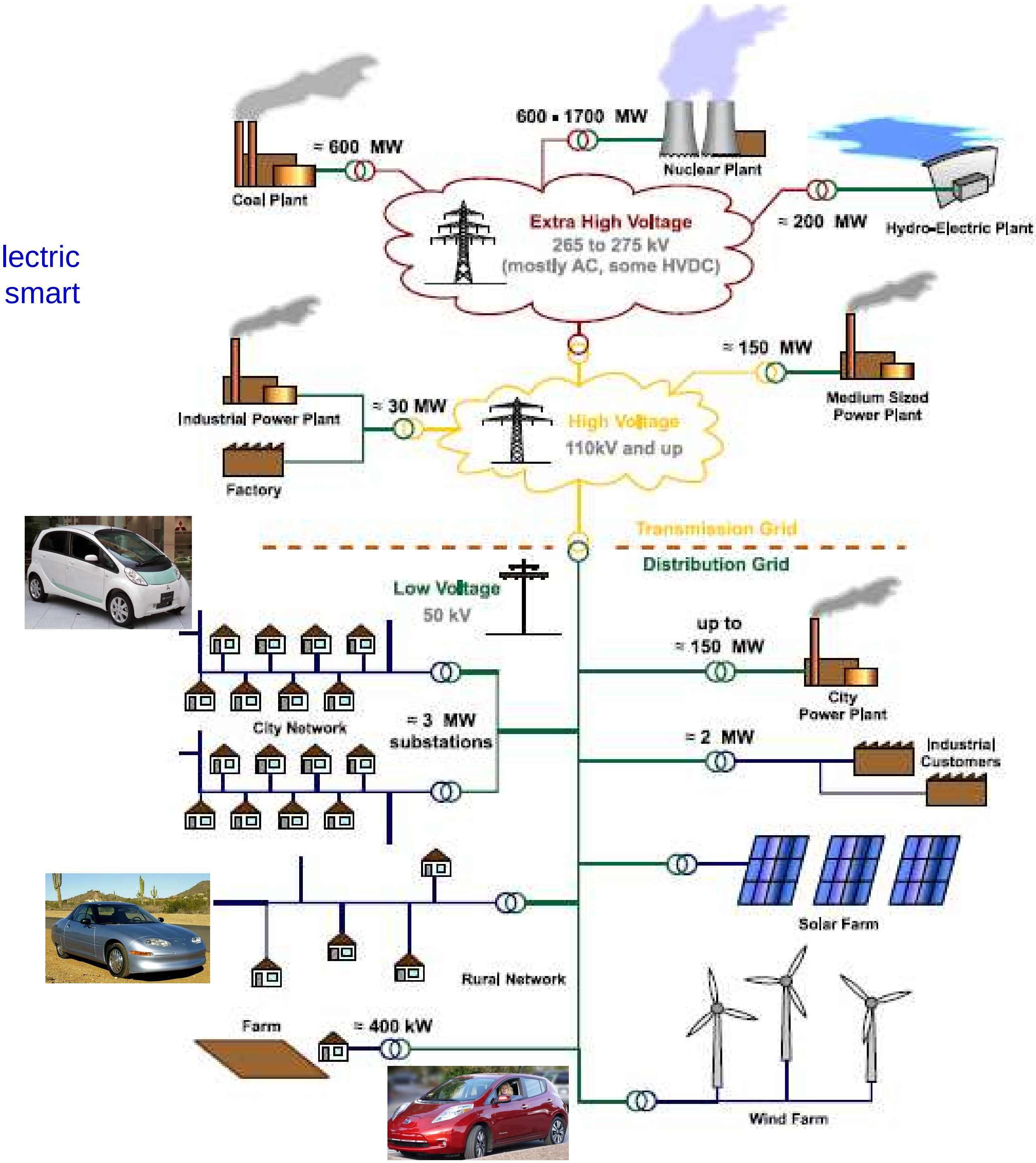
Objectives

The important role of electric vehicle integrated into the smart grid environment





Introduction

Introduction

- One of the world's largest and most complicated and sophisticated system-- **the electricity grid** -- is old and outdated
- Even in the developed countries, millions of people are without power for couple of hours every day. Recently, the numbers of weather-caused major outages have increased rapidly (outdoor facilities)
- Even in the countries with modern power grid, the only way utilities know there is a power outage is when a customer calls and report
- The grid has to be able to handle thousands of generators of different technologies and sizes, as well as supplying electricity to millions of customers in a reliable and sustainable way

Introduction

Today, a smart phone means a phone with a computer in it

Smart grid means “fully computerized” electricity grid

Do we have a dumb Grid?

It includes adding two-way digital communication technology to all devices associated with the grid

A key feature of the smart grid is automation technology that lets the utility adjust and control millions of devices from a central location.

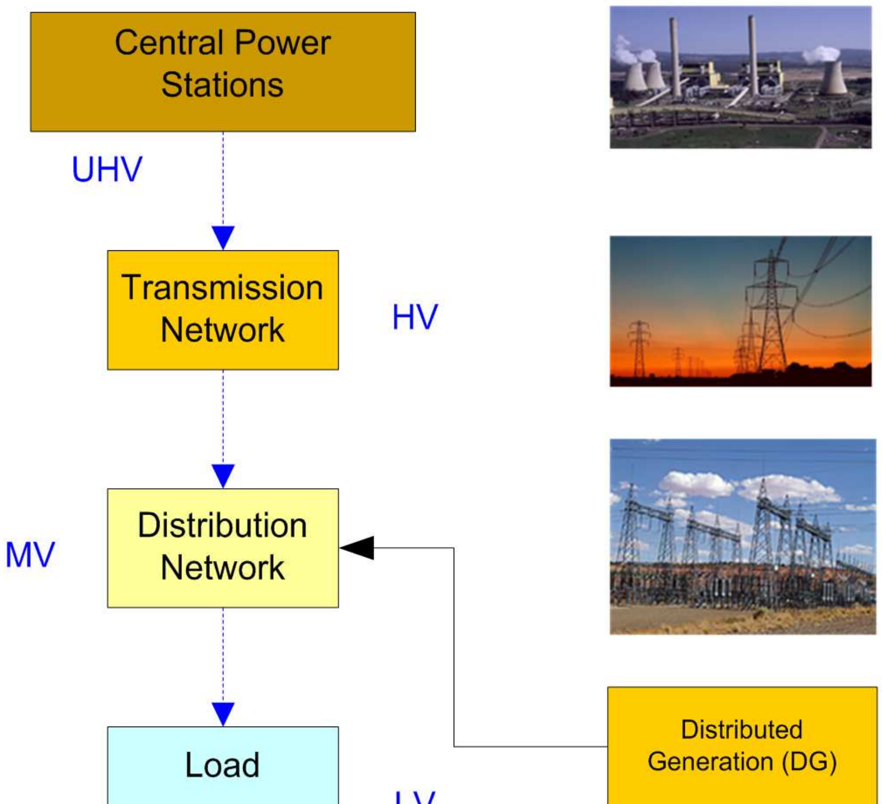
Introduction

- The concept of smart grid has been around for more than 8 years now
- Important for us is to understand what it really means with smart grid and how smart grid can contribute to national energy policy
- The question is what do we want from smart grid to do cost effectively
- One of the key features of smart grid concept, which is challenging, is involvement of the customers (customer engagement) in the process of current network structure
- The other aspect that smart grid is challenging very strongly is use of ICT at all levels

