Electric Vehicle-Grid Integration

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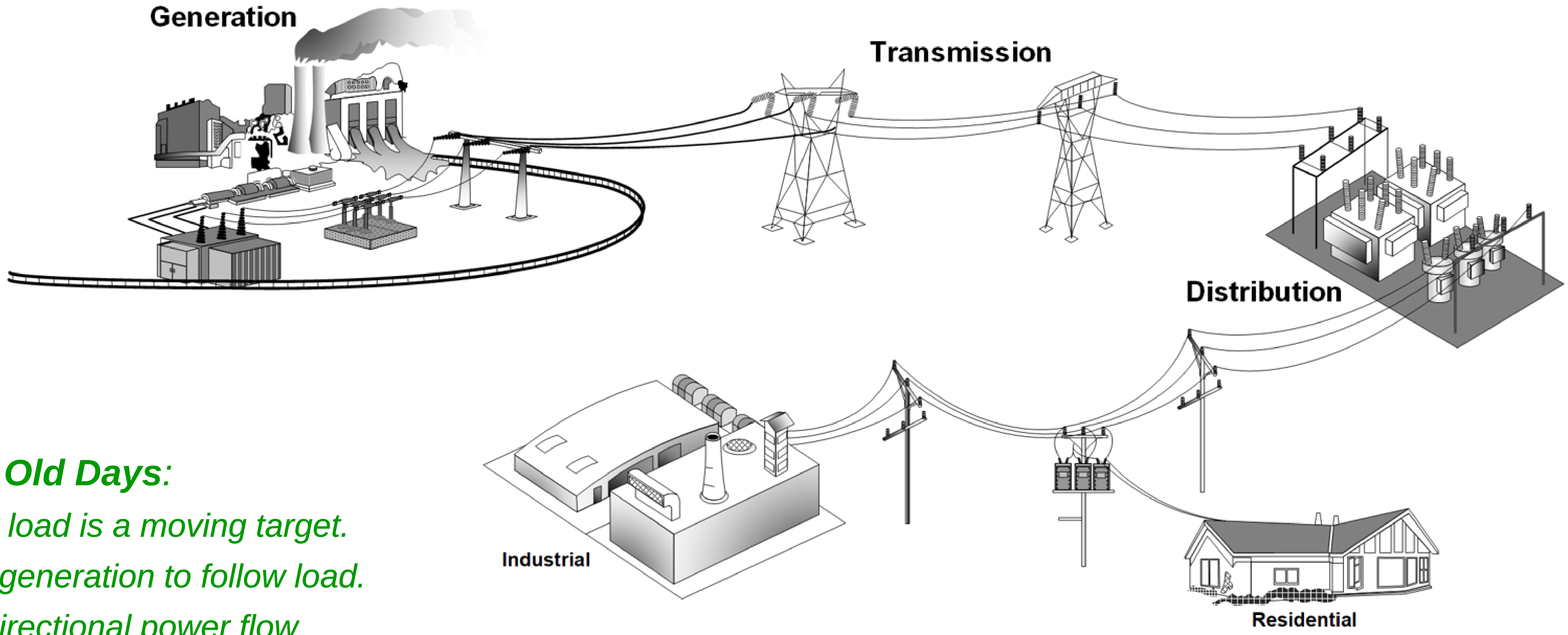
Presentation Outline : Electric Vehicle-Grid Integration

- Power Grid in Changing Landscape
- DER : Key Player in Grid Edge Transformation
- EV as DER
- Practical Use Cases: Vehicle-Grid Integration
- Food for Thought
- Conclusions

