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Electrical Vehicles Long-Term Forecast

Friday 4.7.2025 at 9:00 AM

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Content

- Types of Electric Vehicles and World Wide Statistics.
- Methods of EV Charging (Unmanaged, V1G, V2G)
- Main Inputs for EV Forecast.
- International Trends for EVs Share of Fleet
- Total Cost of Ownership.
- Yearly Projection of EVs.
- EV Energy and Peak Power Forecast.

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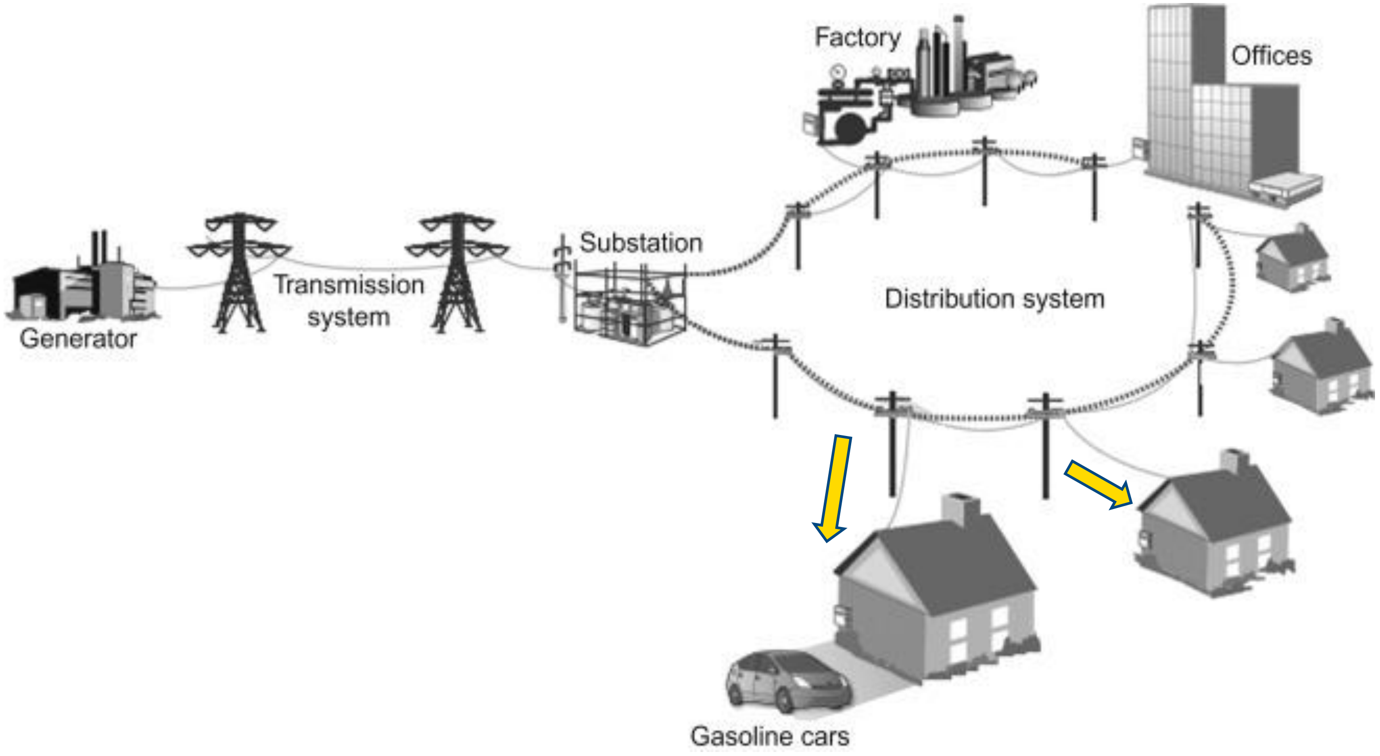
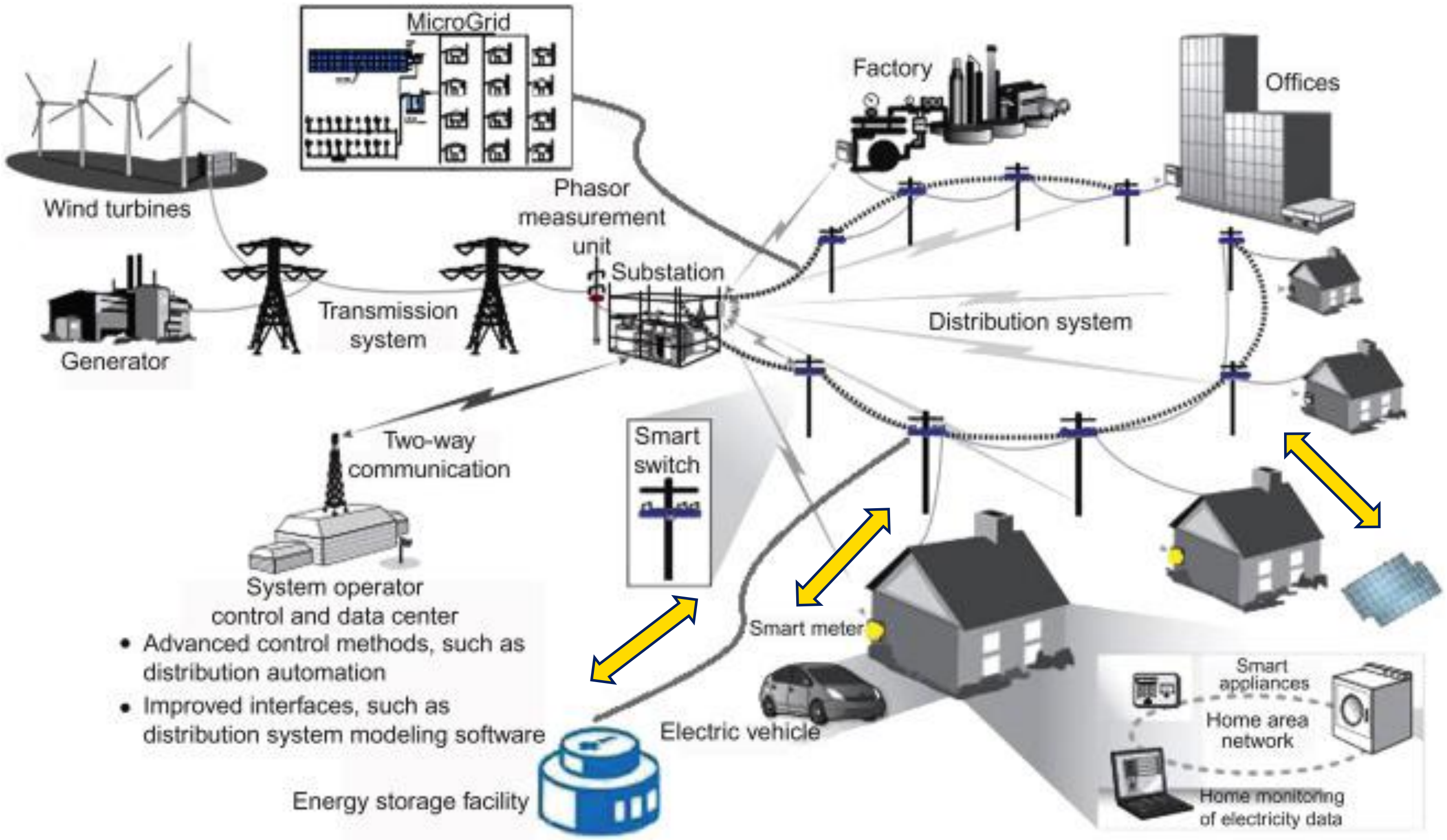
Conventional Distribution Networks



- Unidirectional way energy flow form distribution network to the load.
- With lees distributed energy recourses.
- With traditional Internal combustion engine cars

https://www.sciencedirect.com/topics/computer-science/conventional-grid

Modern Distribution Networks

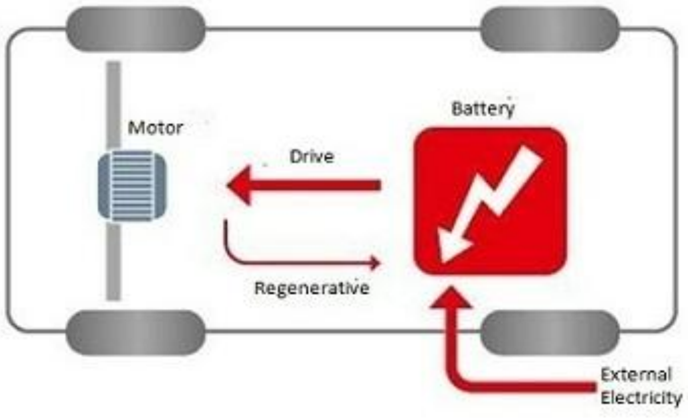


- Bidirectional energy flow for distribution network to the load and Vice-Versa.
- With more integration of distributed energy recourses (DERs)
- With more connection to the electrical vehicles (EVs), V1G, and V2G.

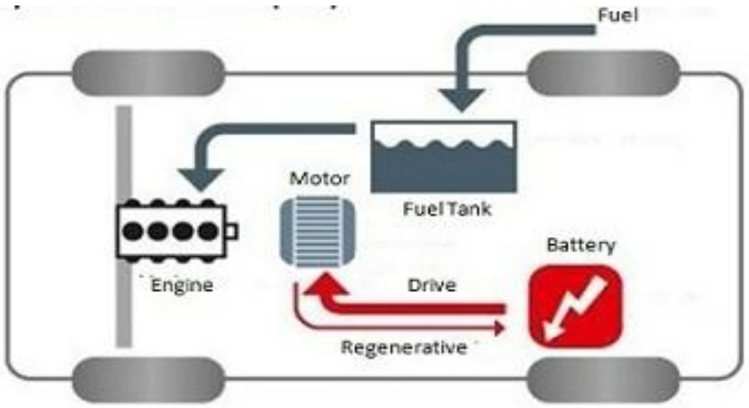
https://www.sciencedirect.com/topics/computer-science/conventional-grid

Types of Electric Vehicles

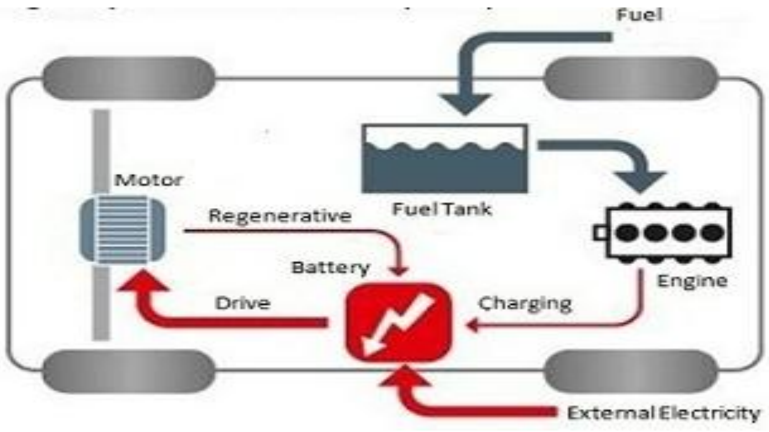
1- Battery Electric Vehicles (BEVs)



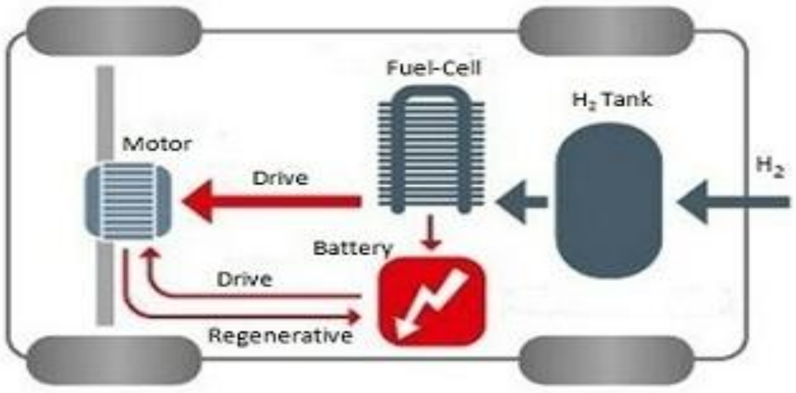
2- Hybrid Electric Vehicle (HEV)



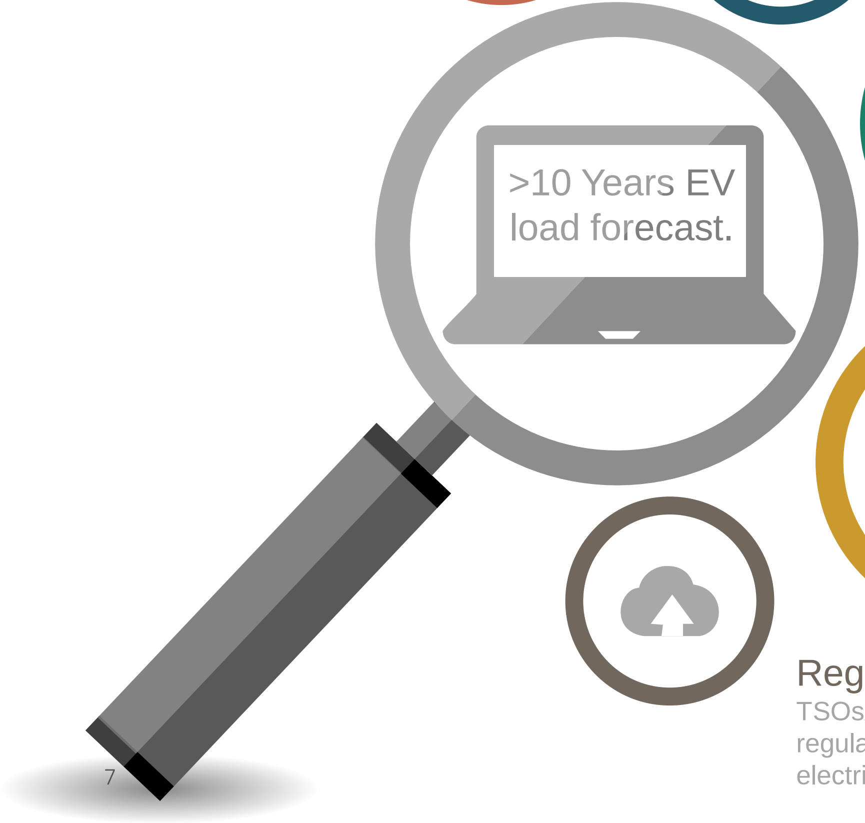
3- Plug-in Hybrid Electric Vehicle (PHEV)



4. Fuel Cell Electric Vehicle(FCEV)



Why Long term EV Forecast is Essential for Grid Planners?