Grid Structure


Grid
Structure

Conventional Grid

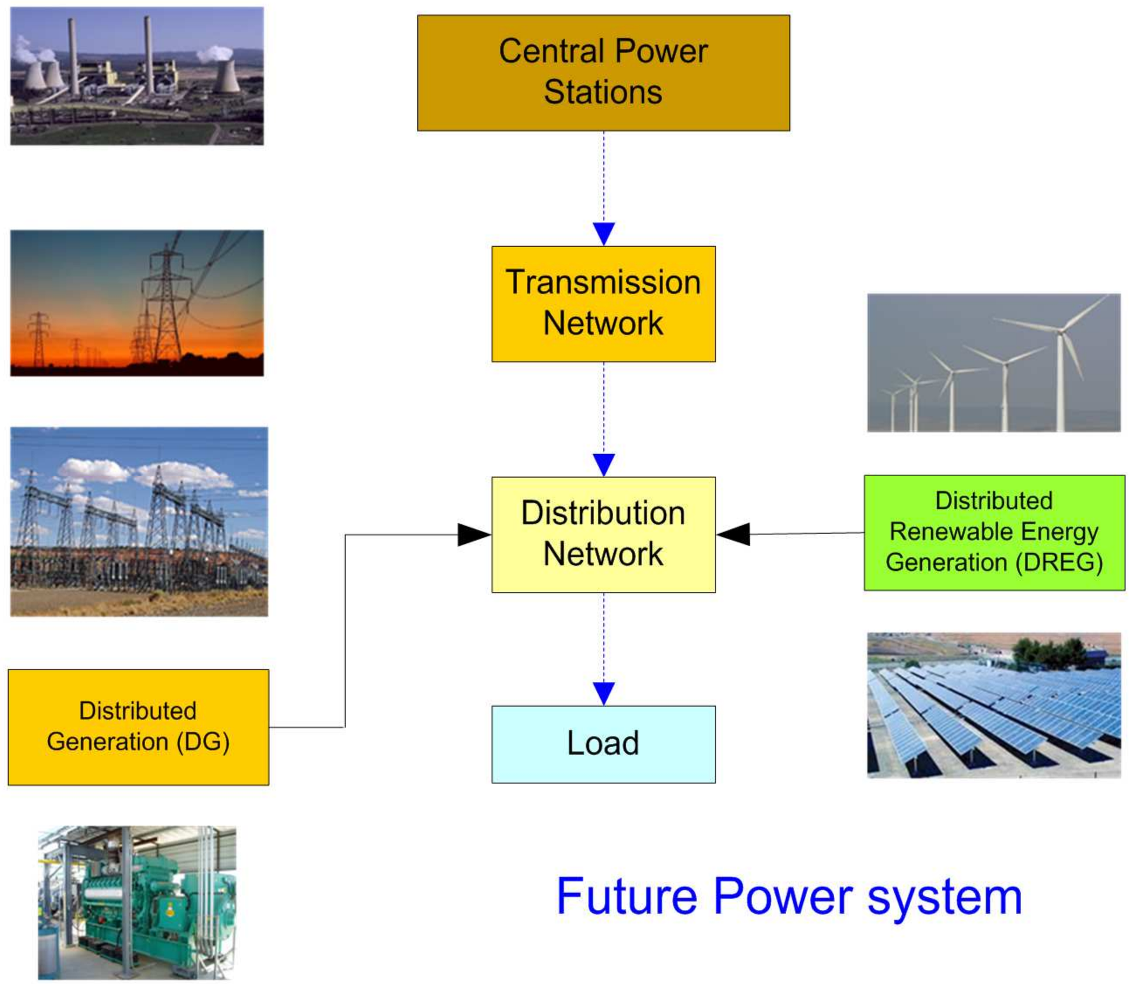


Conventional Power system

The traditional power networks can be described as:

- Centralized power generation
- Controllable generation, un-controllable loads
- Generation follows the load
- Power flows in only one direction
- Power system operation is mainly based on historical data and experience
- Overloads in the system is detected by the operators
- Rerouting of power flow in the case of overload is performed by the operators
- Utilities do not have sufficient information about the grid conditions
- High power loss
- Likely events of costly power blackout

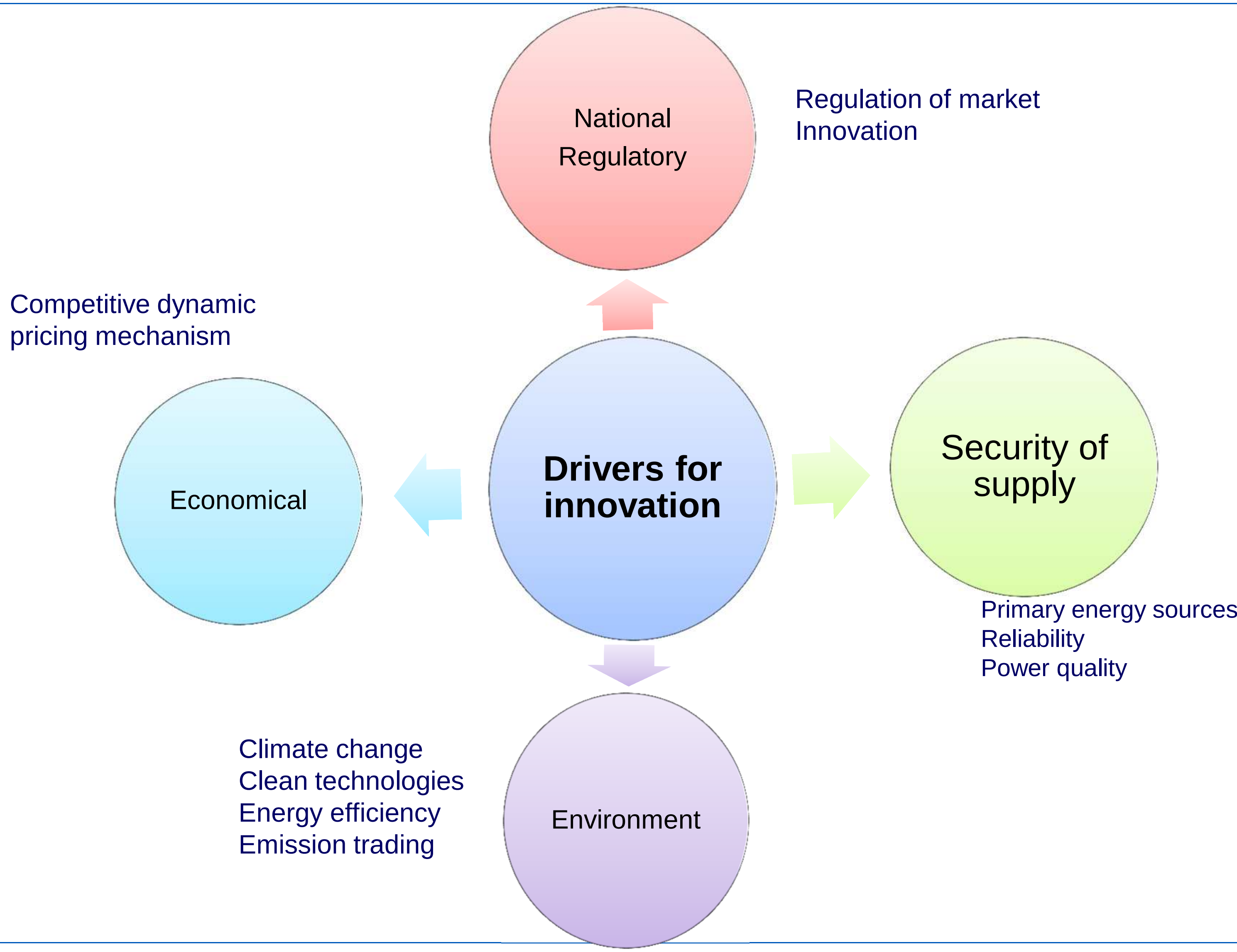
Future Grid



Future Power system

Innovations in Power Industry to make grid smarter

Innovation in and modernization of power grid is essential



Smart Grid

What is a Smart Grid

There is no uniform definition of smart grid.

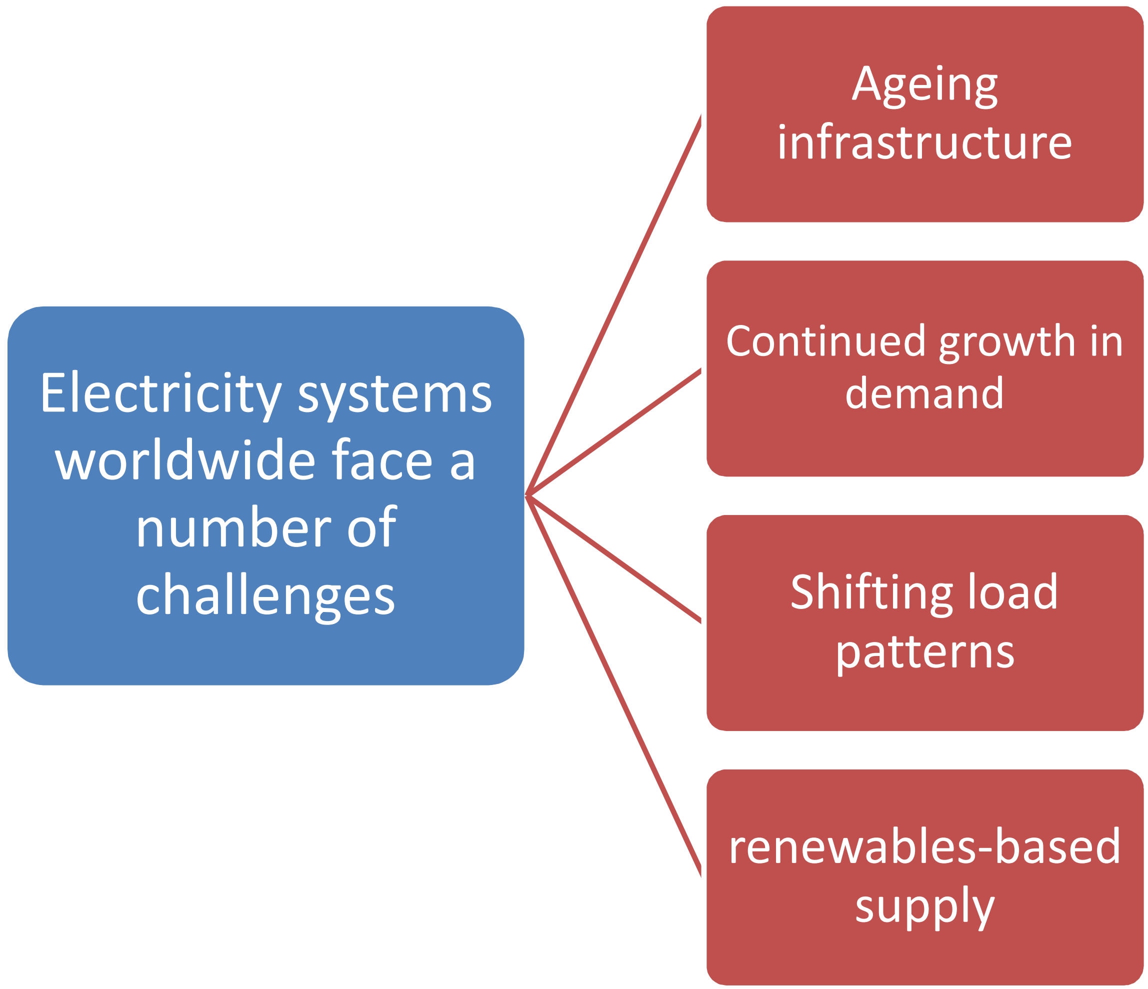
- According to the European Technology Platform, a Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it in order to efficiently deliver sustainable, economic and secure electricity supplies.