DER = Distributed Energy Resource

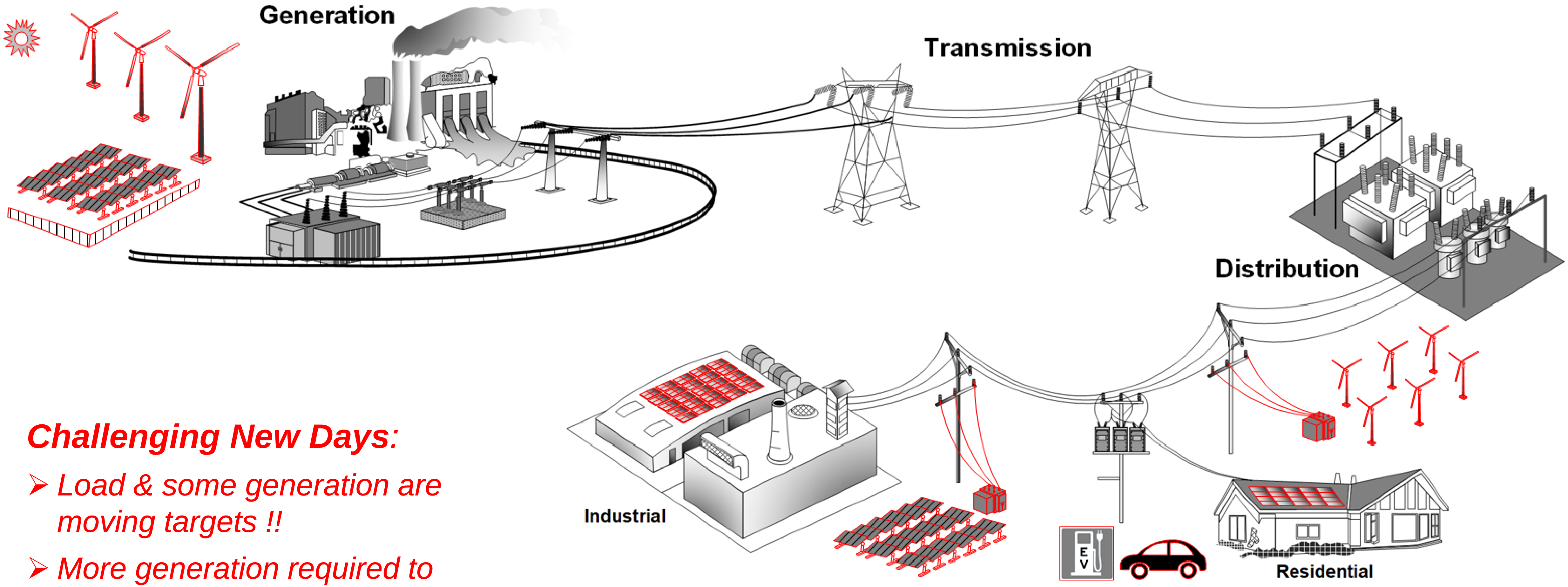
Power Grid in Changing Landscape



***Good Old Days*:**

- *Only load is a moving target.*
- *Use generation to follow load.*
- *Unidirectional power flow*

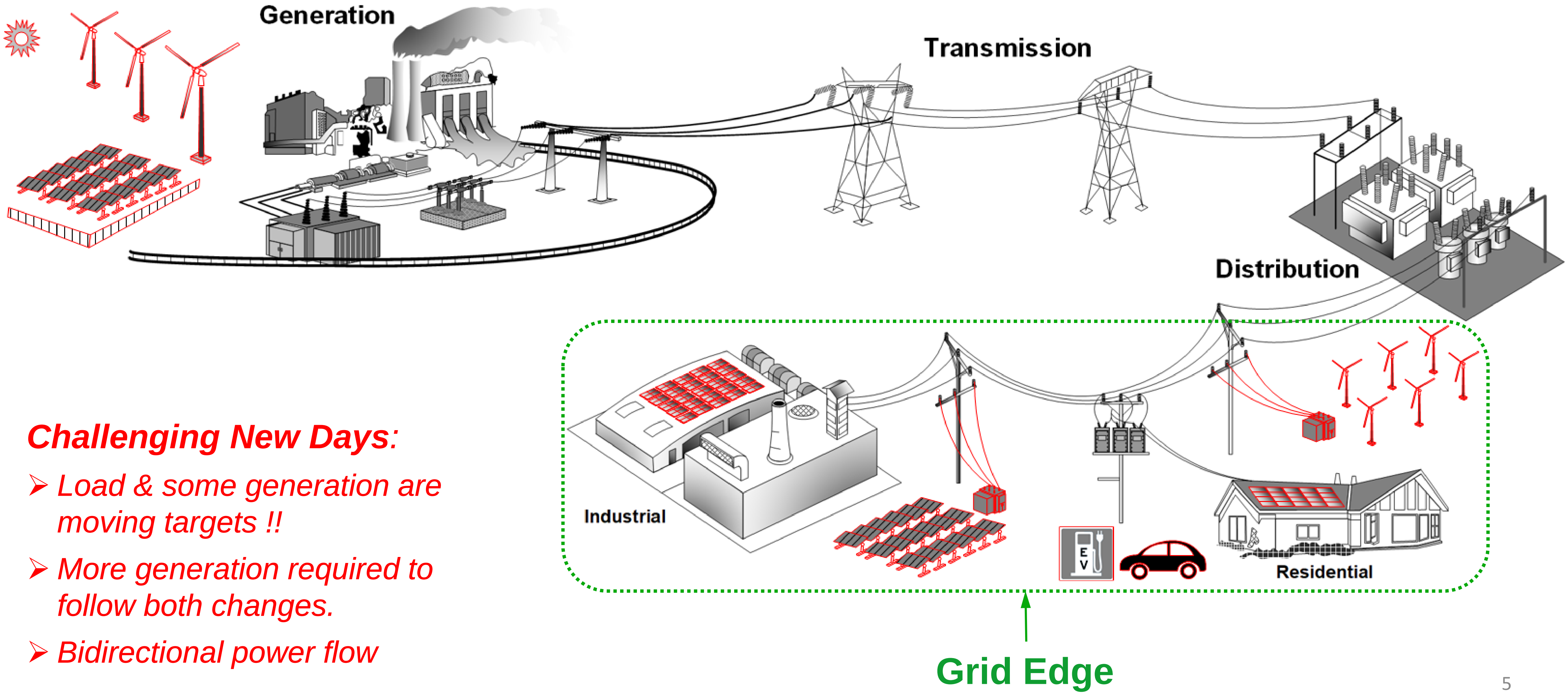
Power Grid in Changing Landscape



Challenging New Days:

- *Load & some generation are moving targets !!*
- *More generation required to follow both changes.*
- *Bidirectional power flow*