Grid Capacity Planning.
To plan reinforcements in transmission lines, substations, and distribution networks.

Investment Timing.
Ensures timely and cost-effective investments for infrastructure upgrades (e.g. transformers, cables).

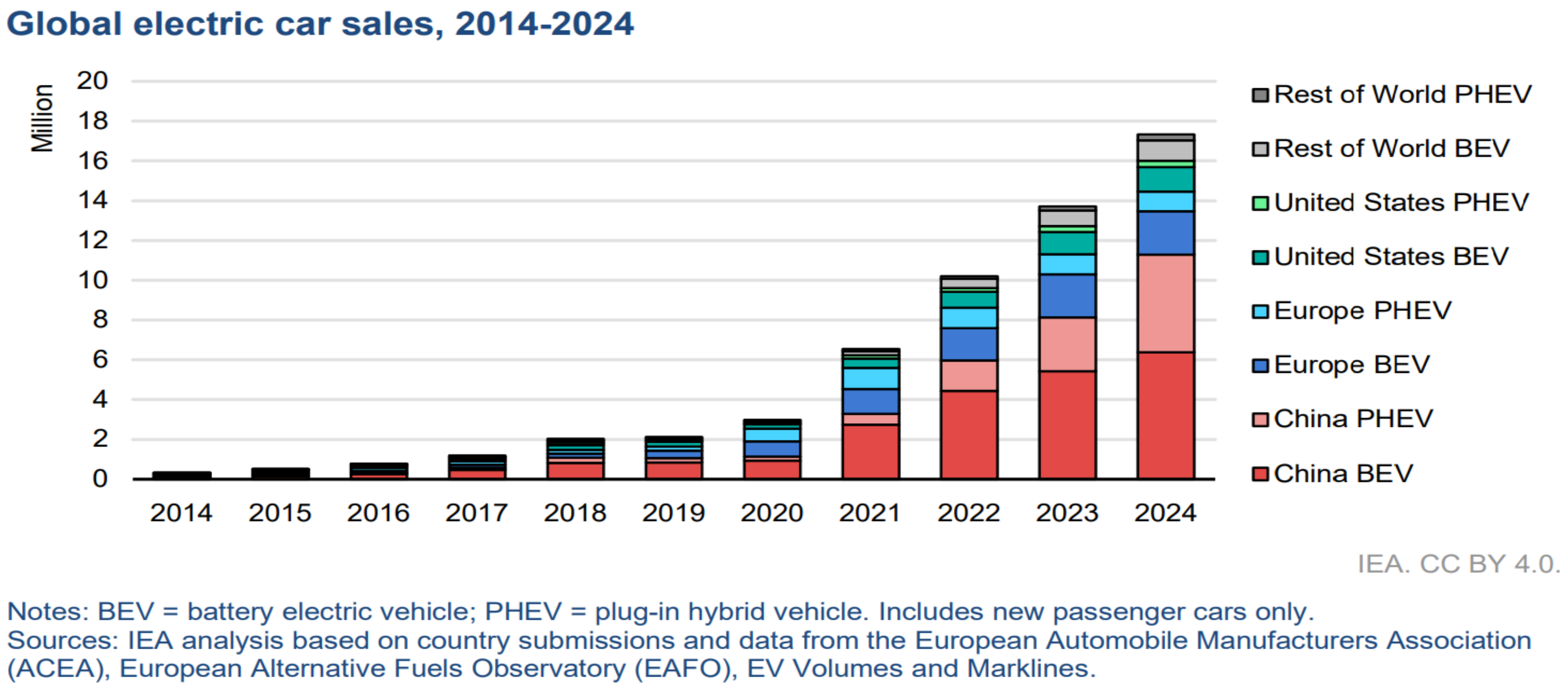
System Reliability.
Maintain grid stability as EV charging increases overall and peak demand.

Integration of Renewables.
EVs can act as flexible loads or storage. Forecasting supports aligning EV demand with variable RES generation.

Regulatory and Market.
TSOs/DSOs use forecasts to inform regulatory bodies and shape future electricity market structures and tariffs.

Global electric car sales exceeded 17 million in 2024

Additional 3.5 million cars sold in 2024 compared to 2023



Source: IEA Global EV Outlook 2025

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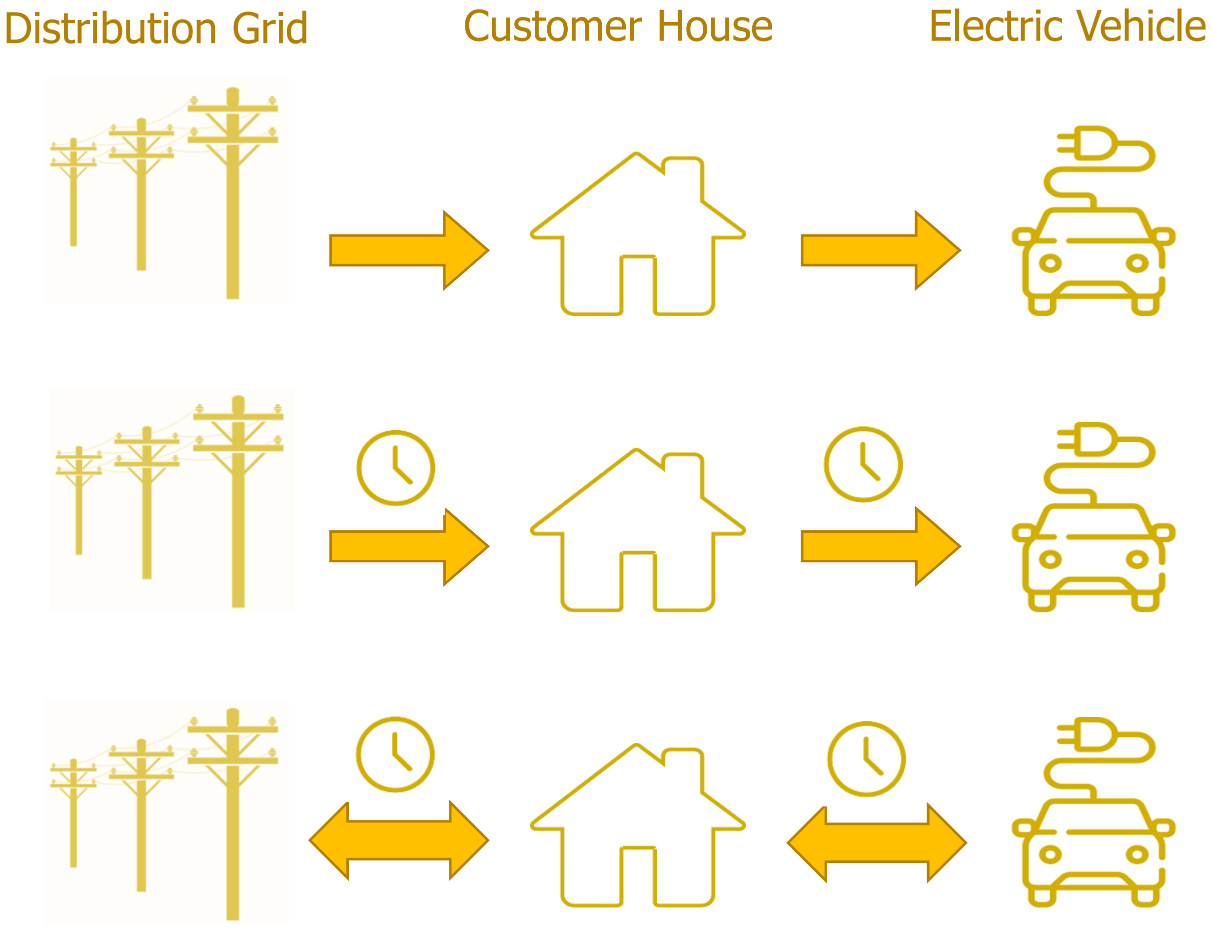
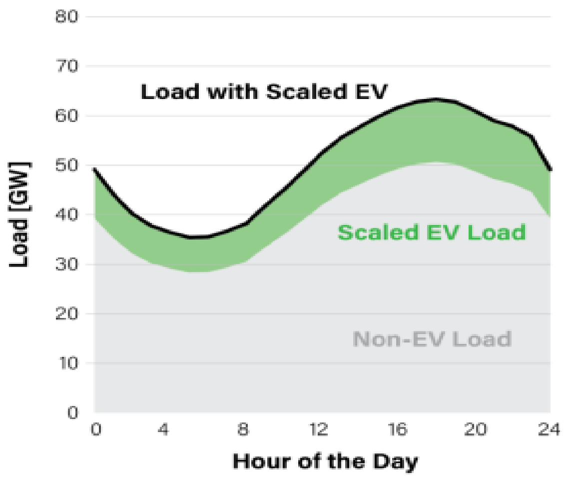
Methods of EV Charging in Smart Grid

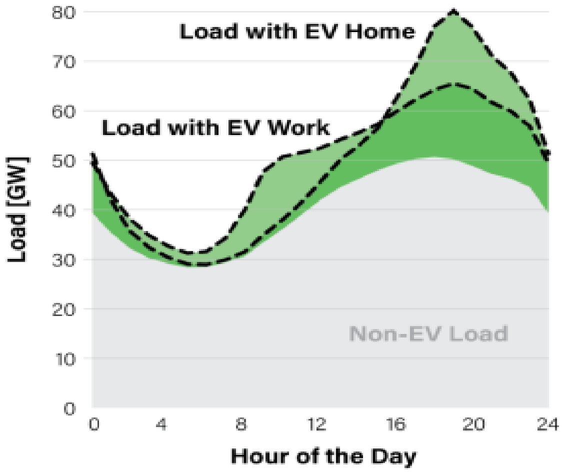


- ❑ Unmanaged.
  - ✓ Unmanaged time of charge
- ❑ Grid-to-vehicle (V1G).
  - ✓ Managed Charging in a specific time.
- ❑ Vehicle-to-grid (V2G).
  - ✓ Charge from/to Grid.

EVs as a flexible load

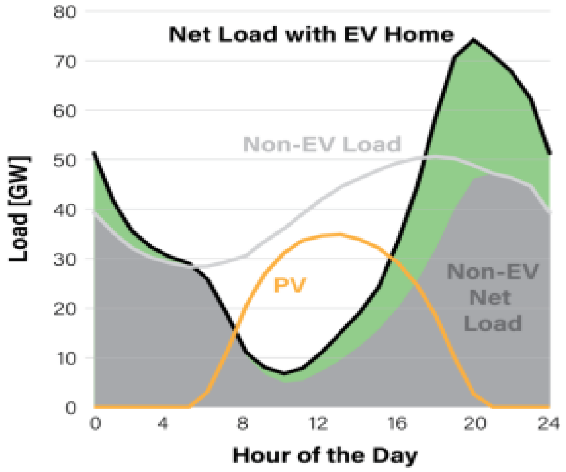
a) ASSUMPTION:
EV charging is often assumed to simply scale up electricity demand.

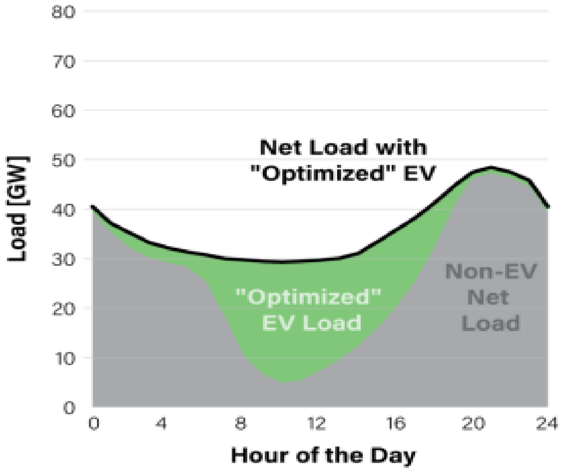




b) COMPLEXITY:
Future EV charging could change the shape of demand, depending on when and where charging occurs.

c) INTEGRATION:
EV charging can impact power system planning and operations, particularly with high shares of variable renewable energy.





d) FLEXIBILITY:
Optimizing EV charging timing and location could add flexibility to help balance generation and demand.