- According to the US Department of Energy, the Smart Grid is self-healing, enables active participation of consumers, accommodate all generation and storage options, enable introduction of new products, services and markets, optimize asset utilization and operate efficiently, provide reliable power quality for the digital economy.

- According to the Australian Government (DEWHA) smart grid combines advanced telecommunications and information technology applications with ‘smart’ appliances to enhance energy efficiency on the electricity power grid, in homes and in businesses

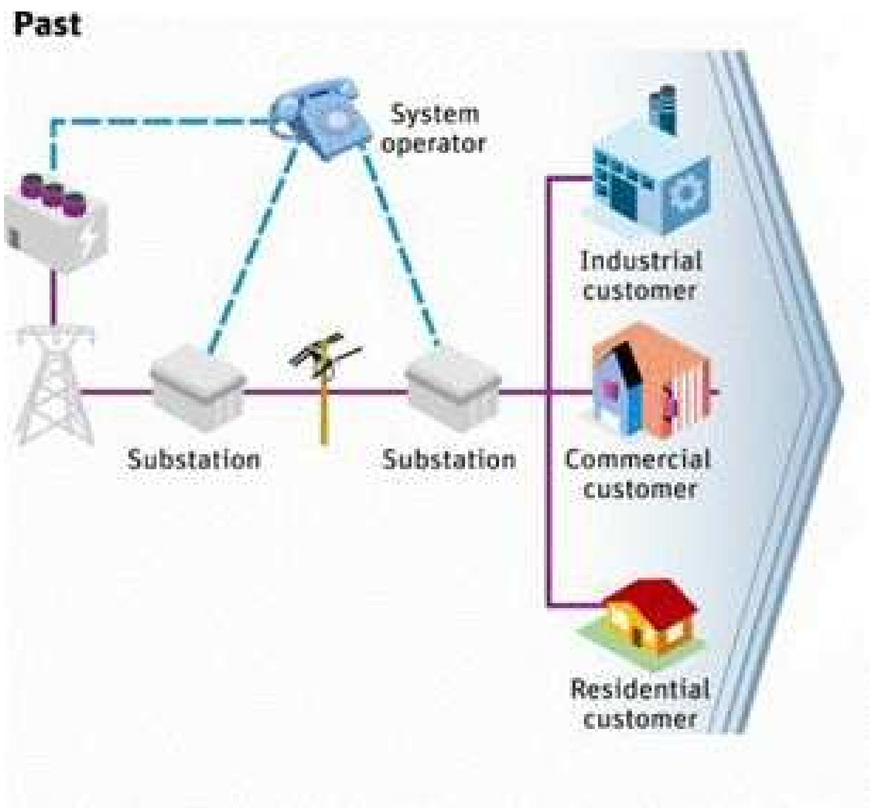
What we Expect from Smart Grid

Smart Grid



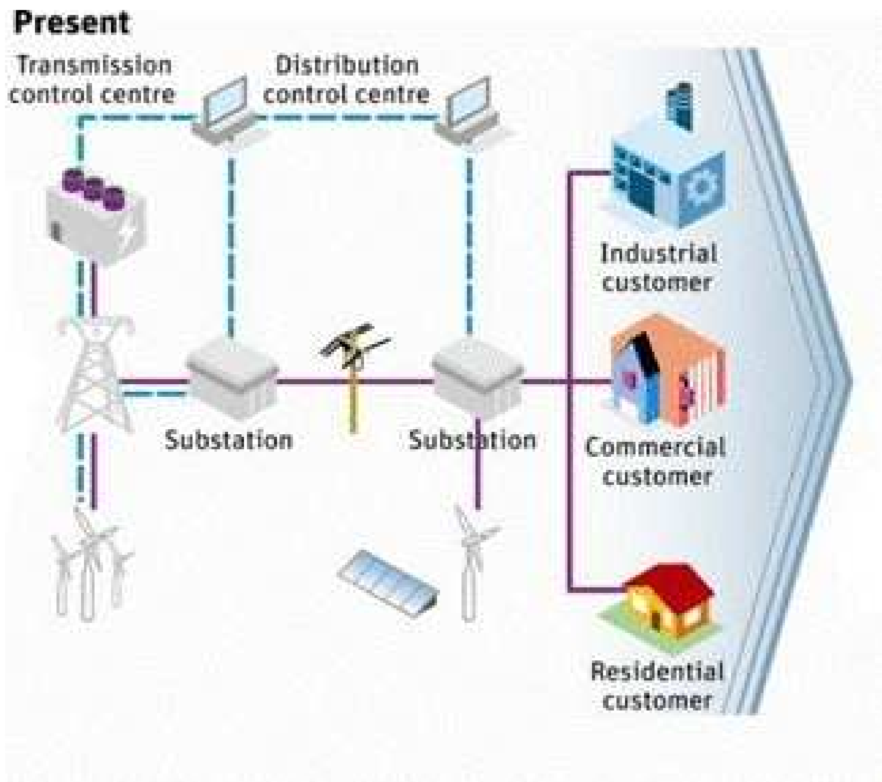
Electricity systems worldwide face a number of challenges
Ageing infrastructure
Continued growth in demand
Shifting load patterns
renewables-based supply

Past Grid



Source: IEA

Present Grid



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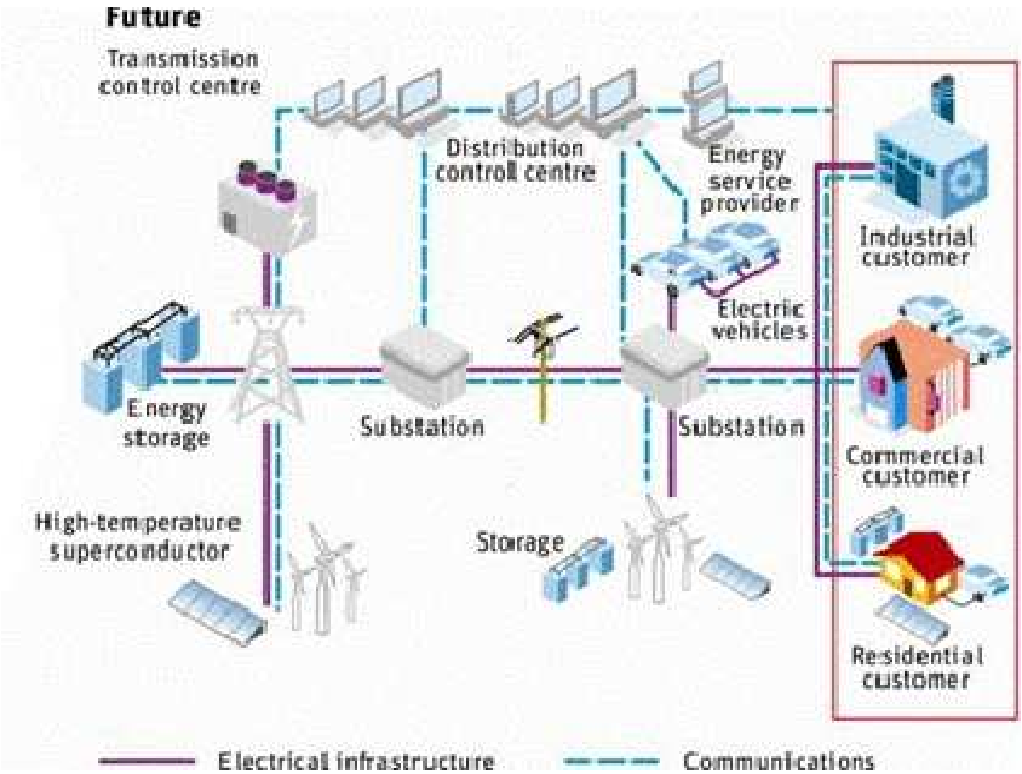
Future Grid



Source: IEA

Smart is to:

- Know exactly where a power failure happens and quickly to fix it
- Extend life of aging equipment
- Detect and minimising outages by sensing potential equipment failures
- Reducing power loss by using real-time data to match generation & demand
- Smooth power demand to take advantage of off-peak supply
- Maintain a sufficient, cost-effective power supply while managing GHG target
- Make it easier for consumers to use renewable energy sources
- Use meters that show consumers their energy use in real time
- Use variable pricing that allows consumers to choose off-peak energy
- Help customers to establish a “smart home” that turns appliances ON/OFF

Customers Benefits

Customer-side applications

Consumers can't be expected to manage what they can't measure or see (lack of visibility)

The Smart Grid overcomes this 'lack of energy invisibility', making real-time usage and pricing data available through:

- in-home displays
- online portals
- smart-phones
- Consumers can identify energy intensive appliances that they have

Demand management methods help consumers :

- to reduce energy use during peak time,
- slowing the need for investments in costly generation, transmission and distribution infrastructure,
- improving reliability, and reducing the overall cost of supply and etc.