Power Grid in Changing Landscape ▶ Grid Edge



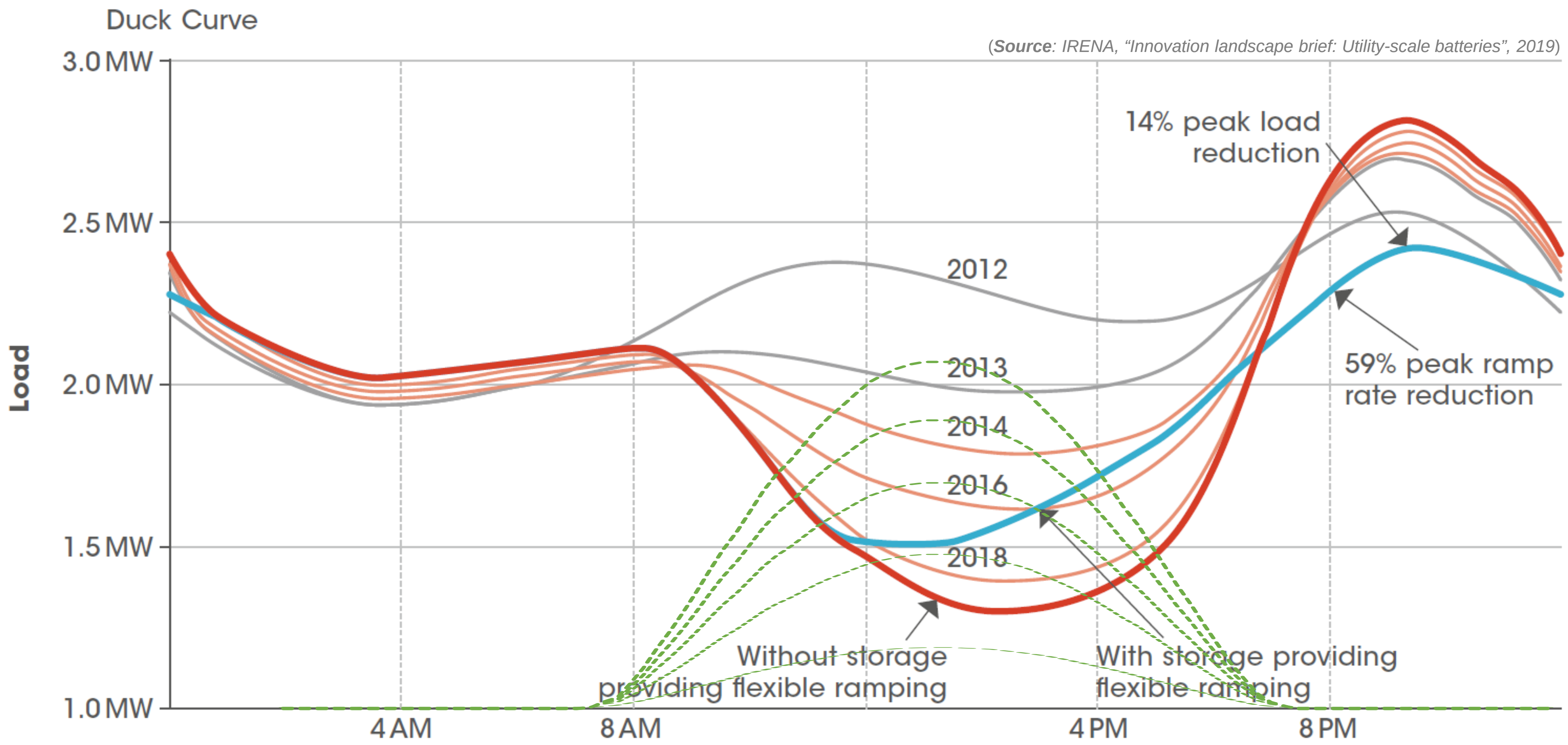
Challenging New Days:

- *Load & some generation are moving targets !!*
- *More generation required to follow both changes.*
- *Bidirectional power flow*

Power Grid in Changing Landscape ▶ Grid Edge

Duck Curve ▶ Challenges due to increase in distributed solar power

- Daily net load profiles (*i.e. native load minus solar power*) based on an example a 3 MW distribution feeder from California ISO.

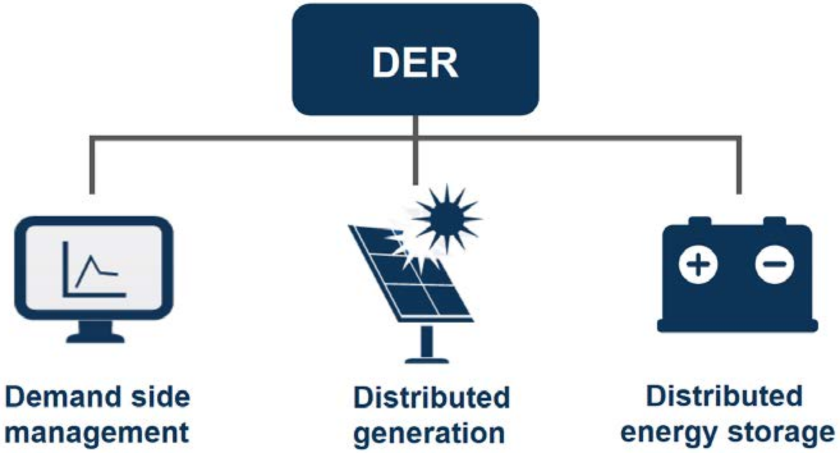


(**Source**: IRENA, "Innovation landscape brief: Utility-scale batteries", 2019)