National Renewable Energy Laboratory (NREL)

[1] Electric Vehicle Adoption & Infrastructure Analysis Eric Wood, NREL – December 2022

Source: *Muratori and Mai, The Shape of Electrified Transportation*

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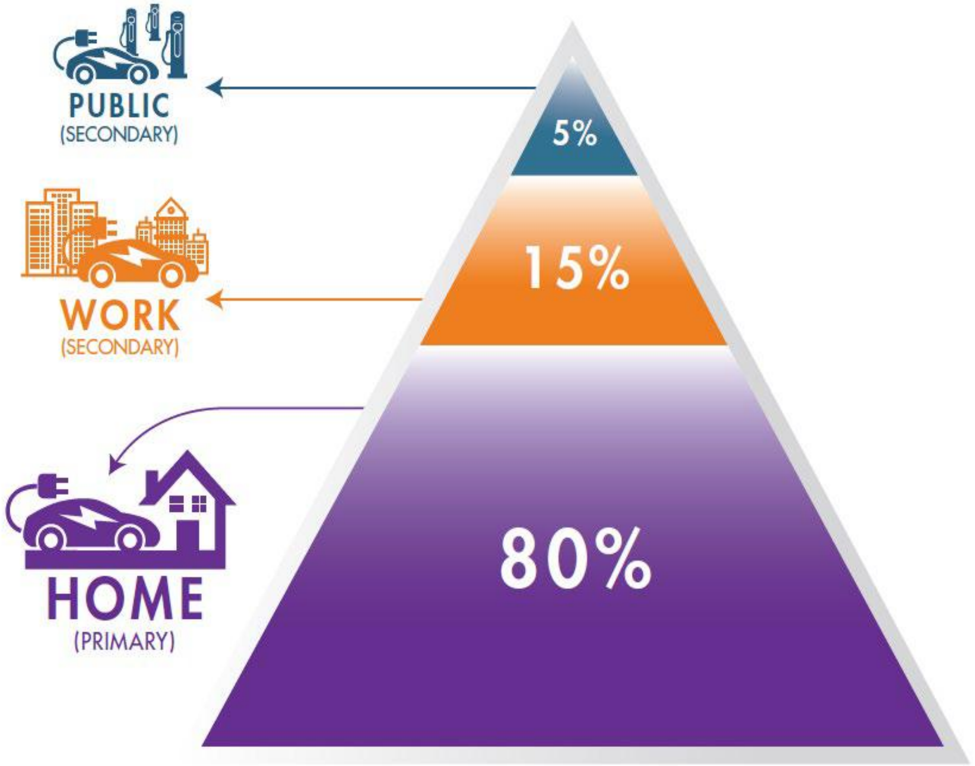
Charging Station usage by Location

ELECTRIC POWER
RESEARCH INSTITUTE

EPRI conducted a study in collaboration with Salt River Project in the Phoenix, Arizona region.

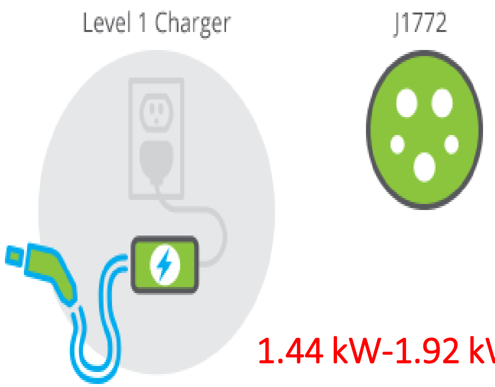


[1] Electric Vehicle Charger Selection Guide
[2] Electric Vehicle Driving, Charging, and Load Shape Analysis: A Deep Dive into Where, When, and How Much Salt River Project Electric Vehicle Customers Charge. EPRI, Palo Alto, CA: 2018. 3002013754.

EV Charger Types

❑Slow Charging (On-Board)

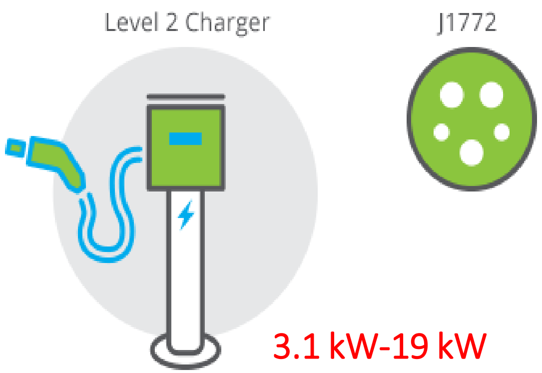
Level 1: AC Charger



1.44 kW-1.92 kW

120 Volts AC, 12-16 A

Level 2: AC Charger



3.1 kW-19 kW

208/240 Volts AC, up to 80 Amps

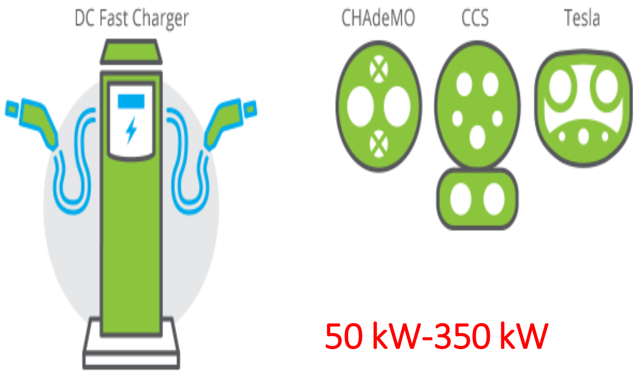
2 and 5 miles of electric range per hour of charging

10 and 20 miles of electric range per hour of charging

Residential and workplace settings

❑Fast Charging (Off-Board)

Level 3: Fast Charger



50 kW-350 kW

200 - 500 VDC, up to 350 A

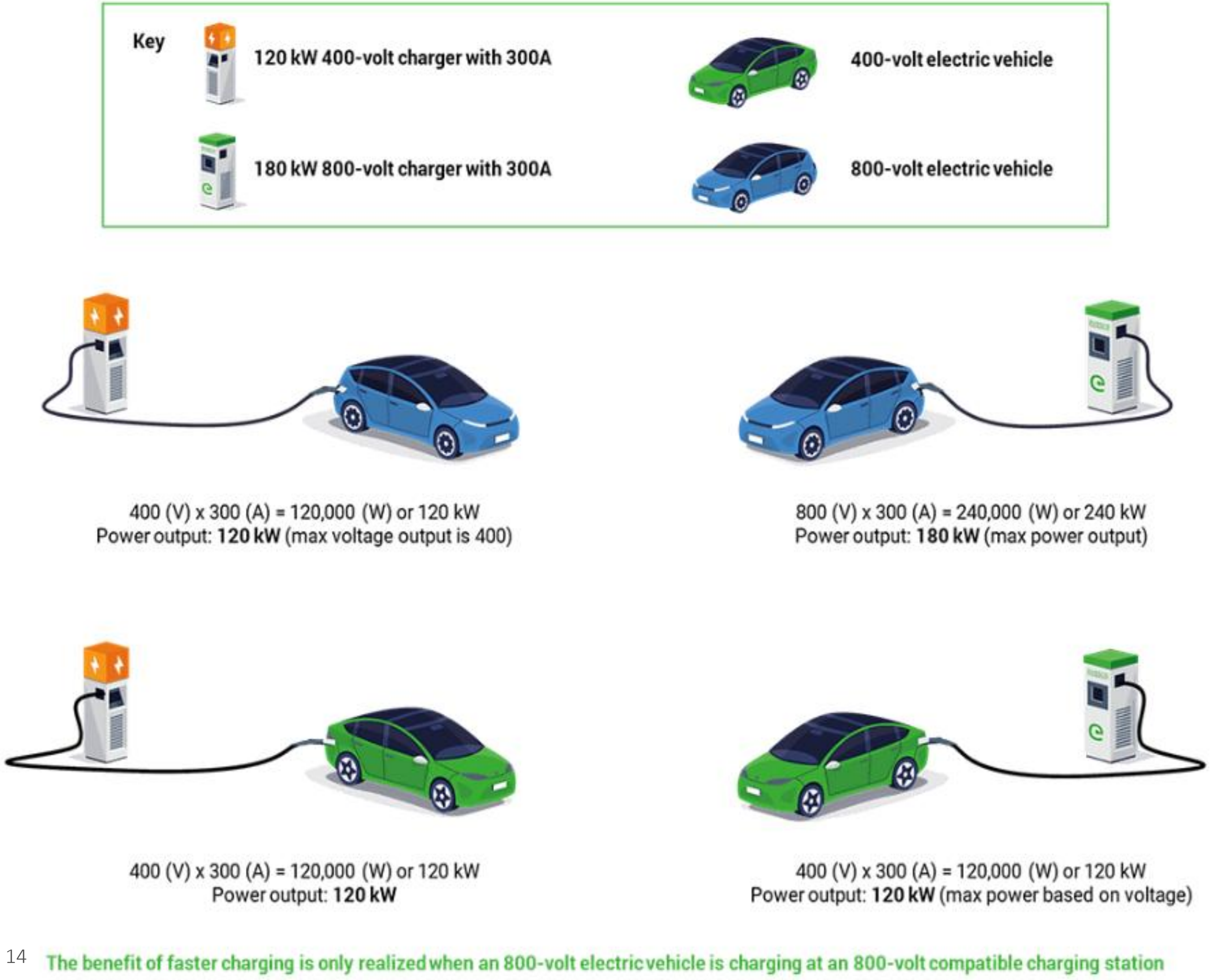
60 and 80 miles of electric range per hour of charging

Commercial, major travel corridors for long-distance trips and in urban environments

1 miles = 1.6km

https://chargedevs.com/newswire/liquid-cooling-in-electric-vehicles-what-to-know-to-keep-evs-on-the-go/

400-Volt VS 800-Volt Electric Vehicle Charging

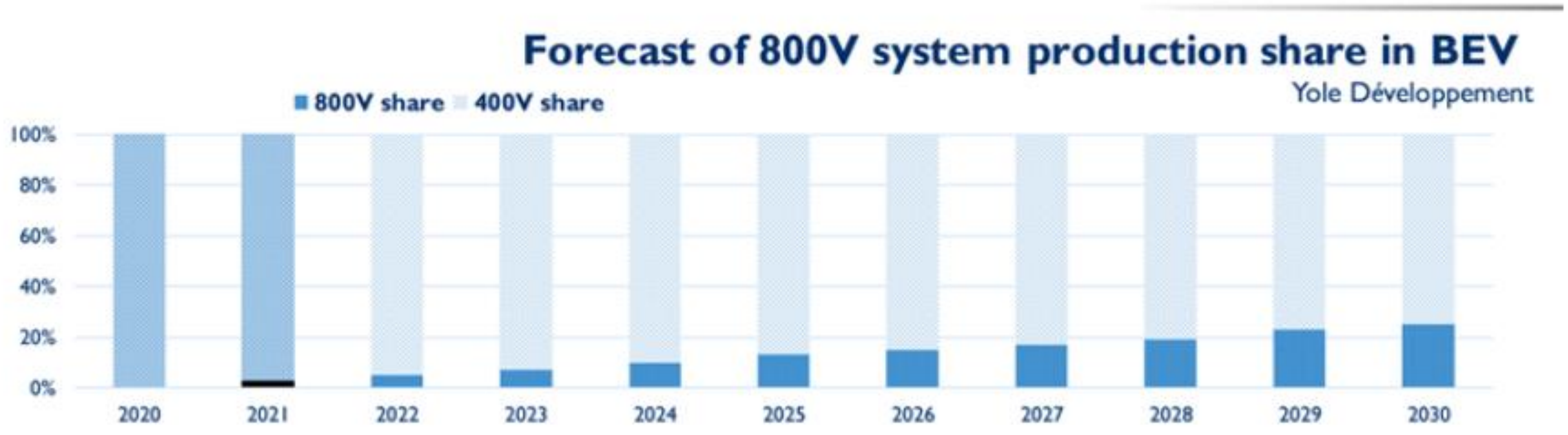


Why EV manufacturers want to shift to 800 volts?

1. Fast charging time (high power delivery).
2. Higher efficiency (less Losses).
3. Enabling Faster acceleration.
4. Better regenerative braking.
5. Electromagnetic Performance Enhancements (improve the power limits).
6. Reduce the inverter losses.
7. Reduce the motor volume and mass.

https://www.power-sonic.com/blog/400v-vs-800v-charging/

Forecast of 800-Volt Electric Vehicle



Bar chart of 800V system production share growth from 2020-2030. Source: Yole market research

Currently, EVs equipped with 800-volt architecture come from Porsche, Hyundai, Genesis, Kia, and Audi in these models:

- Porsche Taycan
- Hyundai Ioniq 5
- Genesis G80 EV
- Kia EV 6
- Audi E-Tron GT

https://www.tek.com/en/blog/resolving-mileage-anxiety-with-800v-ev-powertrain-design

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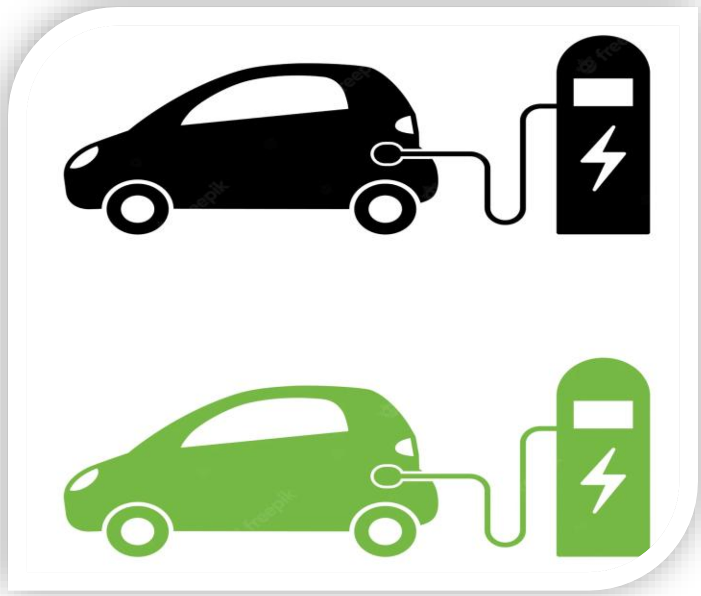
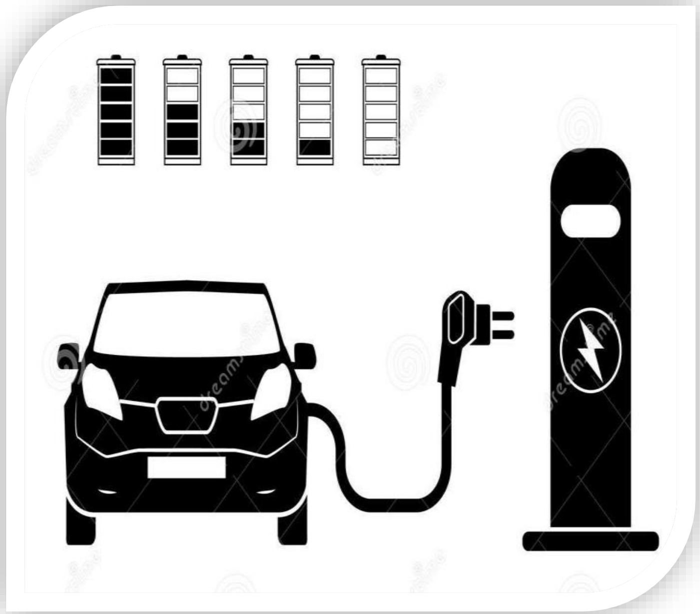
EVs Load Forecasts in Smart Grid