Utilities

Benefits

Utilities-side benefits

Benefits of smart grid

- Better manage their grid
- Customers choice
- Understanding energy usage
- Reduce cost of electric .
- Comm. with appliances
- ….
- Renewable
- Integration of EV

Smart Grid

Self-healing

A self-healing grid uses digital components and real-time communications technologies installed throughout a grid to monitor the grid's electrical characteristics at all times and constantly tune itself so that it operates at an optimum state.

It has the intelligence to constantly look for potential problems caused by storms, catastrophes, human error or even sabotage. It will react to real or potential abnormalities within a fraction of a second.

The self-healing grid isolates problems immediately as they occur, before they snowball into major blackouts, and reorganizes the grid and reroutes energy transmissions so that services continue for all customers while the problem is physically repaired by line crews.

Smart Grid

Self-healing

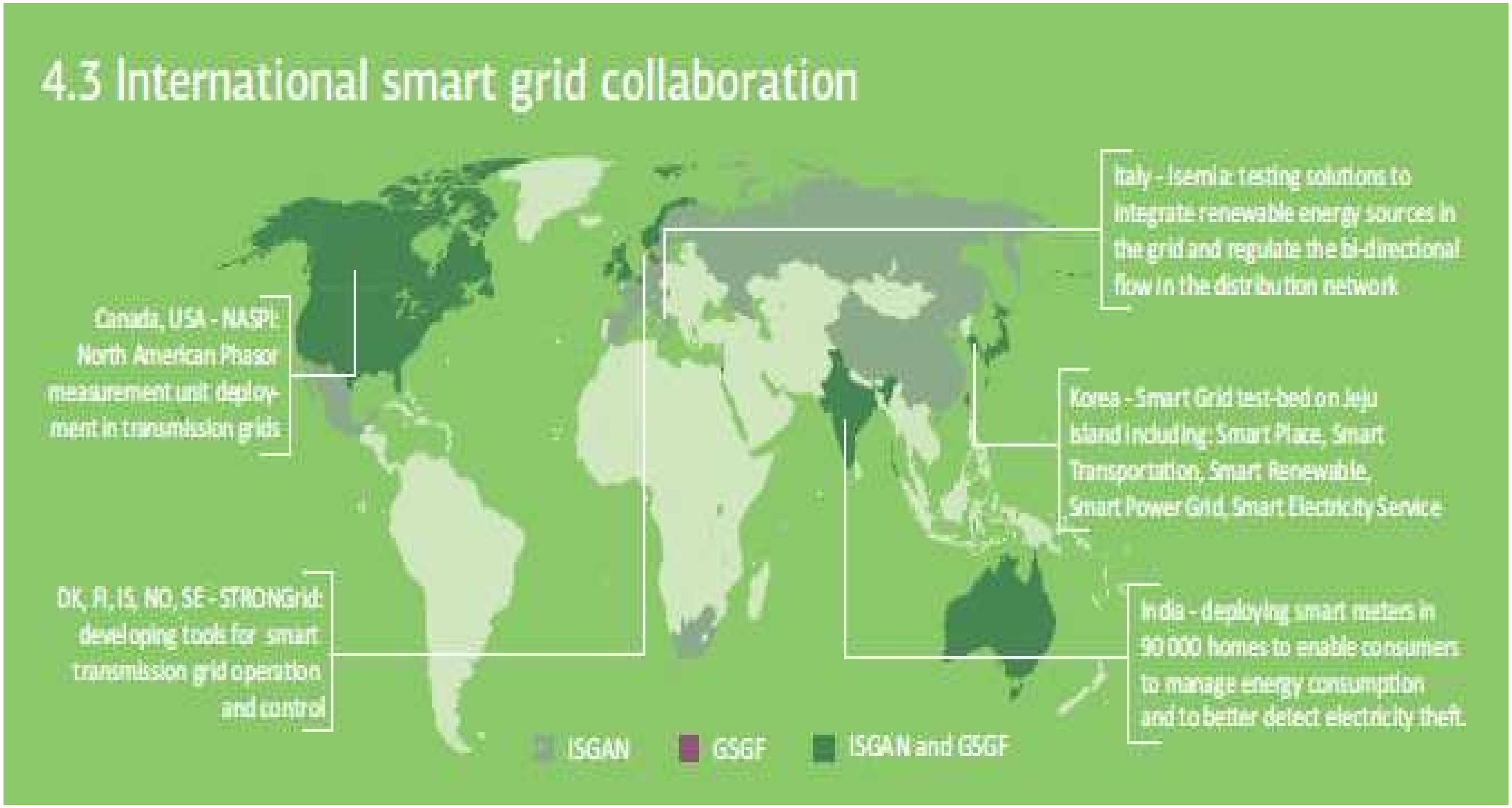
A self-healing smart grid can provide a number of benefits that lend to a more stable and efficient system. Three of its primary functions include:

- Real-time monitoring and reaction, which allows the system to constantly tune itself to an optimal state;
- Anticipation, which enables the system to automatically look for problems that could trigger larger disturbances; and
- Rapid isolation, which allows the system to isolate parts of the network that experience failure from the rest of the system to avoid the spread of disruption and enables a more rapid restoration

As a result of these functions, a self-healing smart grid system is able to reduce power outages and minimize their length when they do occur. The smart grid is able to detect abnormal signals, make adaptive reconfigurations and isolate disturbances, eliminating or minimizing electrical disturbances during storms or other catastrophes.

International Collaboration and Investment on Smart Grid

Smart Grid



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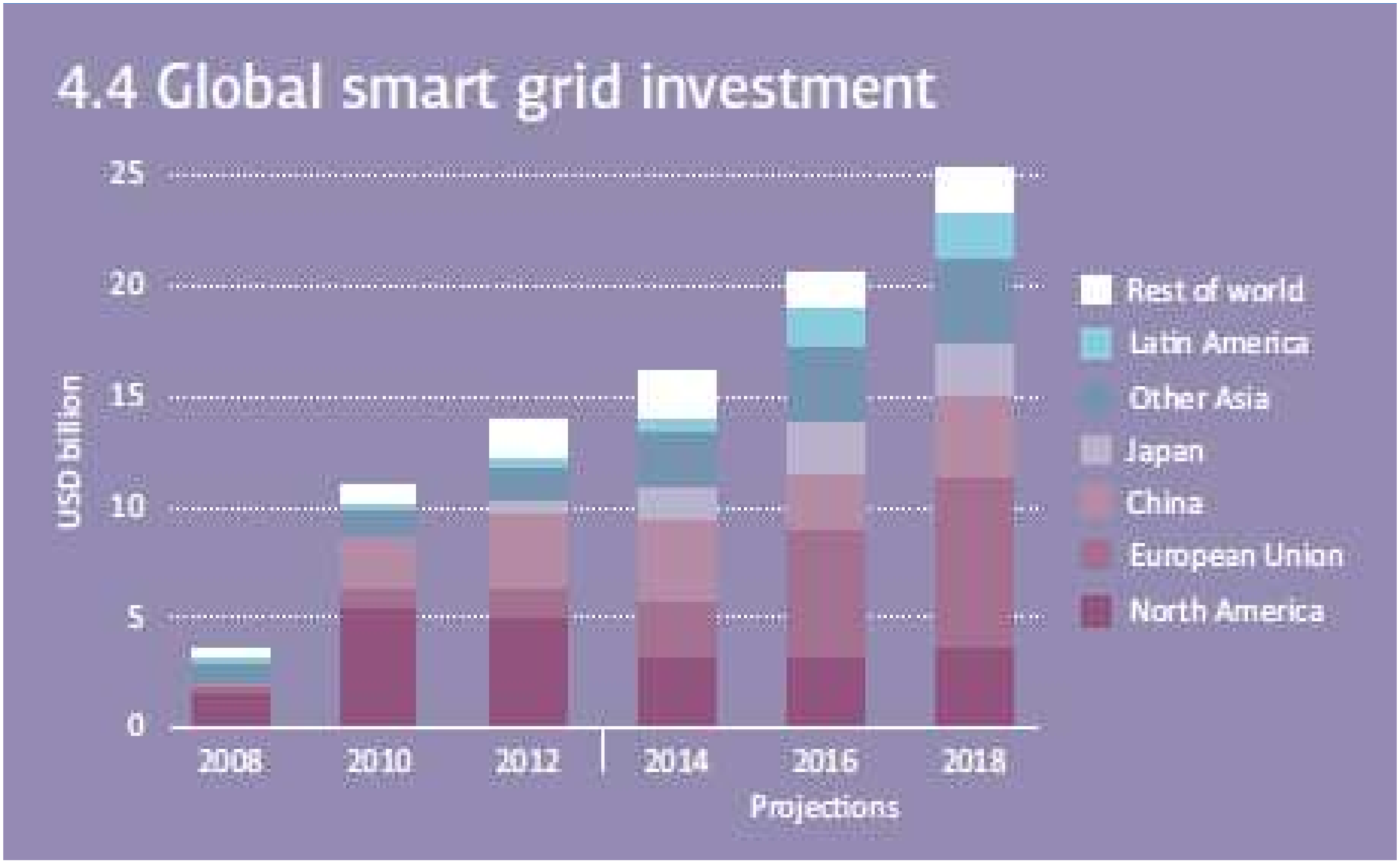
Smart Grid