DER : Key Player in Grid Edge Transformation

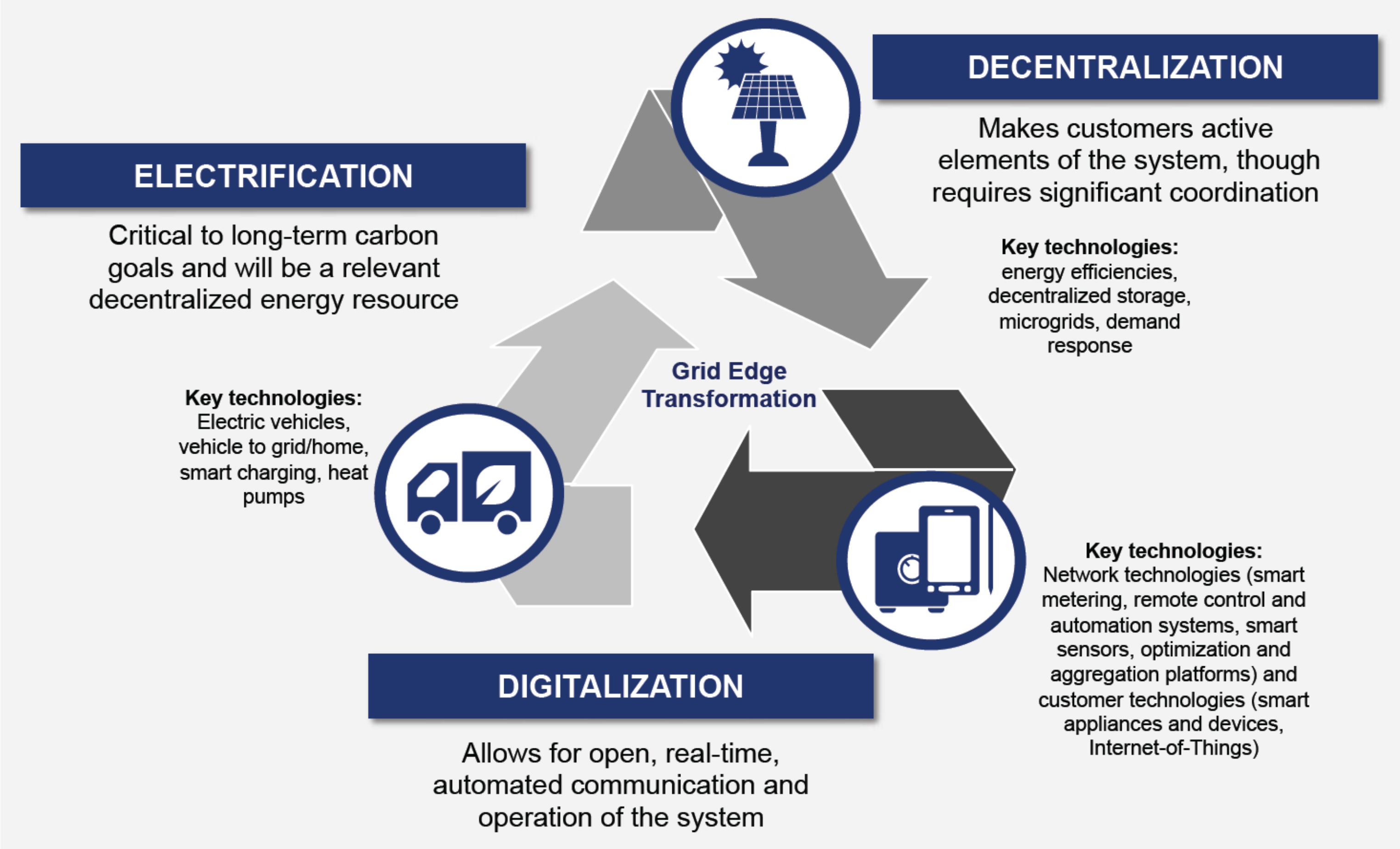
Distributed Energy Resources (DERs):

- Distributed Generation (i.e. solar, wind, biomass, EV)
- Distributed Energy Storage (i.e. small/large storage, EV)
- Demand-Side Management (i.e. controllable load, demand response, EV)

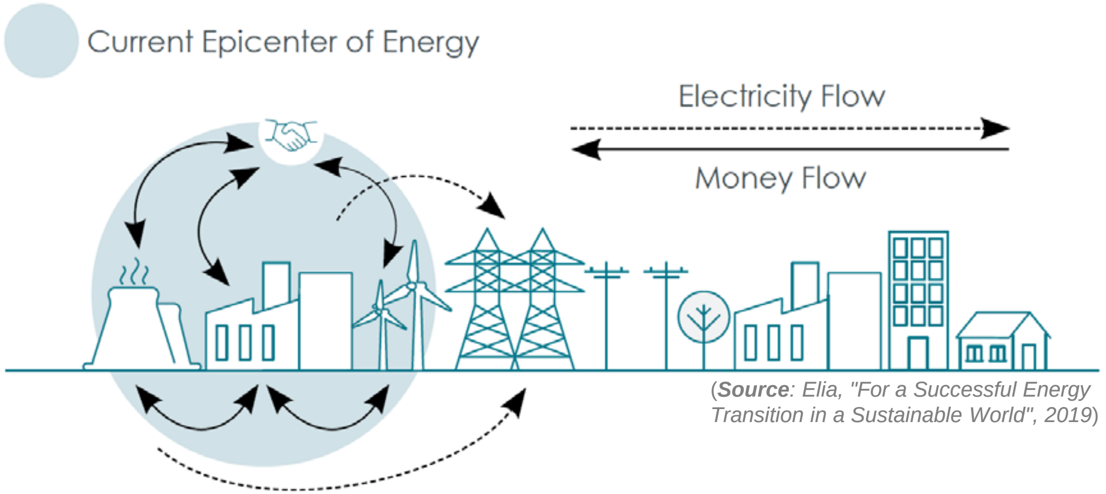


(**Source**: Bob Shively, "Distributed Energy Resources", 2019)

(**Source**: World Economic Forum, "Electric Vehicles for Smarter Cities: The Future of Energy and Mobility", 2018)