1- EVs Number Forecasts



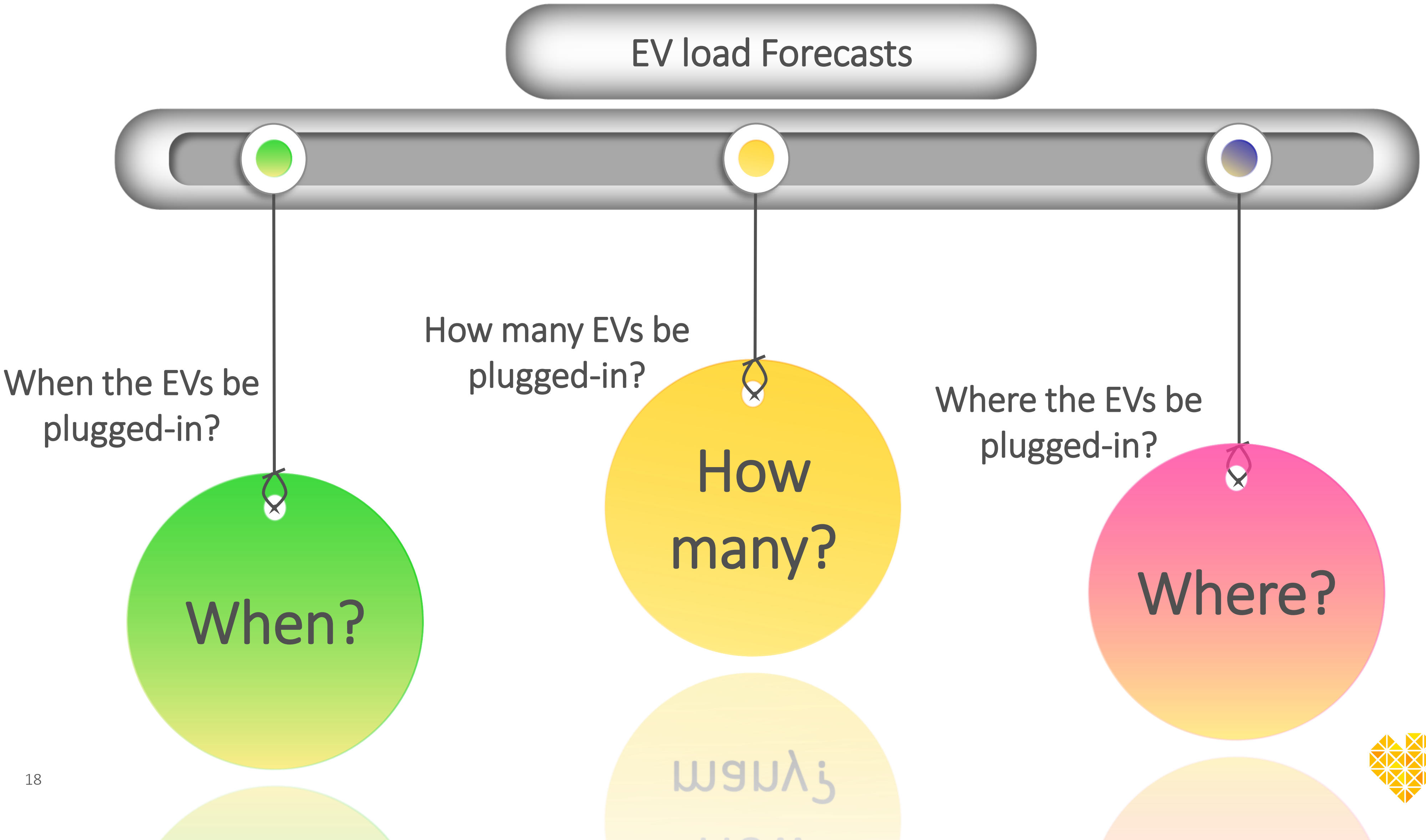
Total EVs Load Forecast

2- EVs charging Characteristics



Peak and energy Load Forecast

Important Questions for EV Load Forecasts



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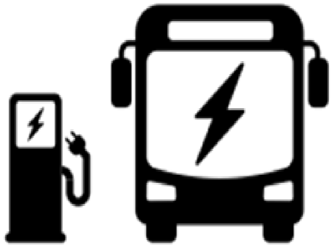
Charging Events & Category of Electric Vehicle

- ❑ **Charging location.**
- ❑ **The charging number/day.**
- ❑ **The plug-in/plug-out time.**
- ❑ **The charging pattern (slow/fast).**
- ❑ **The operating power of the charger.**

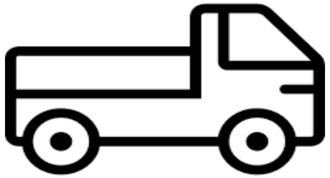
Private EV, PHEV

Electric Taxi

Electric Bus



Light duty vehicles



[1] Zheng Y, Shao Z, Zhang Y, Jian L. A systematic methodology for mid-and-long term electric vehicle charging load forecasting: The case study of Shenzhen, China. Sustainable Cities and Society. 2020 May 1;56:102084.

Charging Behavior

EV connection details

- ❑ Charging strategy (manual/smart).
- ❑ Charging duration.
- ❑ Number of EVs connection.
- ❑ Start time (time of use).
- ❑ Battery capacity.
- ❑ The state of charge (SOC).

Effect of Temperature on EV Driving Ranges

Temperature reduces EV driving range by 10-12%

- High or low temperatures battery capacities and charging/discharging behaviors change, impacting driving ranges.
- High or low temperatures trigger the use of heating or air conditioning to control cabin temperatures, once again resulting in a reduced driving range.

Winter Summer

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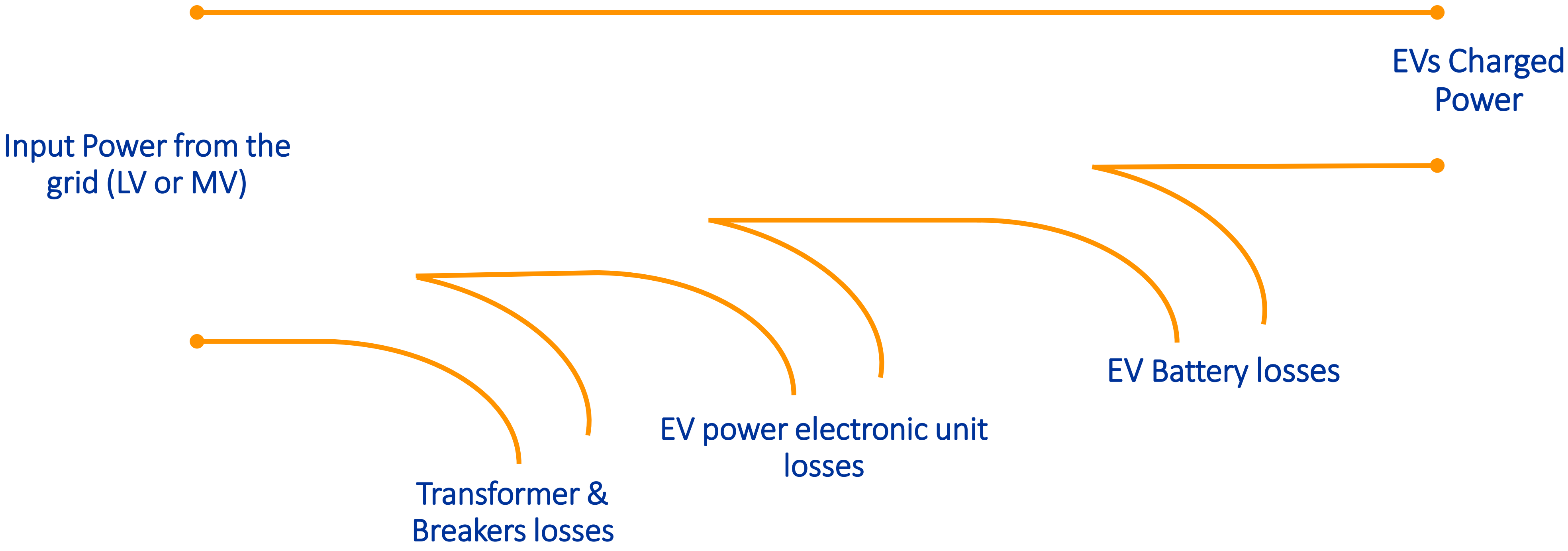
Power Losses of EV System

Total losses ranged between (12 to 15 %)



[1] Measurement of power loss during electric vehicle charging and discharging. Energy.

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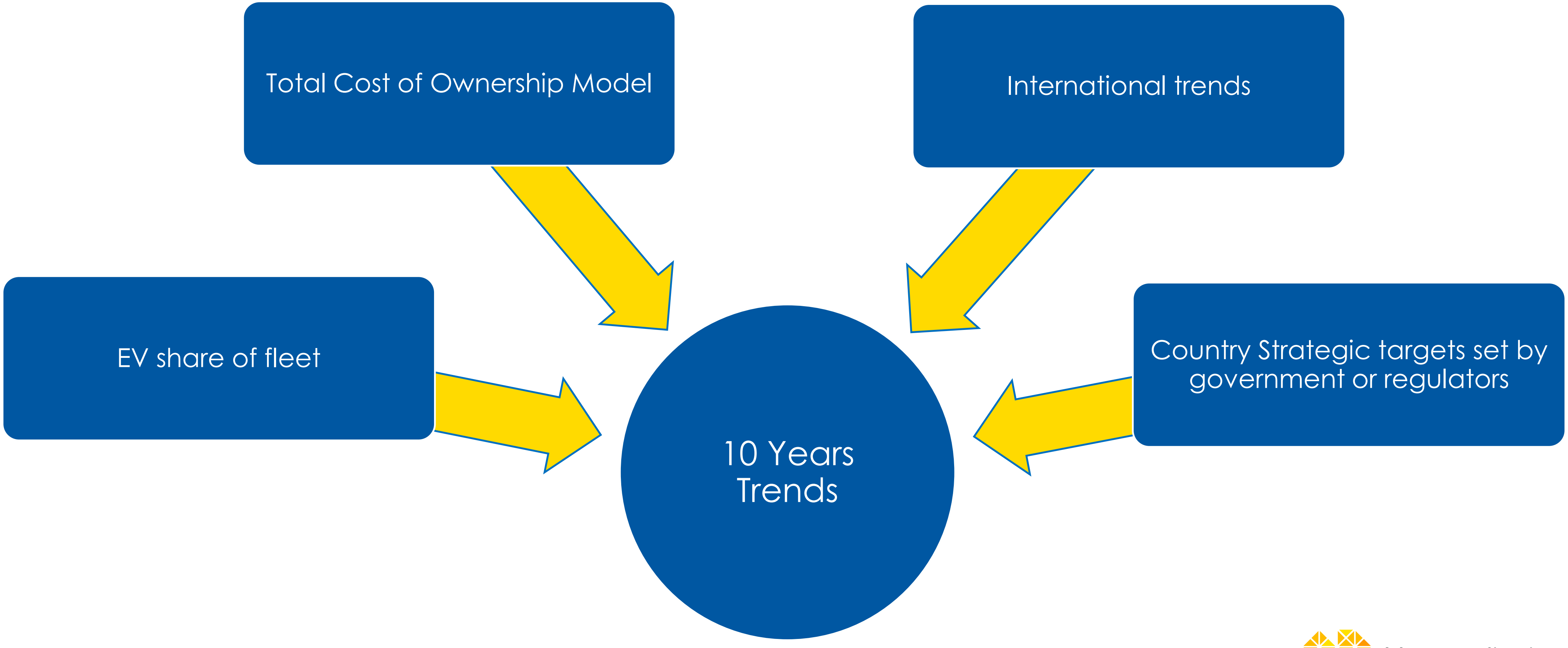
Main Inputs for EV Forecast



Factors that affects EVs load Forecast

Electric Vehicles

>10 Years Outlook

Forecast of vehicle fleet even beyond 10 years considering **population growth** and trends of uptake of electric vehicles **from international experiences.**

Charging Stations

Modelling of **different rated power** of charging points in **many locations** (Home, Work, Public), considering **different charging behaviours of the EV user** and **different charging modes (unmanaged, V1G and V2G) with hourly detail.**

Vehicles Categories

Modelling different types of vehicles covering the most promising categories for EV adoption in the mid-long term:

- Hybrid priv. car
- Full Electric priv. car
- Light Duty Vehicle
- Bus
- Taxi

OA Geographic Detail

Impact of Electric Vehicles is modelled **for each Operating Area (OA)** considering current and projected drivers which characterize each geographical region.