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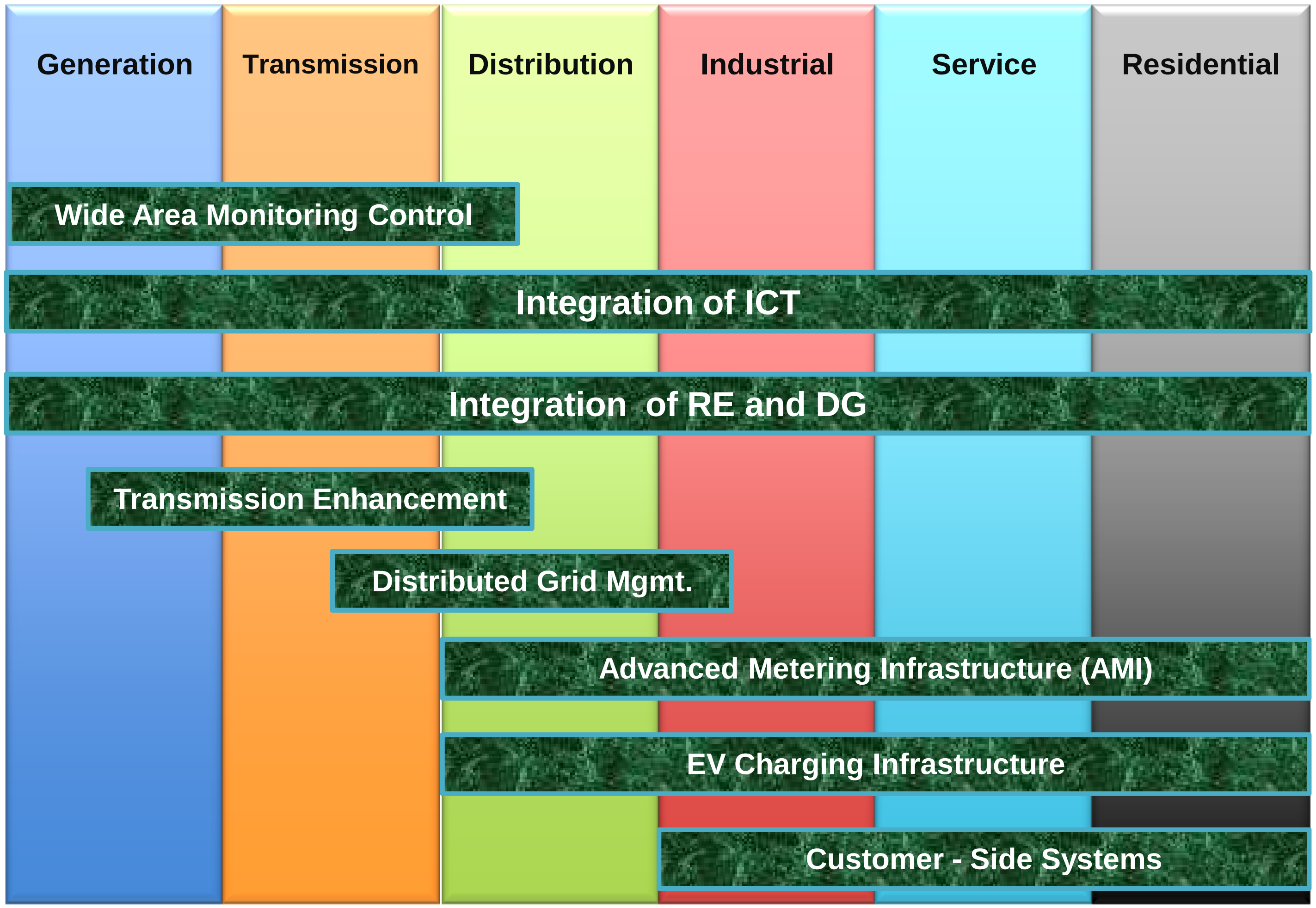
Principals of Smart Grid Technologies

Smart Grid Technologies



Electric Vehicle

An electric vehicle is defined in this talk as a vehicle with an electric battery than that can be charged from the network, i.e. plug-in hybrids and battery electric vehicles (V2H, V2G)

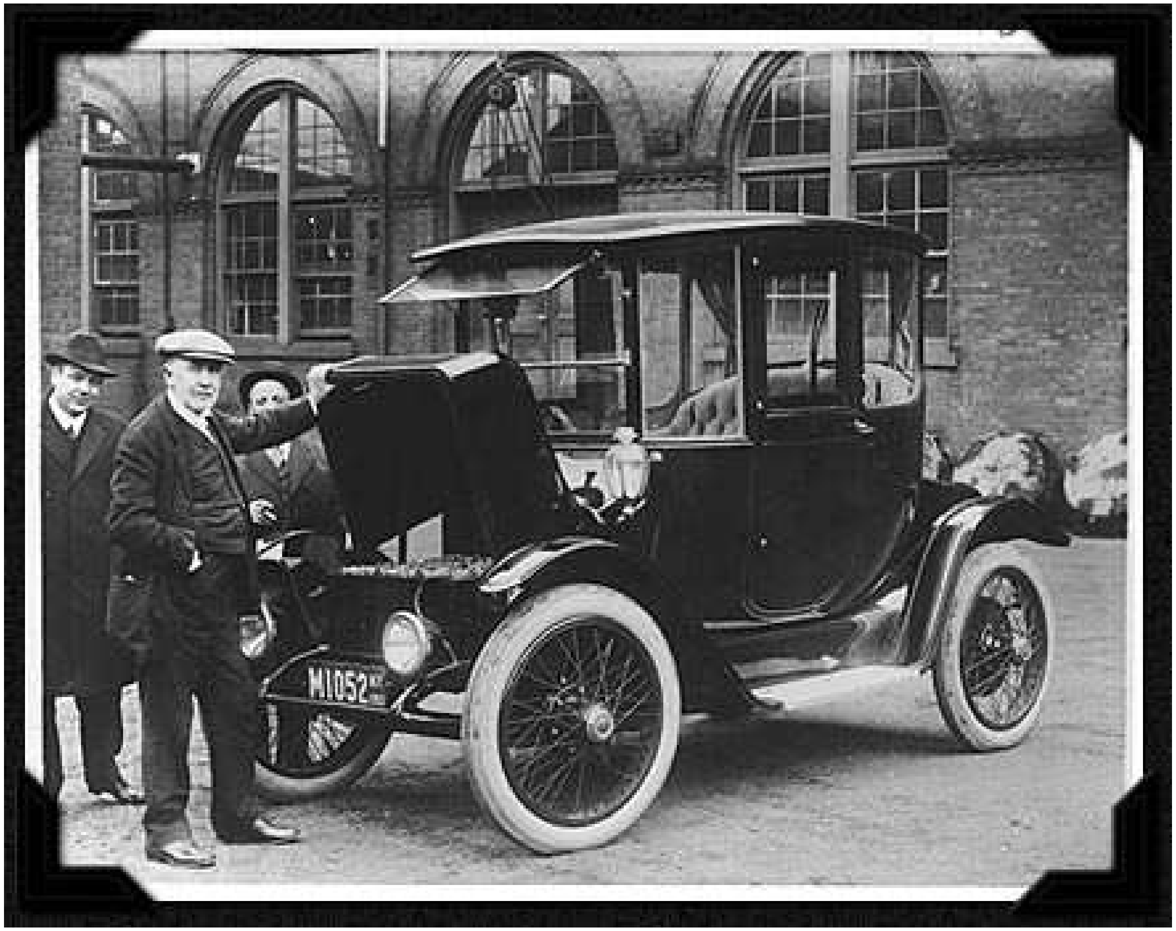
Electric Vehicle

The battery powered electric car has been around for more than 100 years. In 1900, out of a total of less than 4500 cars produced in the US, nearly 30 per cent were battery powered.