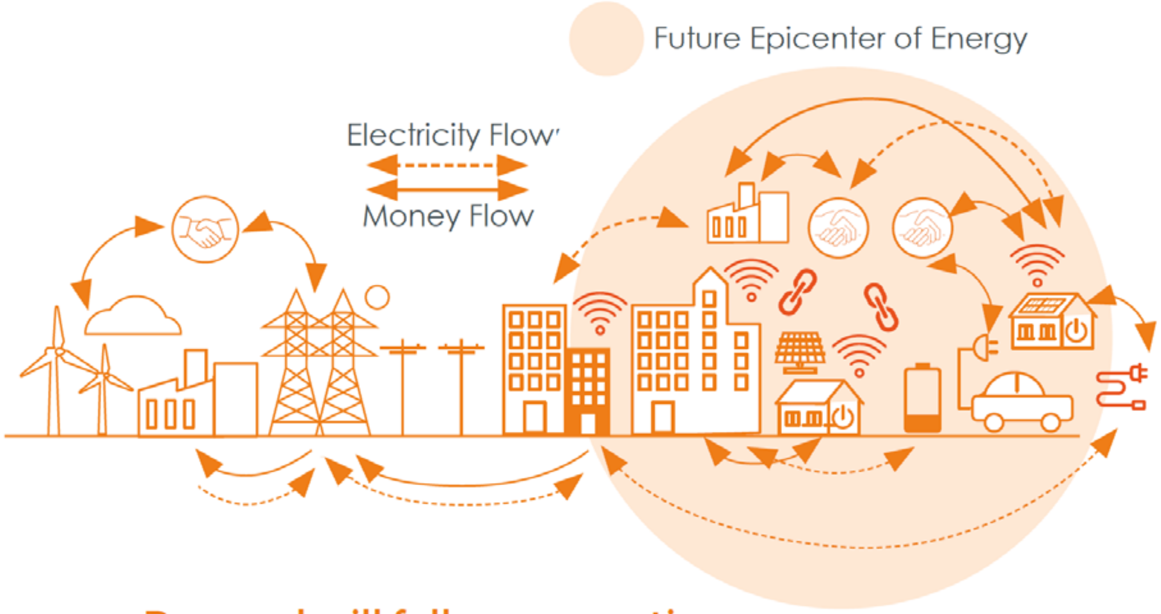


DER : Key Player in Grid Edge Transformation ▶ *Paradigm Shift*



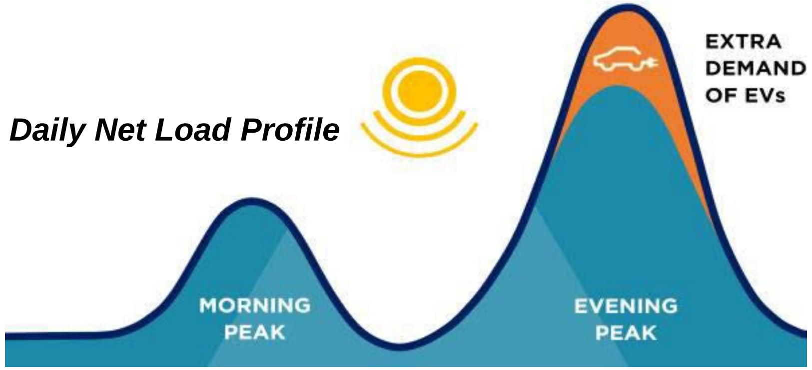
(**Source**: Elia, "For a Successful Energy Transition in a Sustainable World", 2019)

Generation follows consumption

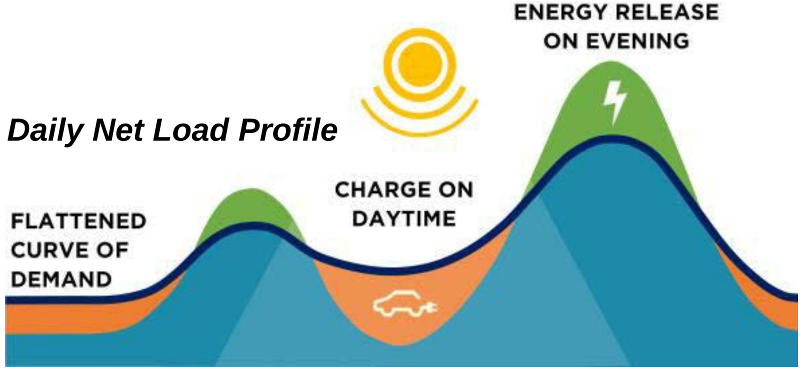


Demand will follow generation

Daily Net Load Profile



Daily Net Load Profile



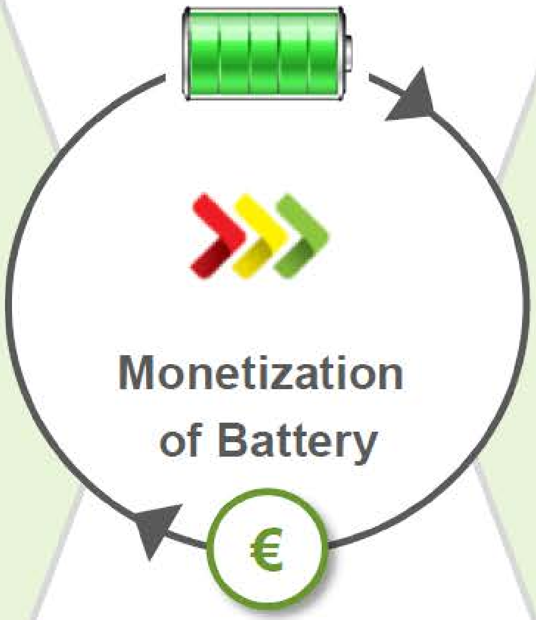
(**Source**: Marco Landi, "Making vehicle-to-grid a reality: V2G Developments in the UK", 2018)