Total Cost of Ownership

Comparison of the **Net Present Value of all the costs** connected to the adoption of a conventional **fossil-fuel vehicle** and the adoption of a **battery electric vehicle**

Vehicle Data and Model

KWh/km

Detailed modelling of the main technical features of each vehicle category:

- Battery Size
- Covered Distance
- Energy Consumption (kWh/Km)

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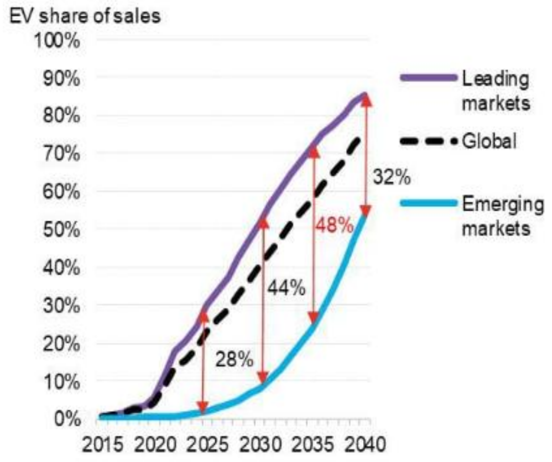
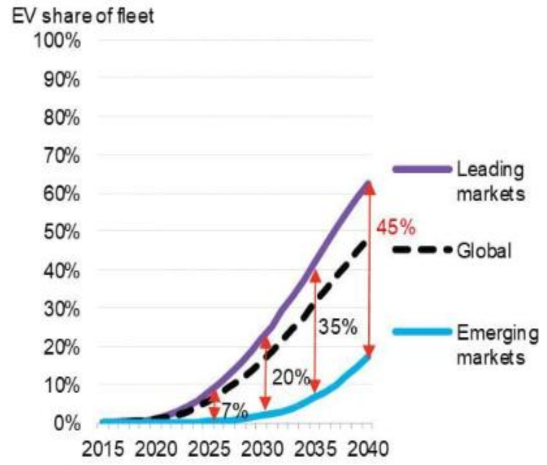
International trends and forecast for EVs in the region

Bloomberg NEW ENERGY FINANCE

Passenger EV share of sales - Economic Transition Scenario



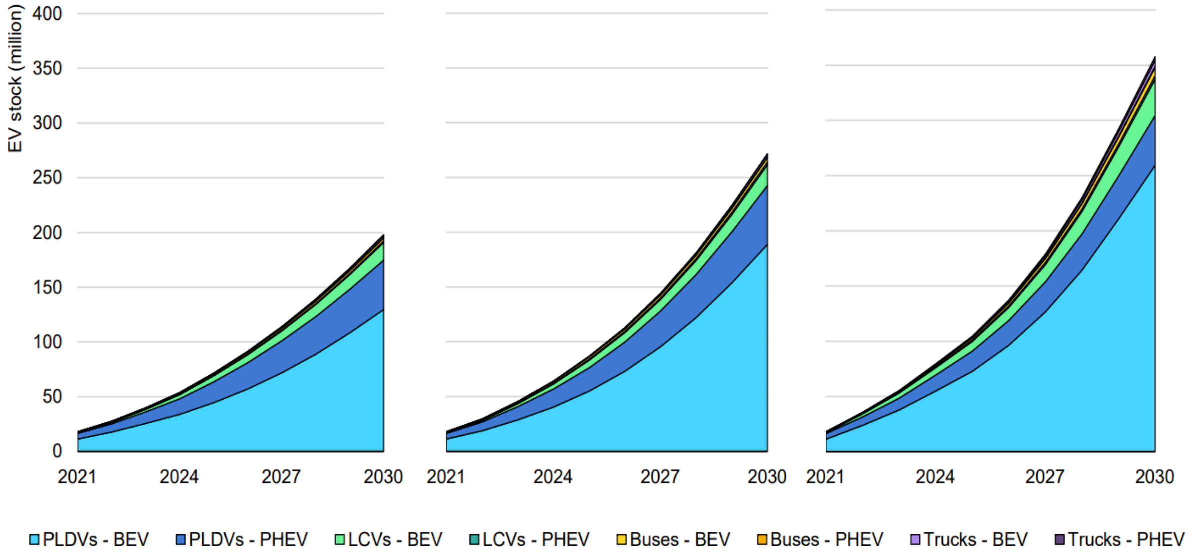
Passenger EV share of fleet - Economic Transition Scenario



Source: BNEF. Note: EV includes battery electric, plug-in hybrid and fuel cell vehicles.

iea International Energy Agency

Global EV stock by mode and scenario, 2021-2030



- For **emerging markets** EV share of fleet of 2% in 2030
- As a **global average** EV share of fleet 18% in 2030
- For **leading markets** EV share of fleet of 22% in 2030

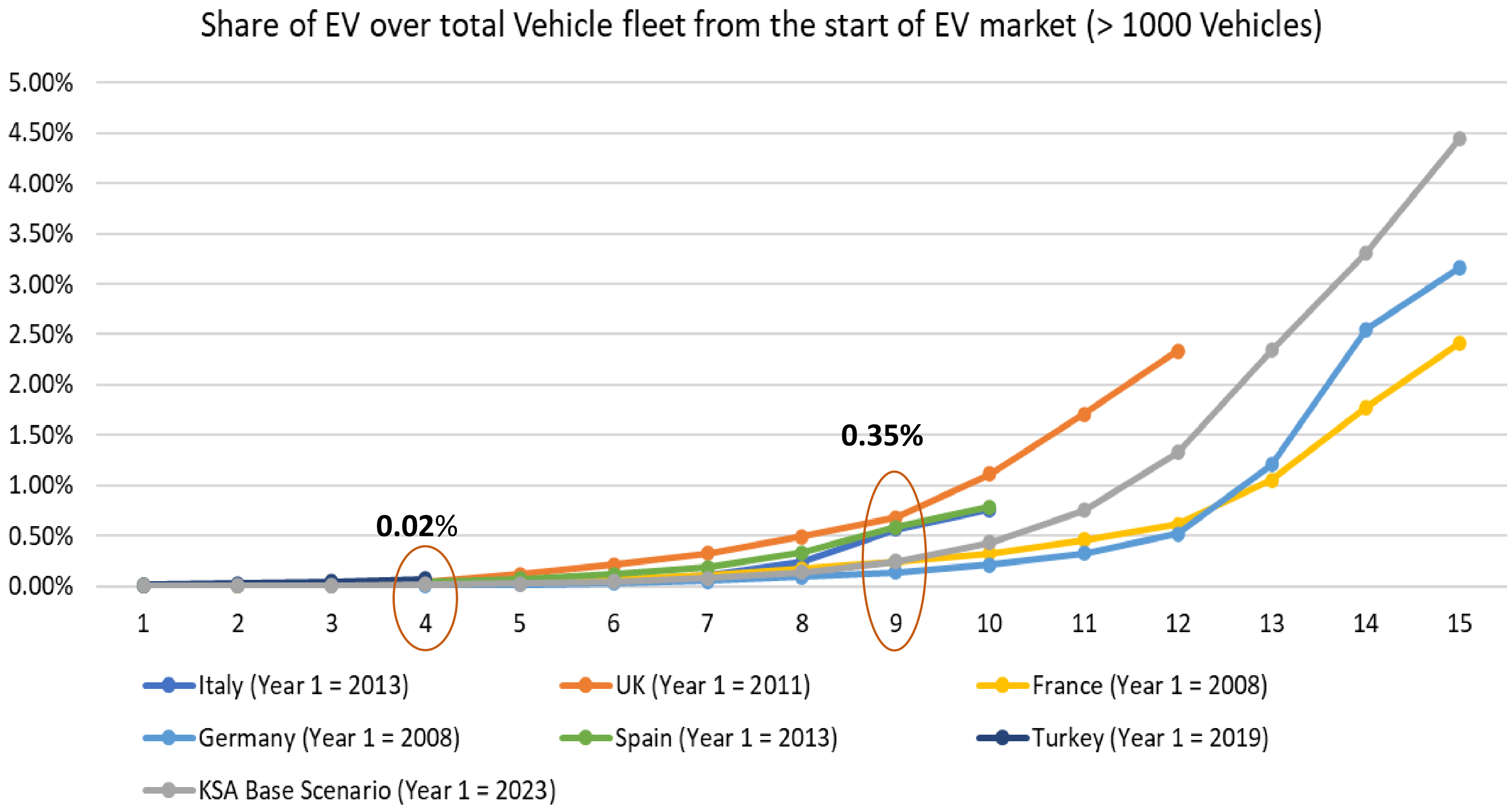
- For **Stated Policies Scenario** EV share of fleet of 10% in 2030
- For **Announced Pledges Scenario** EV share of fleet of 14% in 2030
- For **Net Zero Emission** EV share of fleet of 17% in 2030

Best Practice of Countries (EVs Share of total Fleet)

Base scenario

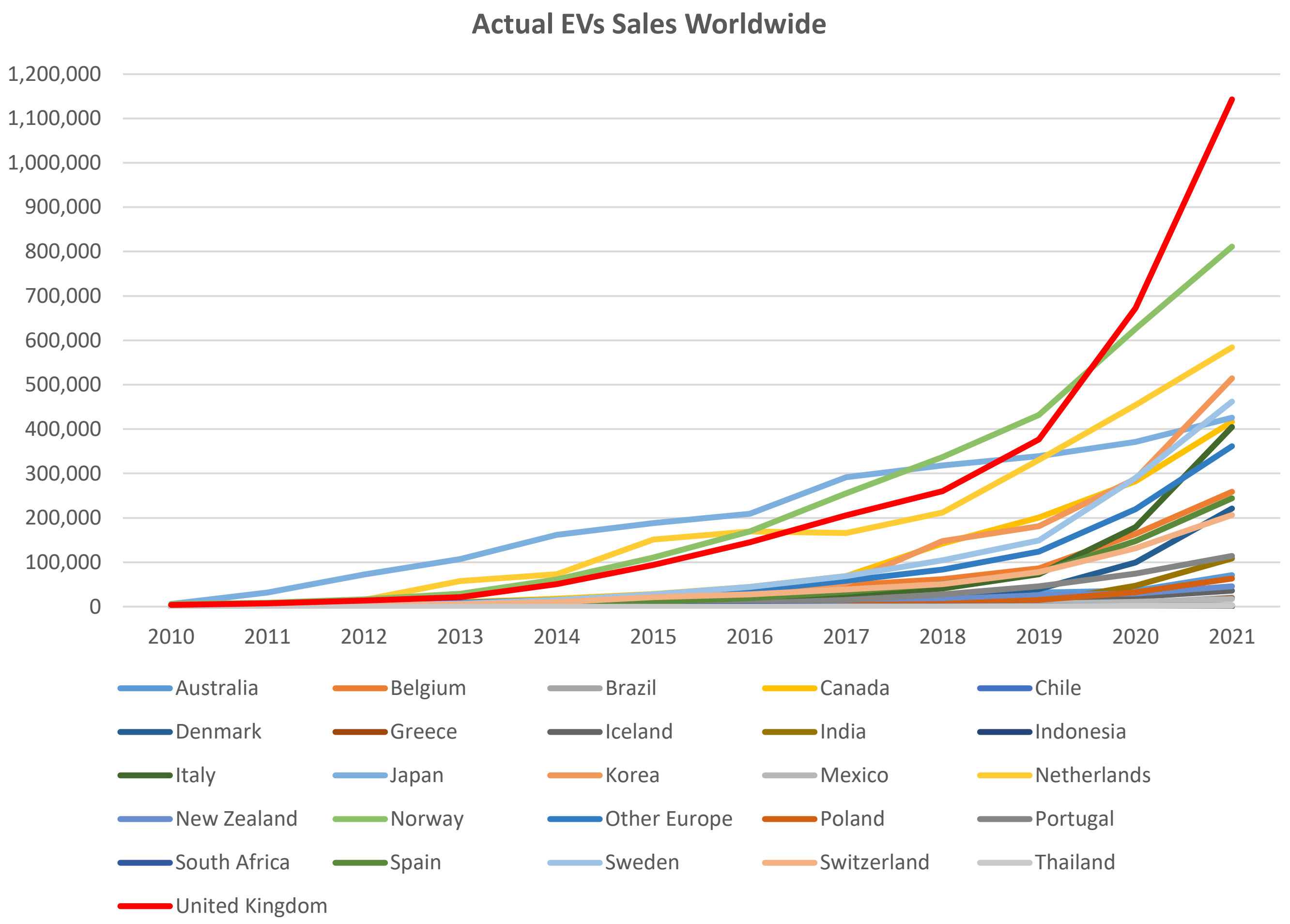
- The share in **2025** is assumed **0.02%** which is the share after 3 years from the start of EV market (>1000 EV) in Turkey, UK, Italy and Spain.
- The share used in **2030** is **0.35%** that is the share after 8 years from the start of EV market (>1000 EV) an average of UK, Italy and Spain.

Exponential increase



Share of EV over total Vehicle fleet from the start of EV market (> 1000 Vehicles)

Best Practice of Countries EV Sales



Exponential increase

Source: IEA Global EV Outlook 2022 https://www.iea.org/data-and-statistics/data-product/global-ev-outlook-2022

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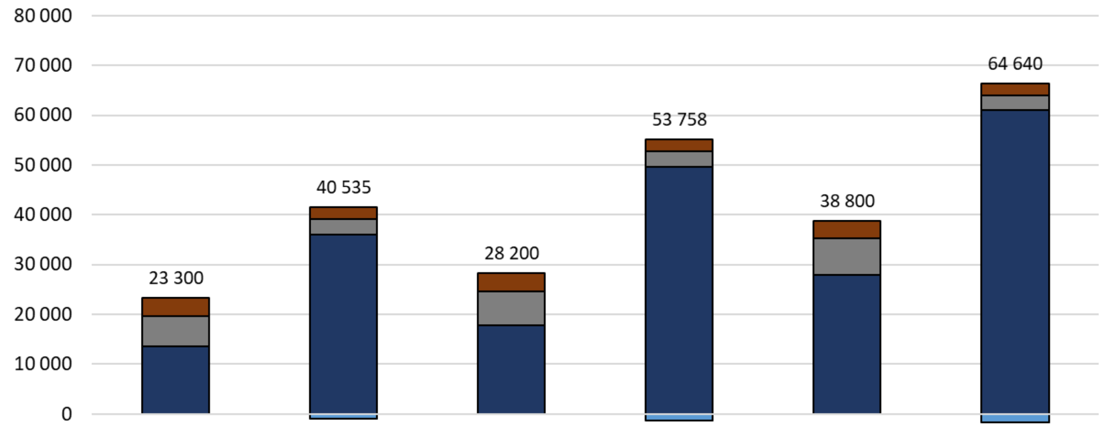
Total Cost of Ownership

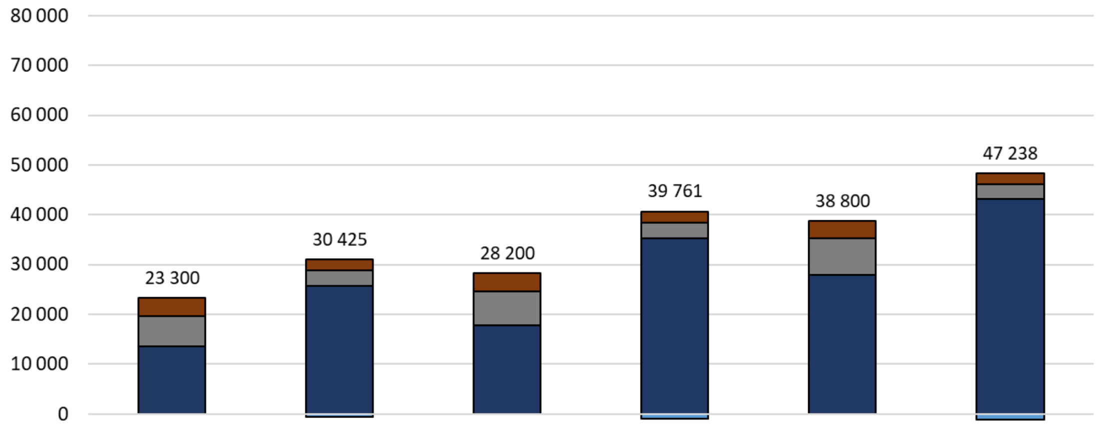
- End of Life
- Maintenance.
- Use.
- Purchase.