Electric Vehicle

German electric car, 1904, with the chauffeur on top

Electric Vehicle

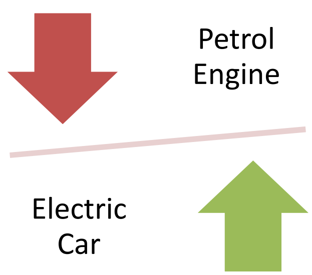


Thomas Edison and an electric car in 1913 (courtesy of the National Museum of American History)

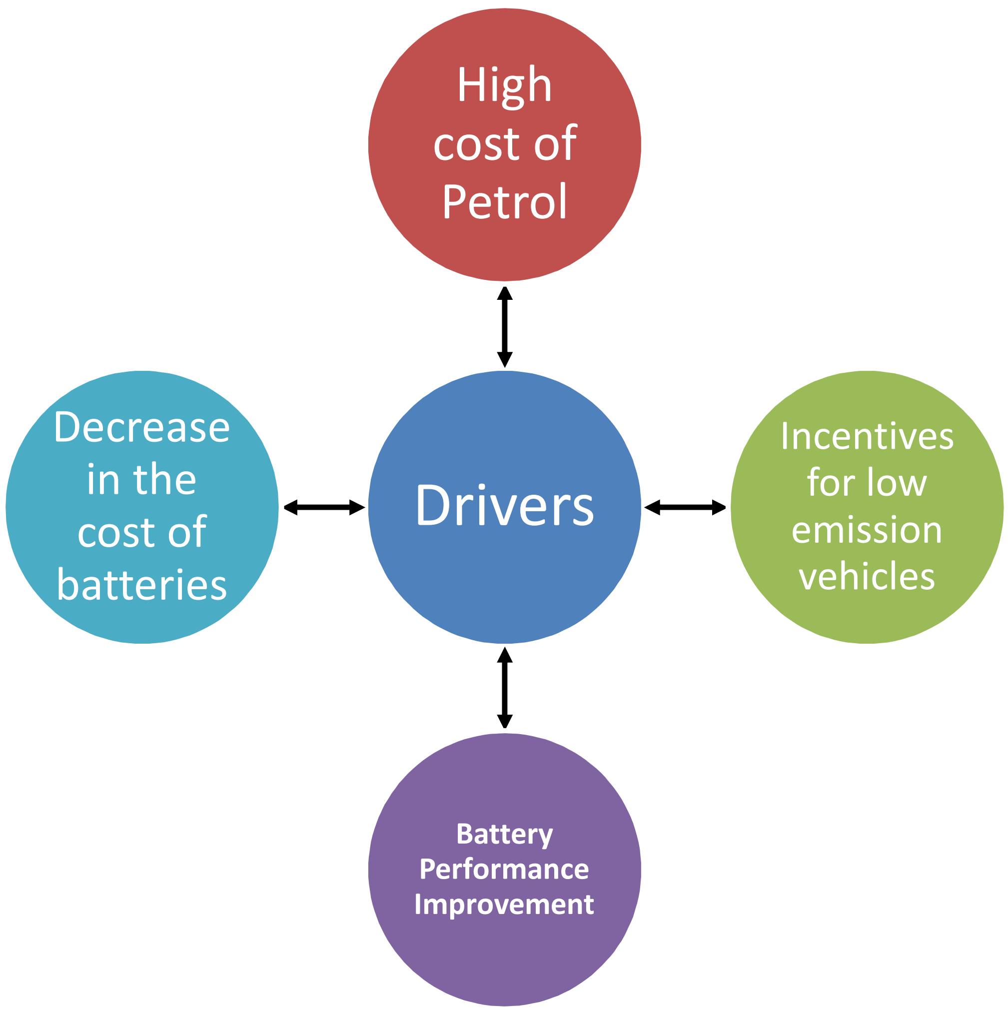
Electric Vehicle

EV was Overshadowed by Petrol Engine

- Availability of Gasoline
- Limited Range of EV



Electric Vehicle



Drivers leading to increased in the number of EVs on the world's roads

EV Historic Timeline

1859: Invention of Lead Acid Battery by Gaston Plante

1879: Thomas Edison installs Electric Lights in NYC popularising Electricity

1891: First Electric Vehicle is built in the USA

1897: First Commercial US Electric Vehicles. Electrobat Taxis hit the roads in NY

1933-45: German, French, and Dutch automakers sell a small range of EV spurred by gas shortage and WWII

1949-51: In japan, Tama Electric Motorcars sells and EV during a severe gas shortage

1960: Automakers experiment with EV, though none are widely adopted

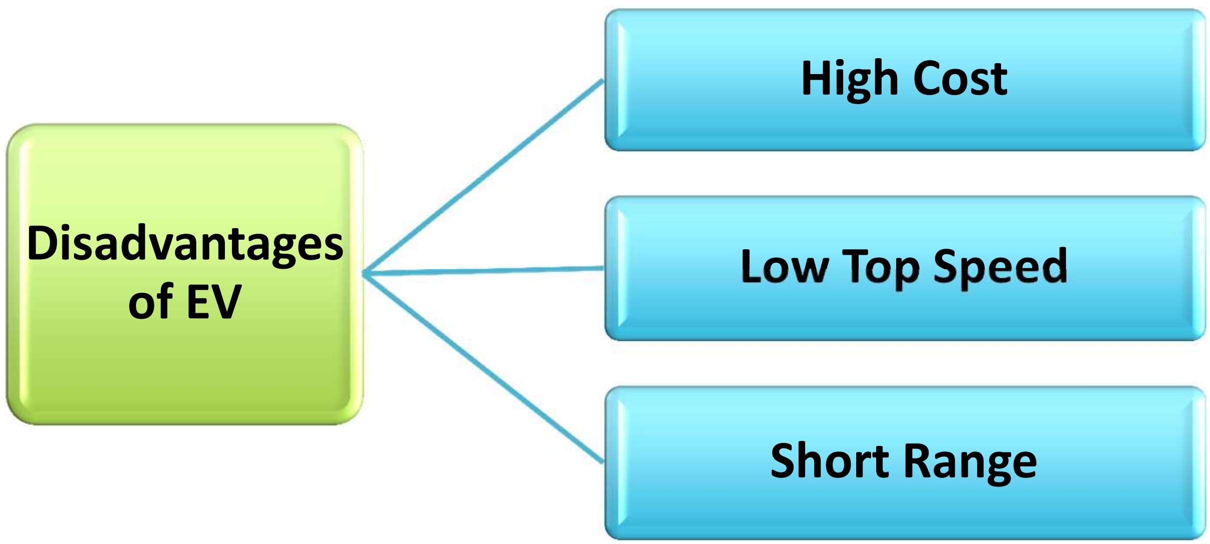
1996: General Motors begins leasing the EV1 one of several electric brands rolled out to meet California's Zero Emission rules

2010: Nissan Delivers first US customer the Leaf, an EV with 100 mile range, a lithium ion battery, and regenerative braking

2011: The Tesla Roadster electric sport car is offered. It has a range of 245 mile but cost over $100,000

Electric Vehicle

The disadvantages of EVs have been their high cost, low top speed and short range. Hybrid plug-in electric vehicles (HPEVs) using an electric battery in conjunction with a conventional internal combustion engine have been on the market for over 25 years. Developed in response to escalating fuel costs, they can be run on a charge-depleting mode (using the battery) or a charge-sustaining mode (using the fuel). Developments in battery technology have enabled auto manufacturers to develop pure plug-in electric vehicles (PEVs), of which an increasing number are on the market. EVs are more energy-efficient than conventional vehicles and dramatically cut CO_2 emissions.

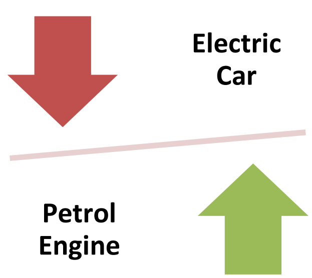


Electric Vehicle

In 1990s the EV came back

Because

- **Rising Petrol Cost**
- **Advancement of Battery Technology**
- **Need to Reduce Emissions**



Electric Vehicle

The first Nissan Leaf delivered in the U.S in 2010
Also available in Australia

Electric Vehicle

Electric Vehicle

A solar-powered public EV charging station made by Honda Japan, in order to conduct a range of tests on electric vehicles in real-world urban transportation environments

Electric Vehicle

Jersey UK-EV
Very low running costs
Low environmental impact
Quiet and emission free
Low maintenance

Electric Vehicle

E6 Electric Car by BYD, China's biggest battery maker, and that gives them an edge over most automakers when it comes to electric cars (the battery's always the big challenge)

Electric Vehicle

Overview	
Manufacturer	BYD Auto
Body and chassis	
Class	Electric MPV
Body style	5-door hatchback
Powertrain	
Electric motor	One or two permanent magnetsynchronous motors
Battery	75 kW·h ($LiFePO_4$)
Range	195 km (121 mi)
Dimensions	
Wheelbase	2,830 mm (111.4 in)
Length	4,554 mm (179.3 in)
Width	1,822 mm (71.7 in)
Height	1,630 mm (64.2 in)
Curb weight	2,020 kg (4,453 lb)