EV as DER ▶ Harmony of Two Industries

Automotive Industry

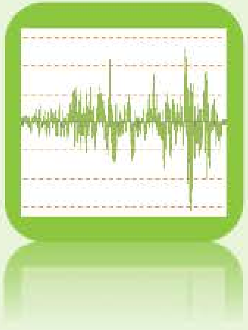
- Growing storage capacity through EVs
- Decreasing battery costs
- Increasing smart connectivity

Abundance of Storage



Power Industry

- Growing grid volatility through renewables
- Decentralized production
- Changing consumption patterns

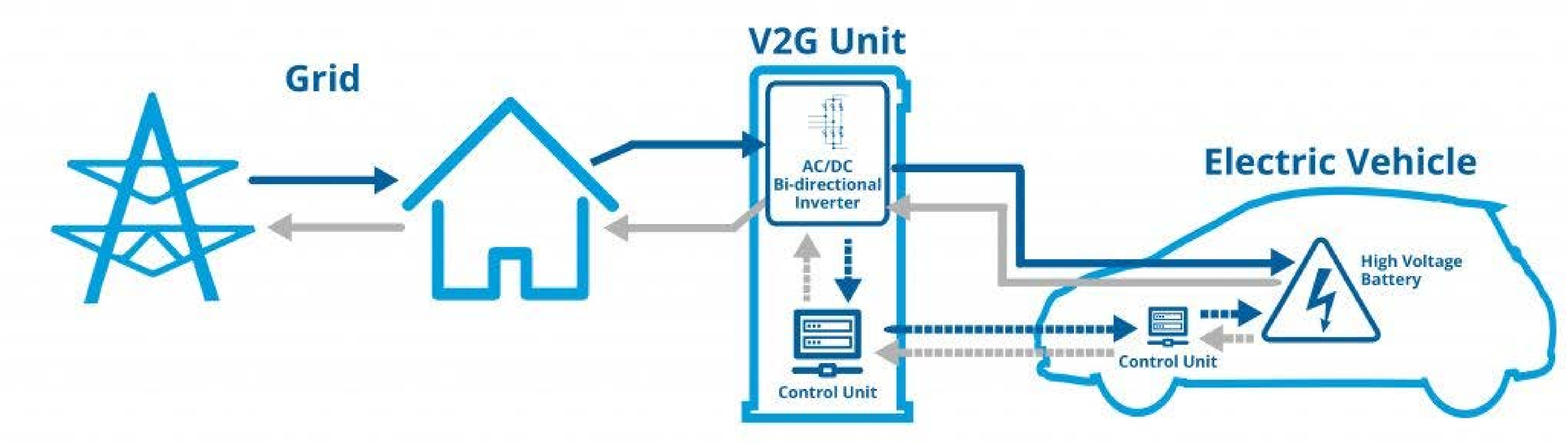


Need for Storage

(*Source: The Mobility House AG, "ELSA - Storage solutions and new services with EV batteries", 2016*)

EV as DER ▶ Vehicle-Grid Integration ▶ Vehicle-to-Grid (V2G)

- EVs act as controllable loads, to smooth load profile and reduce load ramp.
- EVs can act as distributed storage, providing energy back to the power grid.
- EV drivers can earn rewards for providing grid services.
- Moreover, it is not just emission reductions, but also giving resilience under climate change.

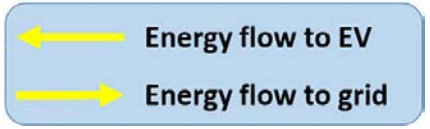


*Note: **V2G** is generally synonymous with Vehicle-Grid Integration (**VGI**) and Grid-Integrated Vehicle (**GIV**).*

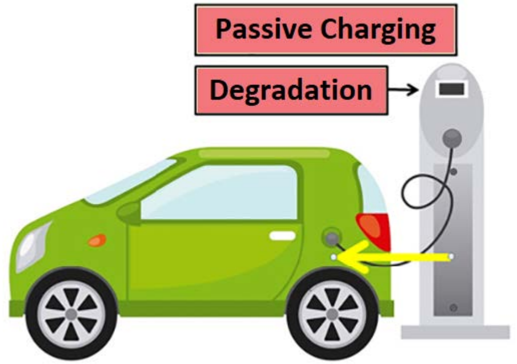
(**Source**: *Cara Clairman et al., "Electric Vehicles as DERs", Distributed Resource Coalition, 2019*)

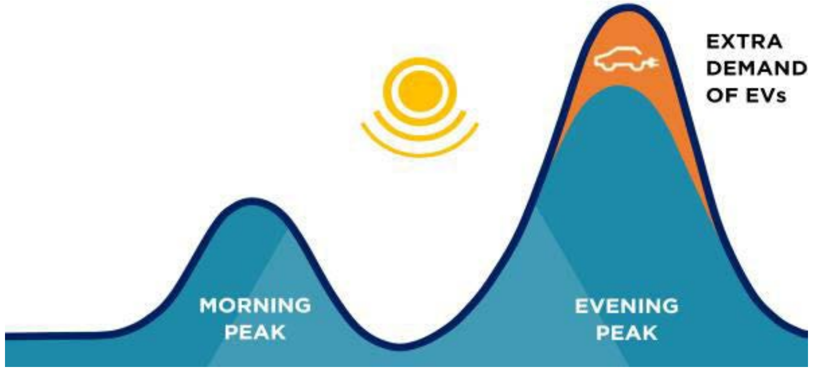
EV as DER ▶ V1G versus V2G

(Source: Philipp A. Gunkel, 2020)