2022



	Segment B		Segment C		Segment D	
	Petrol - ICE	BEV	Petrol - ICE	BEV	Petrol - ICE	BEV
Total	23 300	40 535	28 200	53 758	38 800	64 640
End of Life	0	-965	0	-1 342	0	-1 660
Maintenance	3 600	2 300	3 600	2 300	3 600	2 300
Use	6 100	3 100	6 800	3 200	7 200	2 900
Purchase	13 600	36 100	17 800	49 600	28 000	61 100

2030



	Segment B		Segment C		Segment D	
	Petrol - ICE	BEV	Petrol - ICE	BEV	Petrol - ICE	BEV
Total	23 300	30 425	28 200	39 761	38 800	47 238
End of Life	0	-675	0	-939	0	-1 162
Maintenance	3 600	2 300	3 600	2 300	3 600	2 300
Use	6 100	3 100	6 800	3 200	7 200	2 900
Purchase	13 600	25 700	17 800	35 200	28 000	43 200

Segment B_Petrol - ICE: Toyota Yaris
Segment B_BEV: Renault Zoe

Segment C_Petrol - ICE: Hyunday Elantra
Segment C_BEV: Peugeot e-2008

Segment D_Petrol - ICE: Toyota Camry
Segment D_BEV: Tesla Model 3 - Standard Range

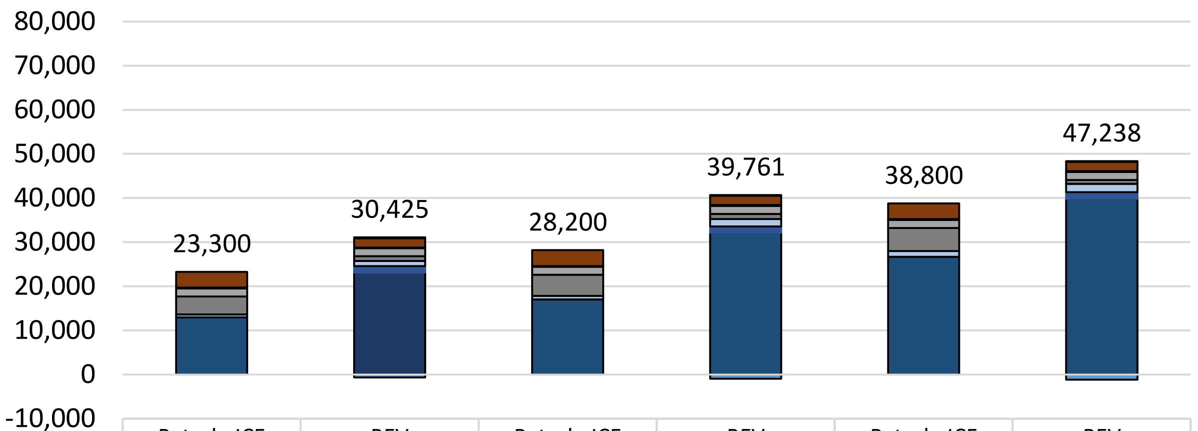
Total Cost of Ownership

A spread index is calculated as the average difference between costs of EV and ICE as a percentage of ICE costs. If the value is 77.1 % means that, on average, the three segments of EV costs 77.1% more than an ICE vehicle.

Parameters for the calculation of the final coefficient

Spread INDEX	Base Scenario Coefficient	
77.1%	Max Coeff	0.95
	Min Coeff	0.05
	Min Spread for saturation	0%
	Max Spread for saturation	50%
	Final coefficient	0.050

Final coefficient for the calculation of the input share of EV over total fleet in case of selection of the option Based on Total Cost of Ownership in the Base Scenario. The higher is the coefficient the more the Base scenario will be closer to the Low scenario. The lower is the coefficient the more the base scenario will be closer to the High scenario



	Segment B		Segment C		Segment D	
	Petrol - ICE	BEV	Petrol - ICE	BEV	Petrol - ICE	BEV
Total	23,300	30,425	28,200	39,761	38,800	47,238
Residual Value & Scrapping	0	-675	0	-939	0	-1,162
Charging System O&M	0	200	0	200	0	200
Vehicle Maintenance	3,600	2,100	3,600	2,100	3,600	2,100
Parking Fee	0	0	0	0	0	0
Road Tax	200	200	200	200	200	200
Insurance	1,800	1,800	1,800	1,800	1,800	1,800
Fuel	4,100	1,100	4,800	1,200	5,200	900
Financing	600	1,100	800	1,600	1,300	1,900
Registration Tax	0	0	0	0	0	0
Charging Infrastructure	0	1,500	0	1,500	0	1,500
Vehicle	13,000	23,100	17,000	32,100	26,700	39,800

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Factors that affects total EVs load Forecast

- Population
- Fuel cost saving.
- Tax credits.
- Price difference.
- EVs models in market.

→ EVs sales.

World trend of EV's industry.

- Battery Electric Vehicles (BEVs).
- Plug-in Hybrid Electric Vehicle (PHEVs)

→ Type of electric cars.

Available No. of Charging stations

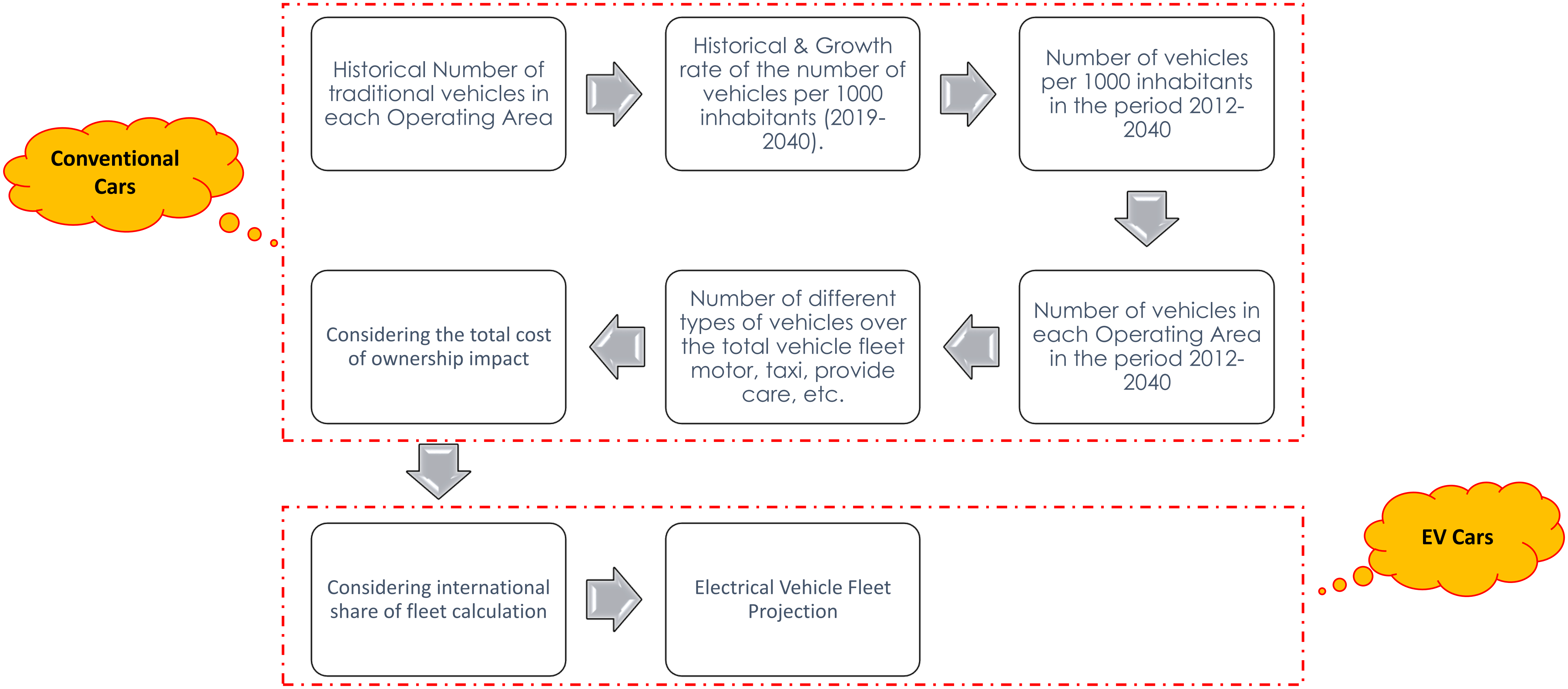
- Private EV.
- Electric Taxi.
- Electric Bus.
- Official EV.

→ Capacity of EV battery.

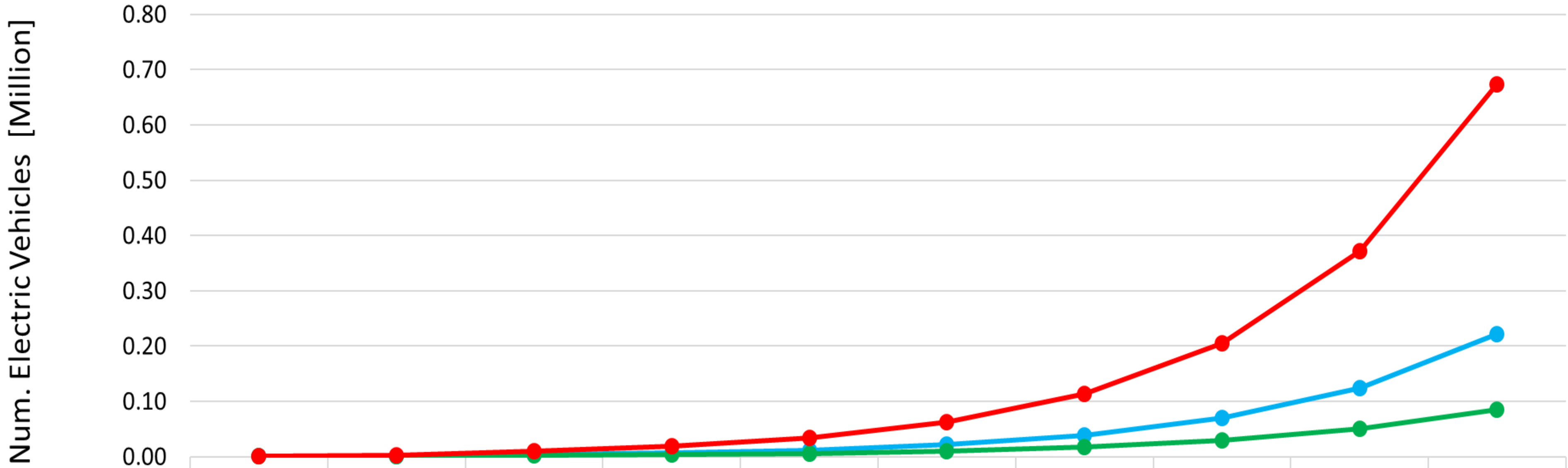
Number of EVs and capacity → Total EVs load Forecast

Flow chart for EVs load forecast per Year

Vehicle Fleet Projection



Vehicle Fleet Projection



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario Base	0.000620	0.002	0.004	0.007	0.012	0.022	0.039	0.070	0.124	0.222
Scenario Low	0.000509	0.001	0.00212	0.004	0.006	0.010	0.018	0.030	0.050	0.085
Scenario High	0.0009	0.003	0.011	0.019	0.035	0.063	0.114	0.206	0.372	0.673

Content

- Types of Electric Vehicles and World Wide Statistics.
- Methods of EV Charging (Unmanaged, V1G, V2G).
- Main Inputs for EV Forecast.
- International Trends for EVs Share of Fleet.
- Total Cost of Ownership.
- Yearly Projection of EVs.
- EV Energy and Peak Power Forecast.

EVs Peak & Energy Load Forecast

- Electric price per day.
- Starting time of charging.
- Method of EV Charging:
  - ✓ Unmanaged.
  - ✓ V1G.
  - ✓ V2G

→ Time of Use (TOU).

Power loss of EV system

- Travel distance per day.
- Charging power.
- Battery capacity.
- Energy efficiency KWh/km

→ State of Charge (SoC)

Temperature effect.

- Transition probability:
  - ✓ At home.
  - ✓ At work.
  - ✓ Public.

→ Charging schedule.

- Fast charging (type 3).
- Slow charging (type 1 &2).

→ Charging pattern.