Electric Vehicle

The "Tesla Roadster", the popular electric car which does not use gasoline, is named after the father of Alternating Current - Nikola Tesla

Electric Vehicle

Overview	
Manufacturer	Tesla Motors
Also called	Code name: DarkStar[1]
Production	2008–2012
Assembly	Hethel, Norfolk, England, Menlo Park, California, USA
Designer	Tesla Motors
Body and chassis	
Class	Roadster
Body style	2-door Roadster
Layout	Rear mid-engine, rear-wheel drive
Related	Lotus Elise
Powertrain	
Electric motor	*1.5, 2.0* : 248 hp (185 kW), 200·lb·ft/s (270 N·m), 3-phase 4-pole; *2.5 Non-Sport* : 288 hp (215 kW), 273·lb·ft (370 N·m), 3-phase 4-pole; *2.5 Sport* : 288 hp (215 kW), 295·lb·ft (400 N·m), 3-phase 4-pole AC induction motor[2]
Transmission	Single speed BorgWarner fixed gear (8.27:1 ratio)
Battery	53 kWh (Lithium-ion battery at the pack level: 117 Wh/kg and 37 Wh/L)
Electric range	244 mi (393 km) using EPA combined cycle

Electric Vehicle

Tesla Roadster recharging from a conventional outlet

Electric Vehicle

The Mitsubishi i-MiEV was launched in Japan in 2009

Electric Vehicle

GM EM1: 3-phase AC induction electric motor, Lead Acid or NiMH batteries

Electric Vehicle

Nissan Leaf

Electric Vehicle

Nissan Leaf Powertrain	
Electric motor	80 kW (110 hp), 280 N·m (210 ft·lb) synchronous motor
Transmission	Single speed constant ratio (7.94:1)
Battery	24 kW·h lithium ion battery
Range	**2011/12 models** 117 km (73 mi) EPA, 175 km (109 mi) NEDC **2013 model** 121 km (75 mi) EPA 135 km (84 mi) EPA range at 100% charge 200 km (120 mi) NEDC 106 km (66 mi) Long-Life Mode (Nissan)
Plug-in charging	3.3 kW and optional 6.6 kW 240 V AC on SAE J1772-2009 inlet, max 44 kW 480 V DC on Chademo inlet, adapters for domestic AC sockets (110-240 V)

Electric Vehicle

BMW I3

Electric Vehicle

BMW I3 Powertrain	
Engine	25 kW 647 cc, two-cylinder generator, with a 9-liter fuel tank (optional)
Electric motor	130 kW (170 hp)
Transmission	Automatic, single speed with fixed ratio
Battery	22 kWh lithium-ion battery
Range	130 to 160 km (80 to 100 mi) with range extender 240 to 300 km (150 to 190 mi) (BMW)
Plug-in charging	7.4 kW on-board charger on IEC Combo AC, optional Combo DC

Electric Vehicle

Name	Production Year
Baker Electric	1899–1915
Chevrolet S10 EV	1997–1998
Detroit Electric	1907–1939
Ford Ranger EV	1998–2002
General Motors EV1	1996–2003
Henney Kilowatt	1958–1960
Honda EV Plus	1997–1999
Mitsubishi i MiEV	**2009–**
Nissan Leaf	**2010–**
REVA (Indian Electric Vehicles)	**2001–**
Tesla Model S	**2012–**
Tesla Roadster	2008–2012
TH!NK City	1999–2002
Toyota RAV4 EV	1997–2002
ZAP Xebra	2006–2009
Škoda Favorit ELTRA 151L & 151 Pick-Up	1992–1994

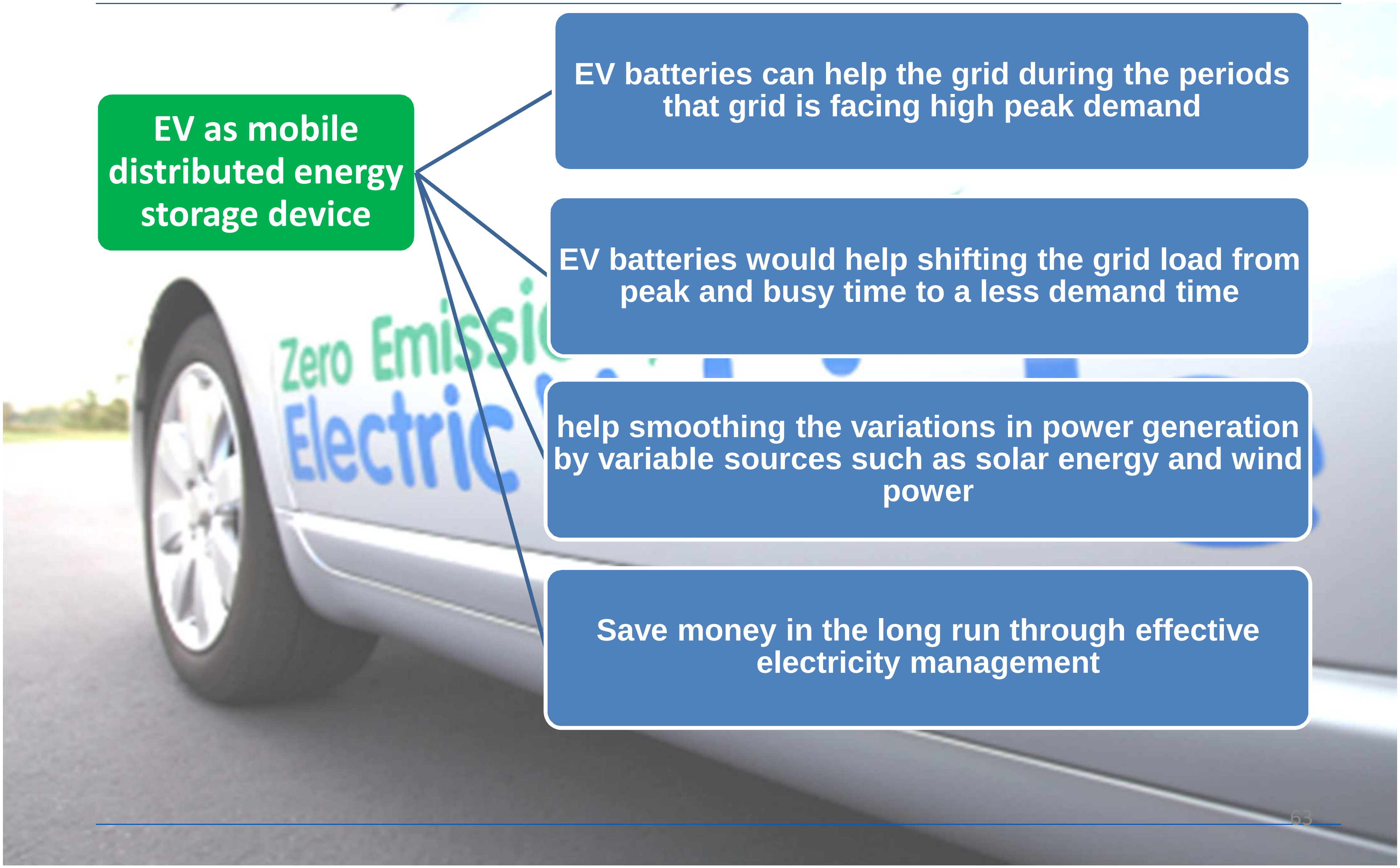
EV Battery for Smart Grid

Benefits of EV battery storage

From grid point of view the EV is considered as an electrical device representing a new demand for electricity during the periods that EVs need to be charged, but they can play a role of storage device that could supply electric power back to the grid.

Through an effective communication with the grid, EV battery can be used as a storage device that can make the electricity grid more reliable especially with large proportion of renewable sources such as grid-connected solar and wind.