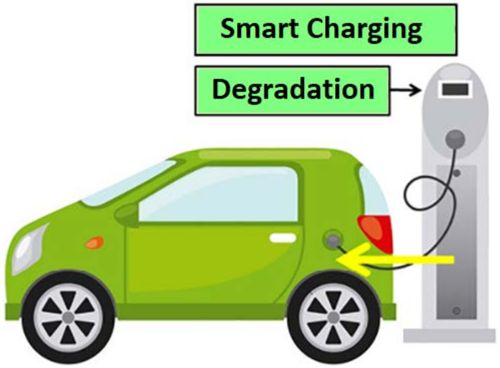


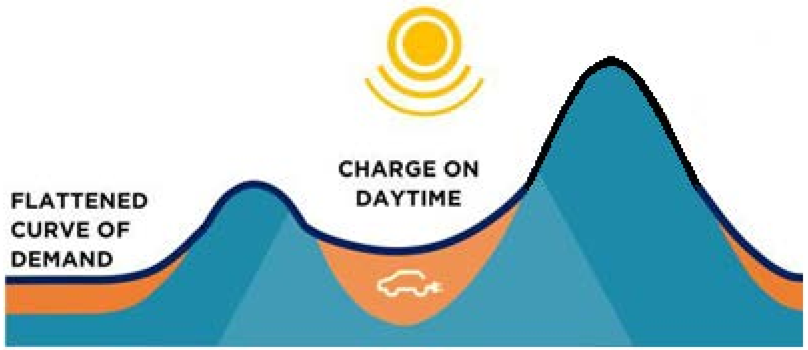
Note: Green boxes indicate the optimized scheduling of energy in combination with battery degradation cost.



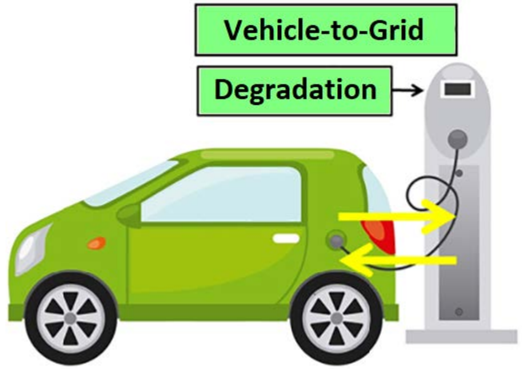


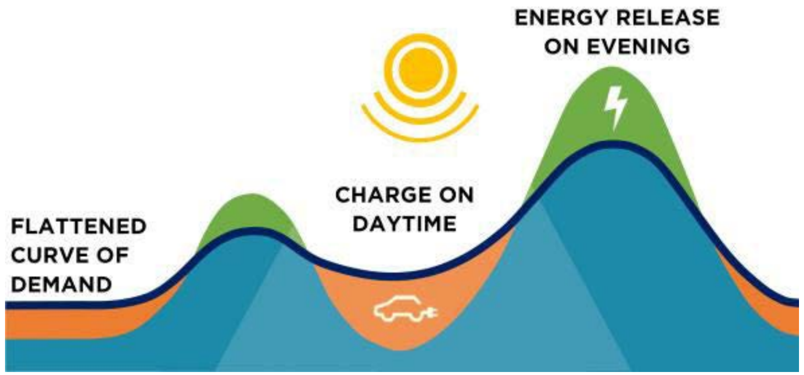
Unmanaged EV Charging (V0G)





Smart EV Charging (V1G)