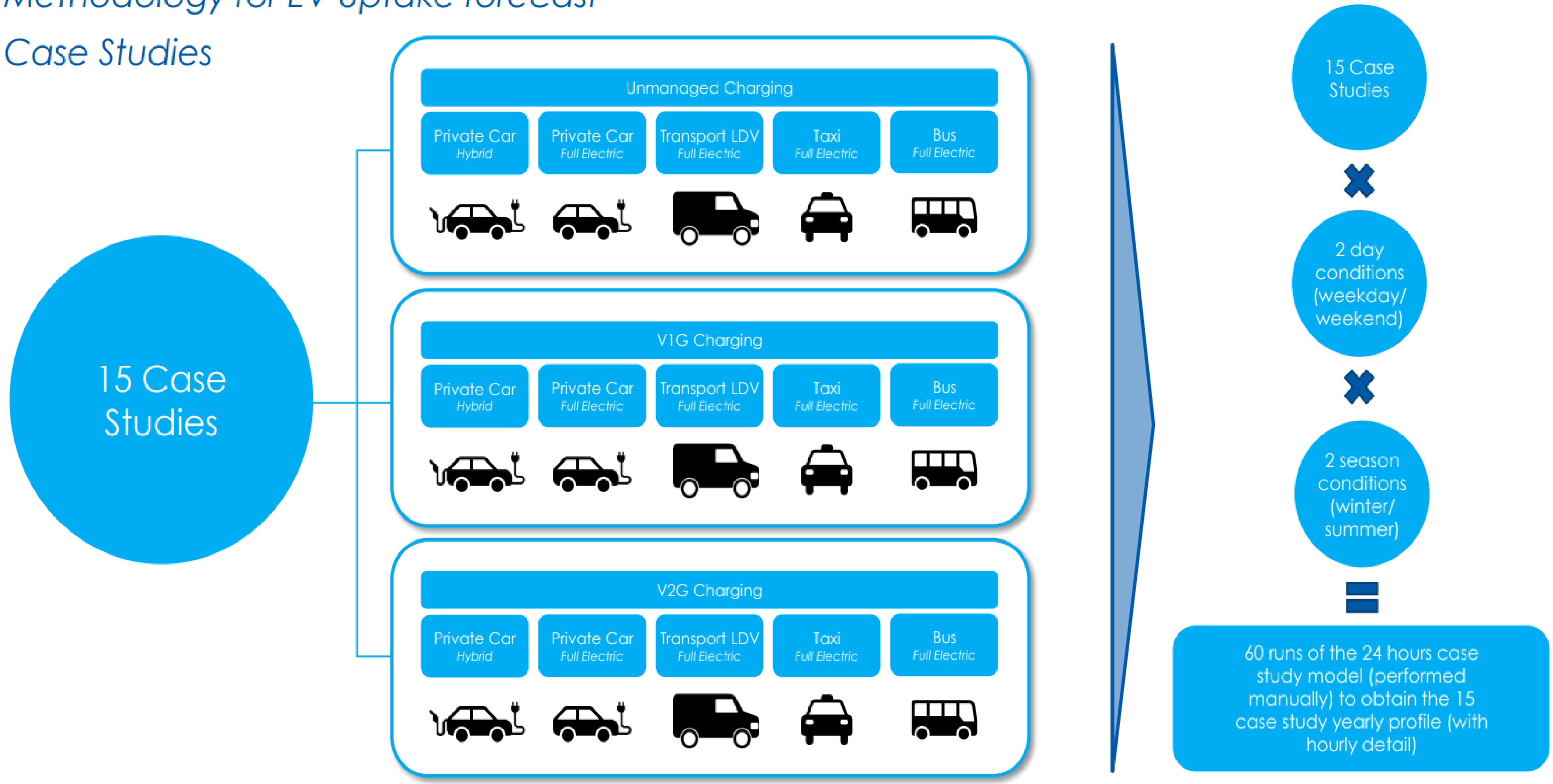
Peak load forecasts → EV peak demand (kw). EV energy demand (kwh). EV demand increase/ year (%).

Flow chart for EVs peak and coincident peak load forecast per Year

EV Forecast Scenarios

Methodology for EV uptake forecast

Case Studies



How the Optimization Model Works?

EV MODEL INPUT

1. Plug in probability: 72hr, 100 EV
- Home commuter & non commuter.
- Work commuter & non commuter.
- Work plugin & Public

2. Vehicles data per type (PHEV, BEV, LDV, Taxi & Bus):
- Battery Energy [kWh]
- Average yearly distance [km/year]
- Average Consumption [kWh/km]
- Average Consumption/day & summer weekday [Kwh/day]
- Yearly Consumption per vehicle [Kwh/Year]

3. Charging Location scenarios.
- 3 charging site considered home, work, public.
- Charging Mode in Charging each Site (Unmanaged, V1G, V2G).
- Rated Power Charging in each Site.
- % Charge in Charging per Site

EV MODEL

Model Run:
- Plug-in Period.
- Linear Variable Charging & Discharging.
- Plug-In First Time
- Unplug Time
- SoC - 1 Vehicle
- SoC when Unplugged.
- Optimize charge/discharge (Hourly charged Energy per 100 Vehicles).
- Objective Function.
- Cost Variation Linear Variable Charging

'OpenSolver2.9.0_ LinearWin. marco

EV MODEL OUTPUT

✓ **3 days Consumption** Profiles for 100 Vehicles (from Case Study Model).

✓ **Total Energy Consumption** per Year including losses per 100 vehicles.

10 Years EV Energy Forecast according to No. of EV Projection.
- Low scenario
- Base scenario
- High scenario

10 Years EV Peak Power Forecast
- Low scenario
- Base scenario
- High scenario

1. Plugin Probability

The plugin probability considering 100 EVs charging pattern during 3 days including (home commuter and non commuter, work commuter and non work commuter, work plugin and public). The study also take into consideration the winter and summer weekday and weekend.

Home commuter: **the commuter has work, but he prefers to charge at home.**

Home non commuter: **the commuter has no work and always charge at home.**

Work commuter: **the commuter has work, and he prefers to charge at work.**

Work plugin: **the consumer always charge at work.**

Public: **probability the consumer to charge at public places.**

Results Scenarios

- Three scenarios about electric vehicles uptake in the mid-long term have been modelled to manage uncertainty on the development of this new market. Values are assumed considering the international experience in countries that had a relevant growth in EV in the past and economics of Electric vehicles

Scenario Low

2025

2,000 Electric Vehicles (0.01% share of electric vehicle for all the categories of vehicle)

2030

30,000 Electric Vehicles (0.13% share of electric vehicle for all the categories of vehicle)

Scenario Base

2025

4,000 Electric Vehicles (0.02% share of electric vehicle for all the categories of vehicle)

2030

70,000 Electric Vehicles (0.3% share of electric vehicle for all the categories of vehicle)

Scenario High

2025

11,000 Electric Vehicles (0.05% share of electric vehicle for all the categories of vehicle)

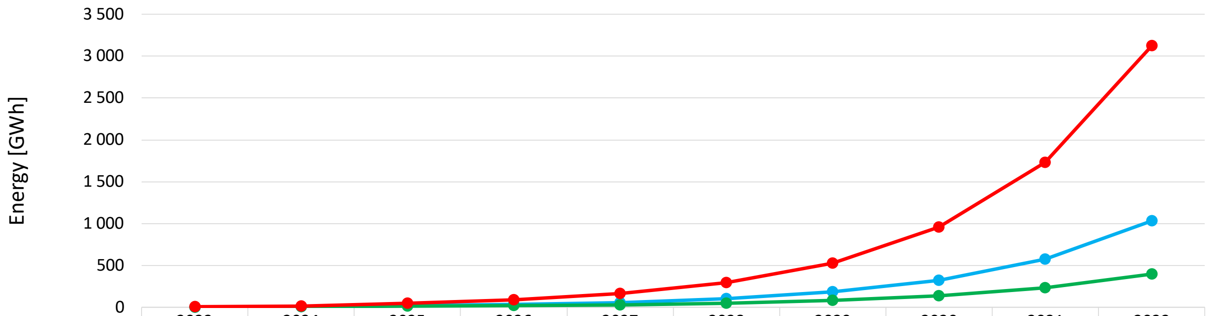
2030

205,000 Electric Vehicles (0.9% share of electric vehicle for all the categories of vehicle)

EV Energy Forecast (GWh)

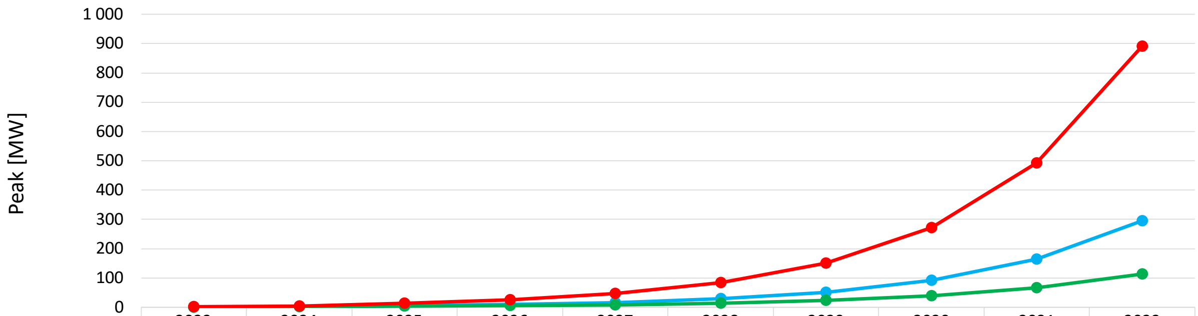
Results

Energy Demand Over the next 10 Years (GWh)



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario Base	3	7	18	32	57	101	181	323	577	1031
Scenario Low	2	5	10	17	28	48	81	138	234	396
Scenario High	4	14	49	89	161	292	528	955	1728	3123

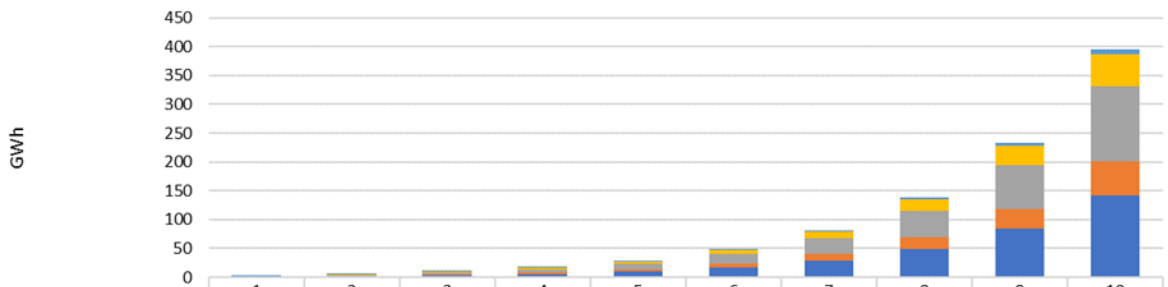
Peak Demand Over the next 10 Years (MW)



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Scenario Base	1	2	5	9	16	29	52	92	165	294
Scenario Low	1	1	3	5	8	14	23	39	67	113
Scenario High	1	4	14	25	46	83	151	272	493	891

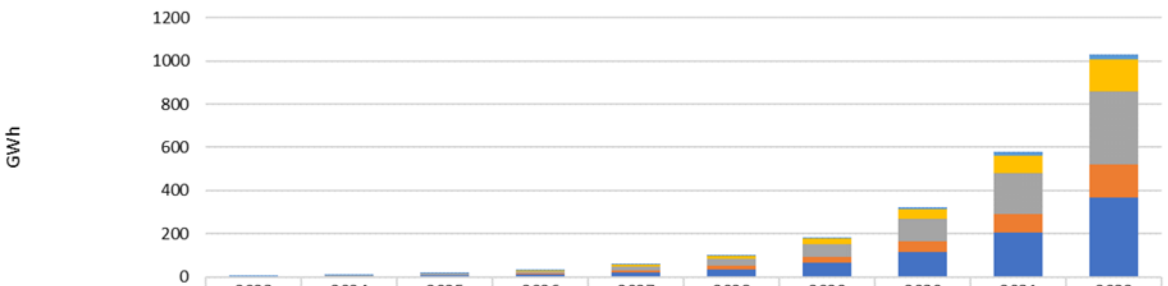
Energy Forecast – by Type of Vehicle

Trend of Energy Demand by EV Type - Scenario Low



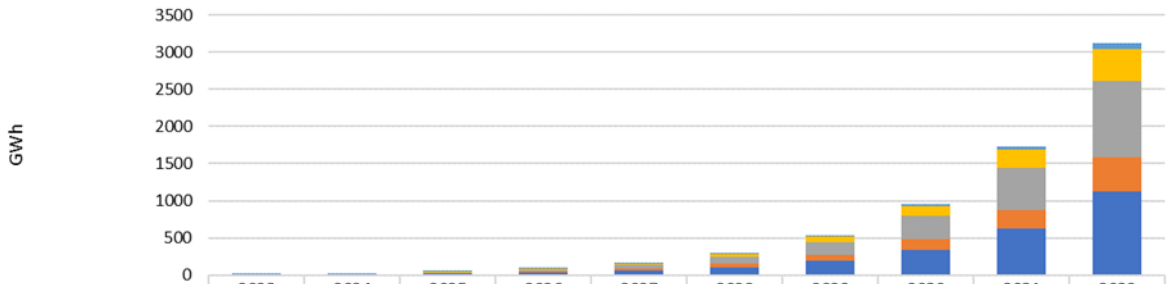
	1	2	3	4	5	6	7	8	9	10
Taxi	0.1	0.1	0.2	0.4	0.7	1.2	2.0	3.4	5.7	9.7
Private Car Hybrid	0.4	0.7	1.4	2.3	4.0	6.8	11.5	19.4	32.9	55.7
Private Car Full Electric	0.7	1.5	3.2	5.5	9.3	15.8	26.7	45.3	76.8	130.0
LDV	0.4	0.7	1.5	2.5	4.2	7.1	12.0	20.4	34.5	58.5
Bus	0.9	1.7	3.5	6.0	10.2	17.2	29.2	49.5	83.9	142.1

Trend of Energy Demand by EV Type - Scenario Base



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Taxi	0.1	0.2	0.4	0.8	1.4	2.5	4.4	7.9	14.2	25.3
Private Car Hybrid	0.5	1.1	2.5	4.5	8.0	14.2	25.5	45.5	81.2	145.1
Private Car Full Electric	0.9	2.2	5.8	10.4	18.6	33.2	59.4	106.1	189.6	338.5
LDV	0.4	1.1	2.6	4.7	8.4	14.9	26.7	47.7	85.3	152.2
Bus	1.0	2.6	6.3	11.4	20.3	36.3	64.9	116.0	207.2	369.8