Benefits of EV battery storage

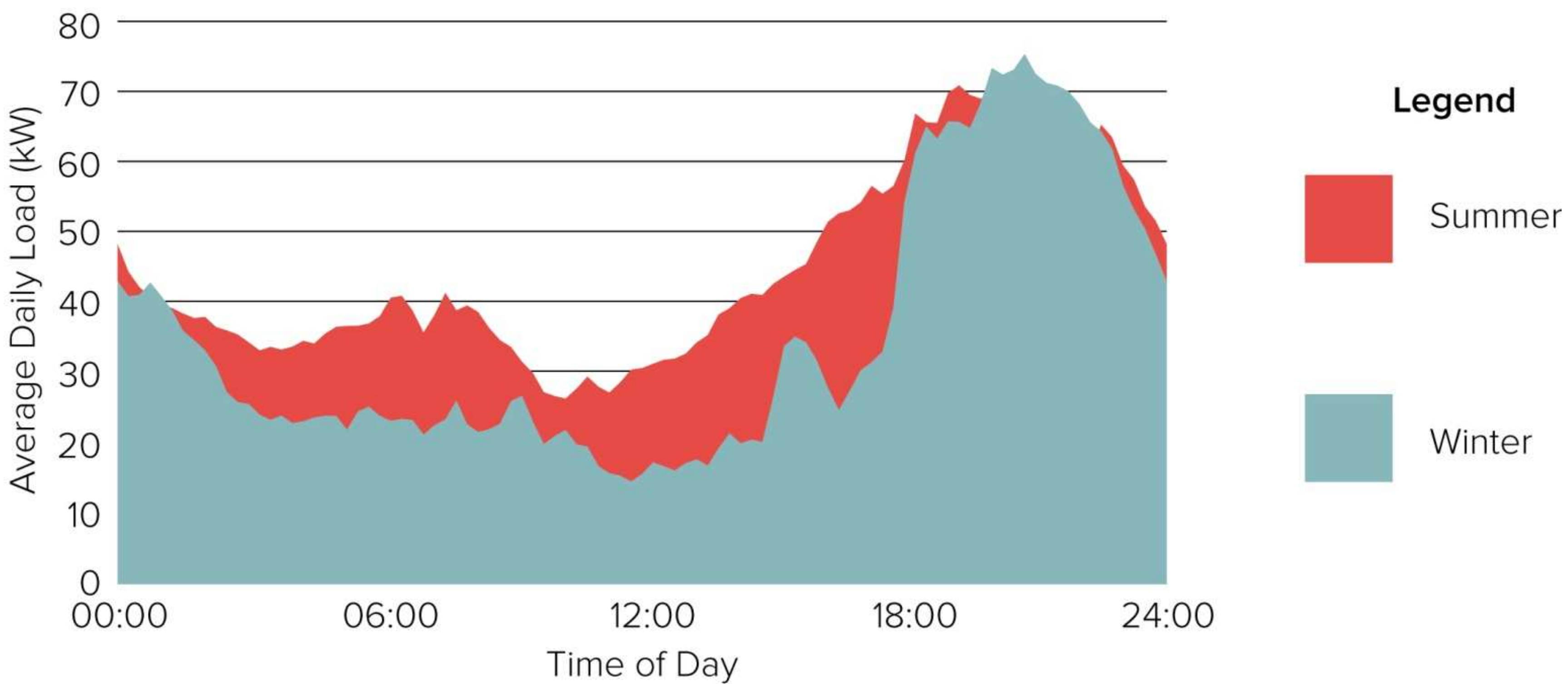


EV as mobile distributed energy storage device

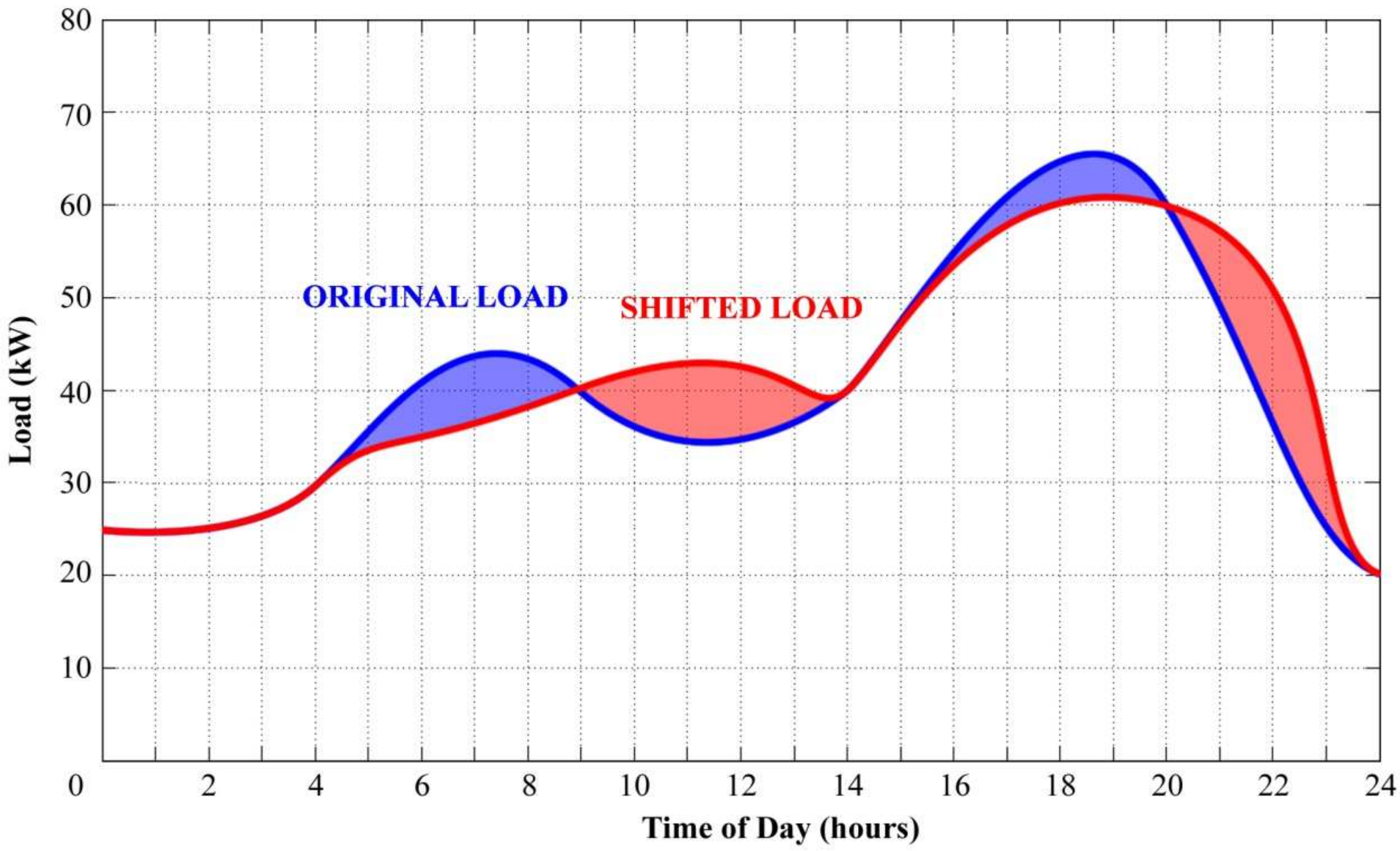
- EV batteries can help the grid during the periods that grid is facing high peak demand
- EV batteries would help shifting the grid load from peak and busy time to a less demand time
- help smoothing the variations in power generation by variable sources such as solar energy and wind power
- Save money in the long run through effective electricity management

Important Role of EV Batteries

Important role of storage in power system



Important role of storage in power system



Challenges

- Cost
- Range Limitation
- Safety and Reliability
- Progress Through R&D
- Driving Adoption Through Education

Opportunities

Opportunities

- Government funding for research will be helpful for technology advancement and cost reduction
- *International RD&D cooperation and coordination can help address common areas of need, accelerate technological breakthroughs*
- *Consumer education campaigns and clear fuel economy labelling can help enhancing public awareness*
- *Etc.*

Research Questions

Research Questions

Research questions:

- How significant is impact of charging and discharging of EVs on electricity demand, specifically in regional areas?
- Is the existing distribution network infrastructure capable of handling the increase in demand associated with widespread EV uptake?
- What is the best method of charge management to cope with the increase in electricity demand?
- How will the extended range of new EVs, such as Tesla and Nissan leaf, impact on customers charging behaviour?
- What costs can be expected for consumers charging EVs on existing distribution networks? And as a consequence, how will the consumer’s ability to exploit time of use rates affect electricity demand?
- What benefits can ‘smart’ technology provide in reducing the impact of EV charging?
- Understanding vehicle use profiles, EV benefits, and battery life challenges
- Integrating renewable resources (solar and wind) with vehicle charging
- Developing and testing grid interoperability standards
- Exploring grid services technology opportunities

Research Questions

Research questions (cont.):

- Wireless Technologies for communications and control of EV systems
- Monitoring and sense-and-control of charging
- Software systems for EV energy management
- Smart Charging Infrastructure
- EV Fleet management technologies and services
- V2G and V2H
- Smart charging infrastructure and scalability
- Environmental issues and benefits
- Energy management
- Role of renewables in EV integration, especially Solar and Wind
- Power quality, reliability, and, stability effects as a result of EVs
- Customer Adoption, Customer Behaviour and Customer Response
- Pricing models for charging stations, roaming across territories

Conclusions

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Considering EV batteries as distributed storage in smart grid environment

Some of technical issues that we need to deal with:

- **Energy management and control strategy in integrating EV into the grid is the key to using EV as distributed storage and needed to be carefully examined**
- **We need to understand the control and management issues when thousands of people plug-in their EV to a grid**
- **We need to realize that at some point during the day, the local utility might experience a deficit of electricity**
- **Before begin charging, the EV batteries need to communicate with the utility to determine if there is spare capacity in the system to begin charging the batteries, so we need an intelligent inverter**

Our network - now

Courtesy of Ian McLeod, Ergon CEO

Our network - future

Courtesy of Ian McLeod, Ergon CEO

Thank you