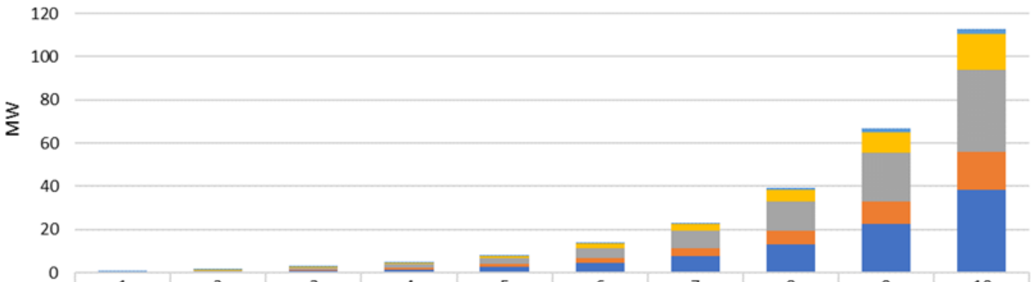
Trend of Energy Demand by EV Type - Scenario High



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Taxi	0.1	0.3	1.2	2.2	4.0	7.2	13.0	23.5	42.4	76.7
Private Car Hybrid	0.7	2.2	6.9	12.5	22.7	41.1	74.3	134.4	243.1	439.3
Private Car Full Electric	1.2	4.4	16.1	29.2	52.9	95.8	173.4	313.6	567.1	1025.1
LDV	0.6	2.1	7.3	13.1	23.8	43.1	78.0	141.1	255.1	461.1
Bus	1.5	5.1	17.6	31.9	57.8	104.7	189.5	342.7	619.8	1120.2

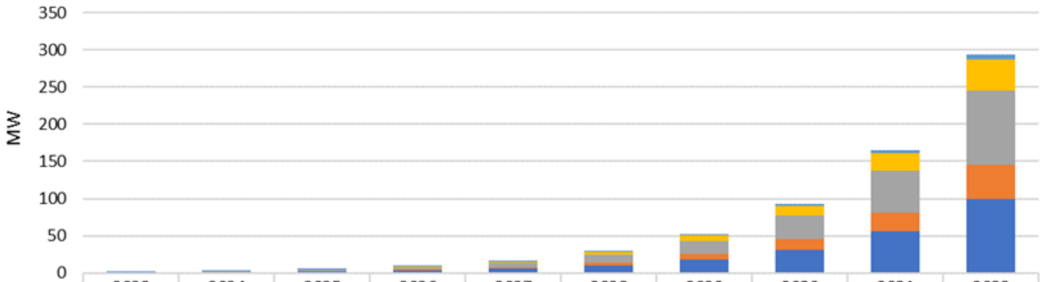
Peak Forecast – by Type of Vehicle

Trend of Peak Demand by EV Type - Scenario Low



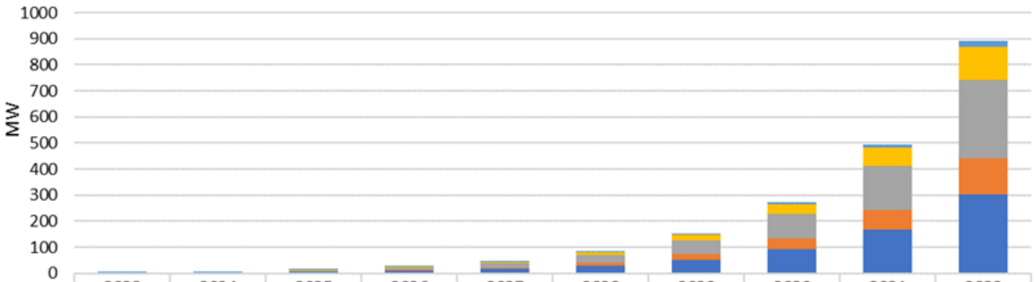
	1	2	3	4	5	6	7	8	9	10
Taxi	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.9	1.5	2.5
Private Car Hybrid	0.1	0.2	0.4	0.7	1.2	2.0	3.4	5.7	9.6	16.3
Private Car Full Electric	0.2	0.4	0.9	1.6	2.7	4.6	7.8	13.3	22.5	38.1
LDV	0.1	0.2	0.4	0.7	1.3	2.2	3.7	6.2	10.5	17.8
Bus	0.2	0.5	0.9	1.6	2.7	4.6	7.8	13.3	22.5	38.2

Trend of Peak Demand by EV Type - Scenario Base



	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Taxi	0.0	0.0	0.1	0.2	0.4	0.6	1.2	2.1	3.7	6.6
Private Car Hybrid	0.1	0.3	0.7	1.3	2.3	4.2	7.5	13.3	23.8	42.5
Private Car Full Electric	0.3	0.7	1.7	3.0	5.4	9.7	17.4	31.1	55.6	99.2
LDV	0.1	0.3	0.8	1.4	2.5	4.5	8.1	14.5	25.9	46.3
Bus	0.3	0.7	1.7	3.1	5.5	9.8	17.4	31.2	55.7	99.4

Trend of Peak Demand by EV Type - Scenario High

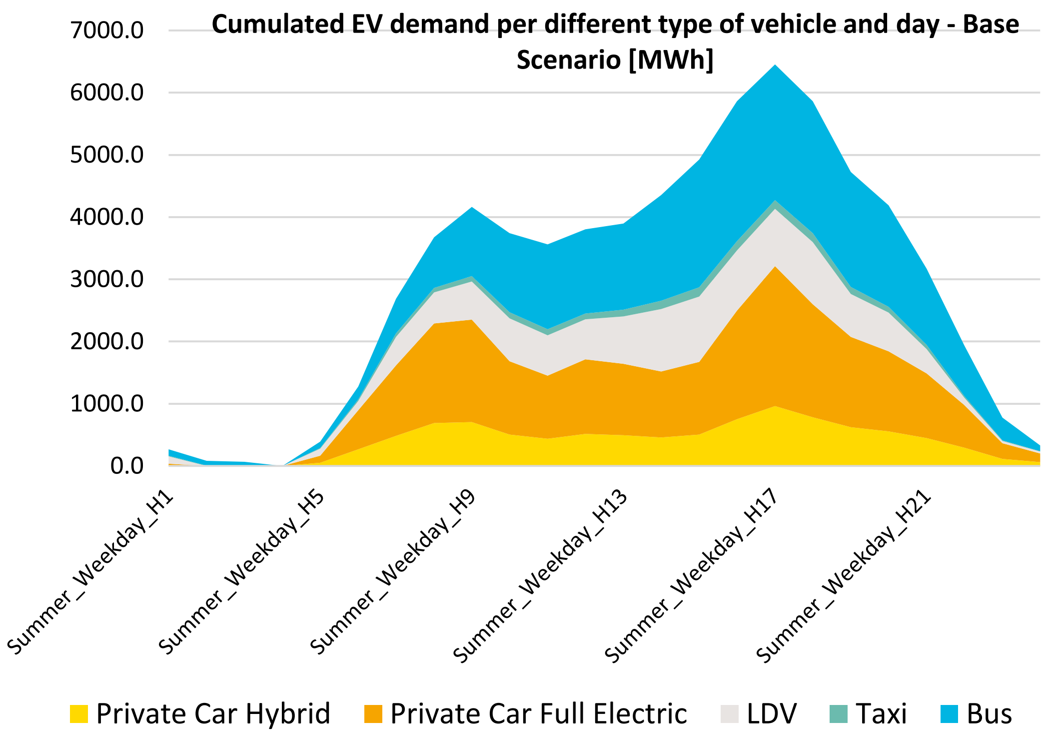


	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Taxi	0.0	0.1	0.3	0.6	1.0	1.9	3.4	6.1	11.1	20.0
Private Car Hybrid	0.2	0.6	2.0	3.7	6.6	12.0	21.8	39.4	71.2	128.8
Private Car Full Electric	0.4	1.3	4.7	8.6	15.5	28.1	50.8	91.9	166.2	300.4
LDV	0.2	0.6	2.2	4.0	7.2	13.1	23.7	42.9	77.6	140.3
Bus	0.4	1.4	4.7	8.6	15.5	28.1	50.9	92.1	166.5	301.0

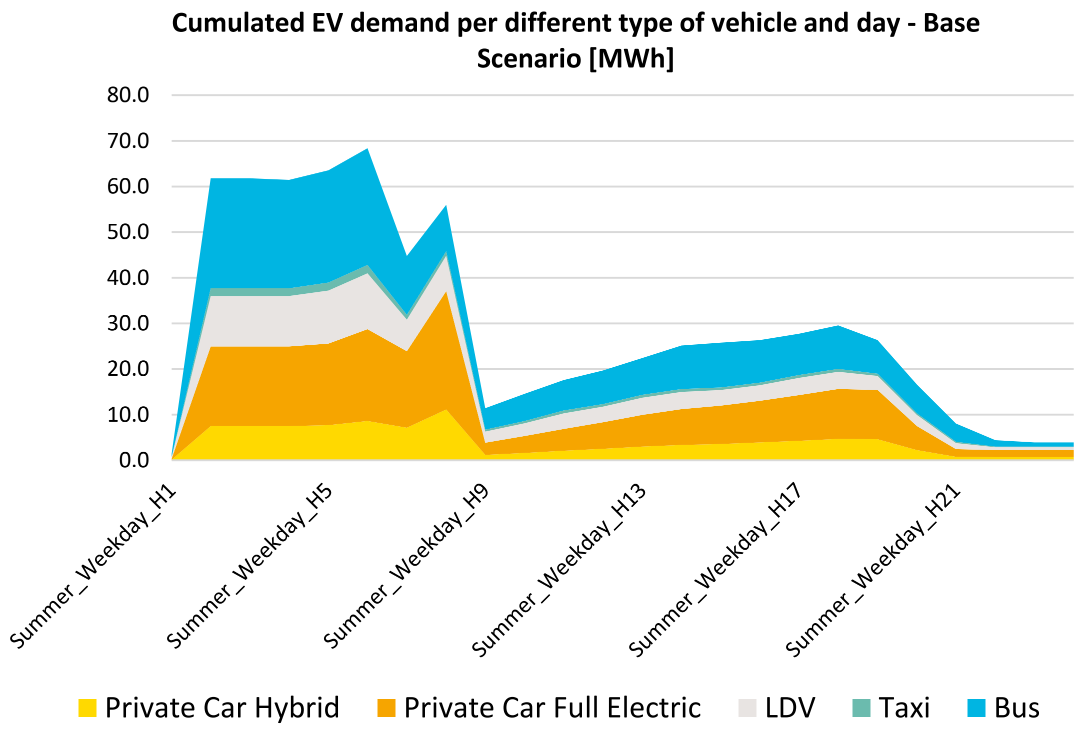
Daily Charging Pattern

2030

(1) Unmanaged Charging



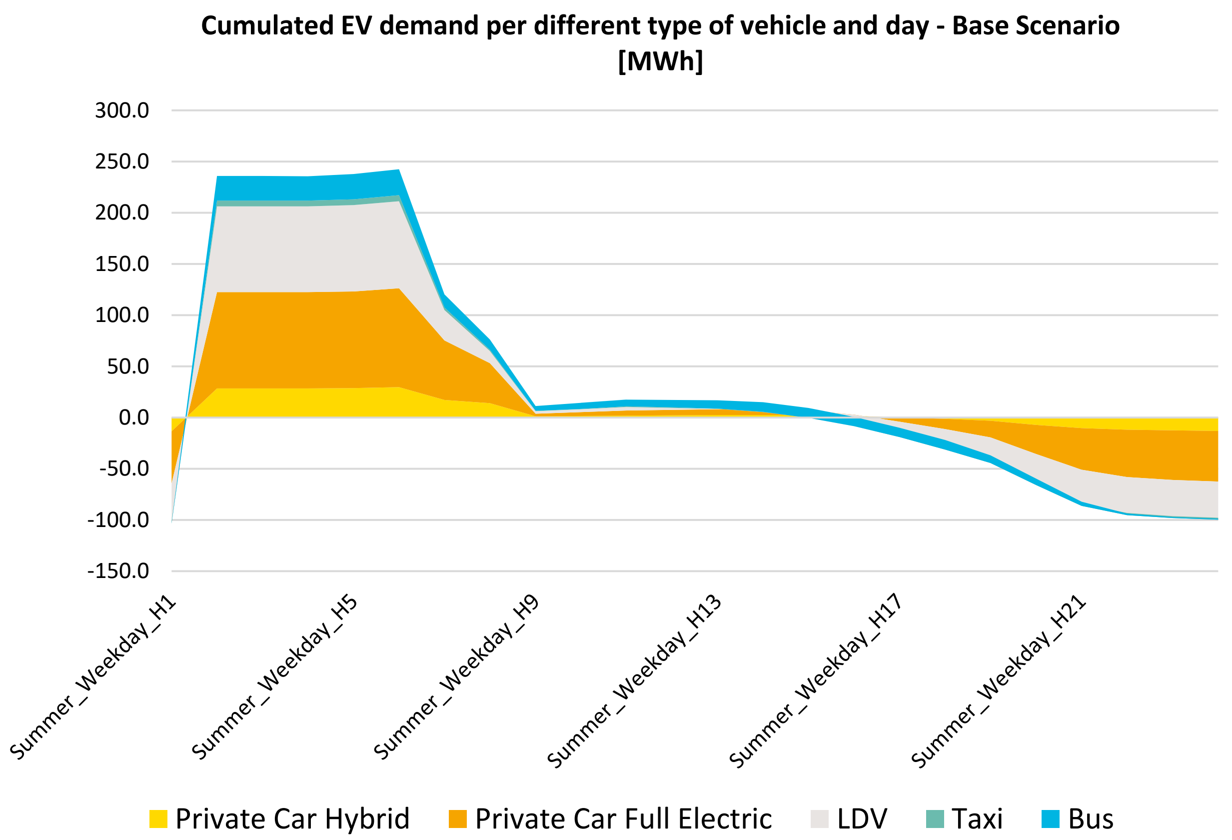
(2) V1G Charging Managed



Daily Charging Pattern

(2) V2G Charging

2030



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Thank You