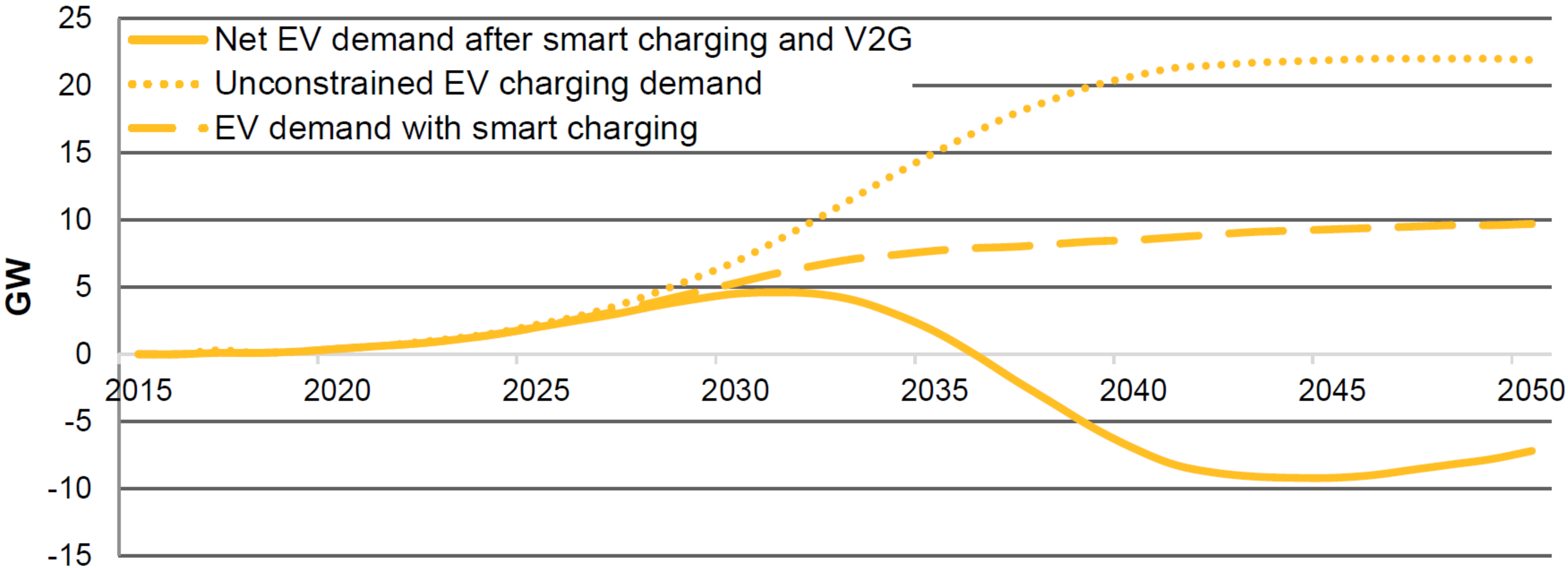


Vehicle-to-Grid (V2G)

(*Source*: Marco Landi, "Making vehicle-to-grid a reality: V2G Developments in the UK", 2018)

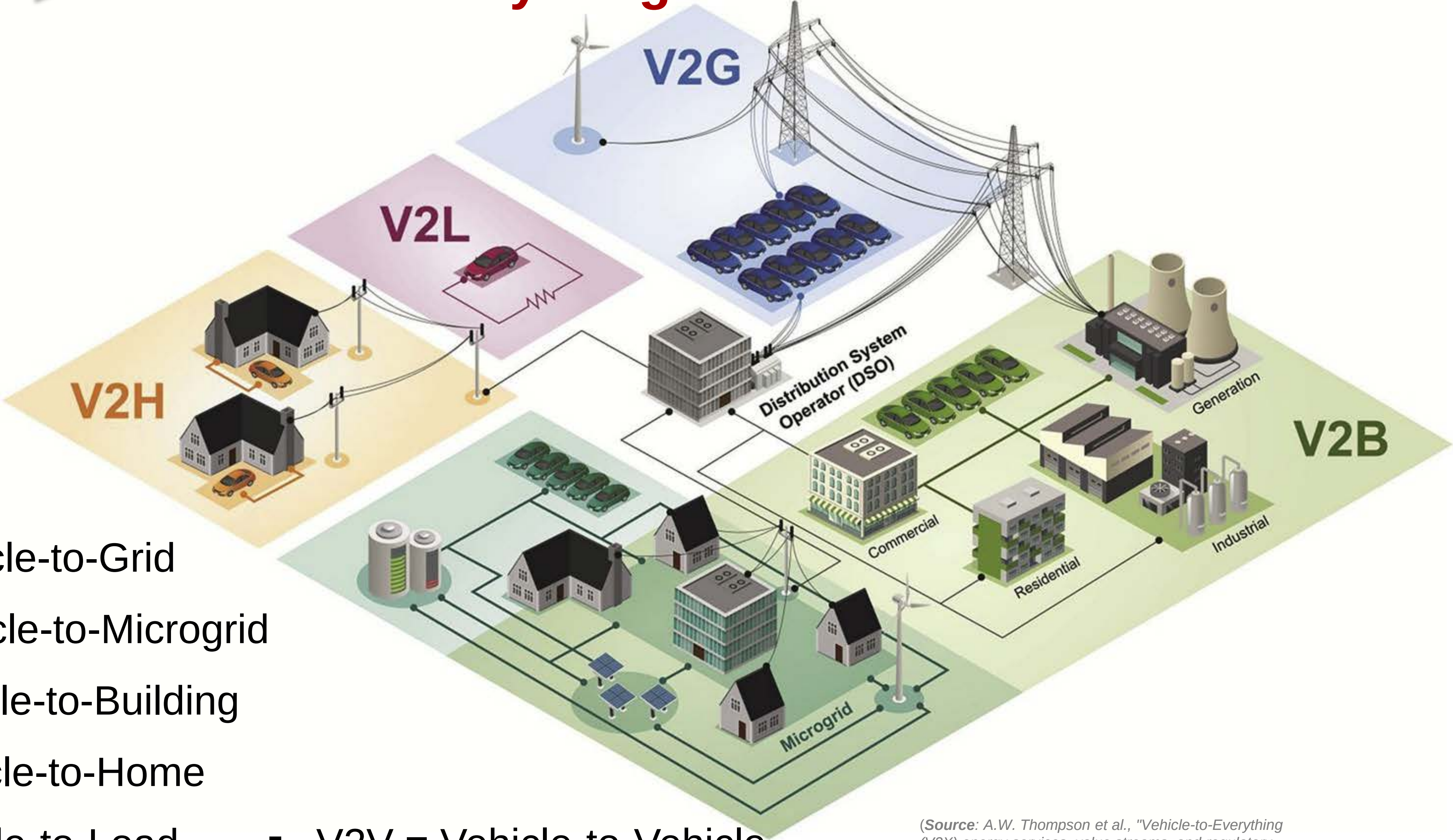
EV as DER ▶ V2G Could Help to Reduce Global Peak Demand

Potential impact of V2G energy technologies on an increase in future peak demand from National Grid (UK) - Future Energy Scenarios 2020



(*Source*: *Department for Business, Energy & Industrial Strategy (UK), "Role of Vehicle-to-X Energy Technologies in a Net Zero Energy System", 2021*)

EV as DER ▶ Vehicle-to-Everything = V2X

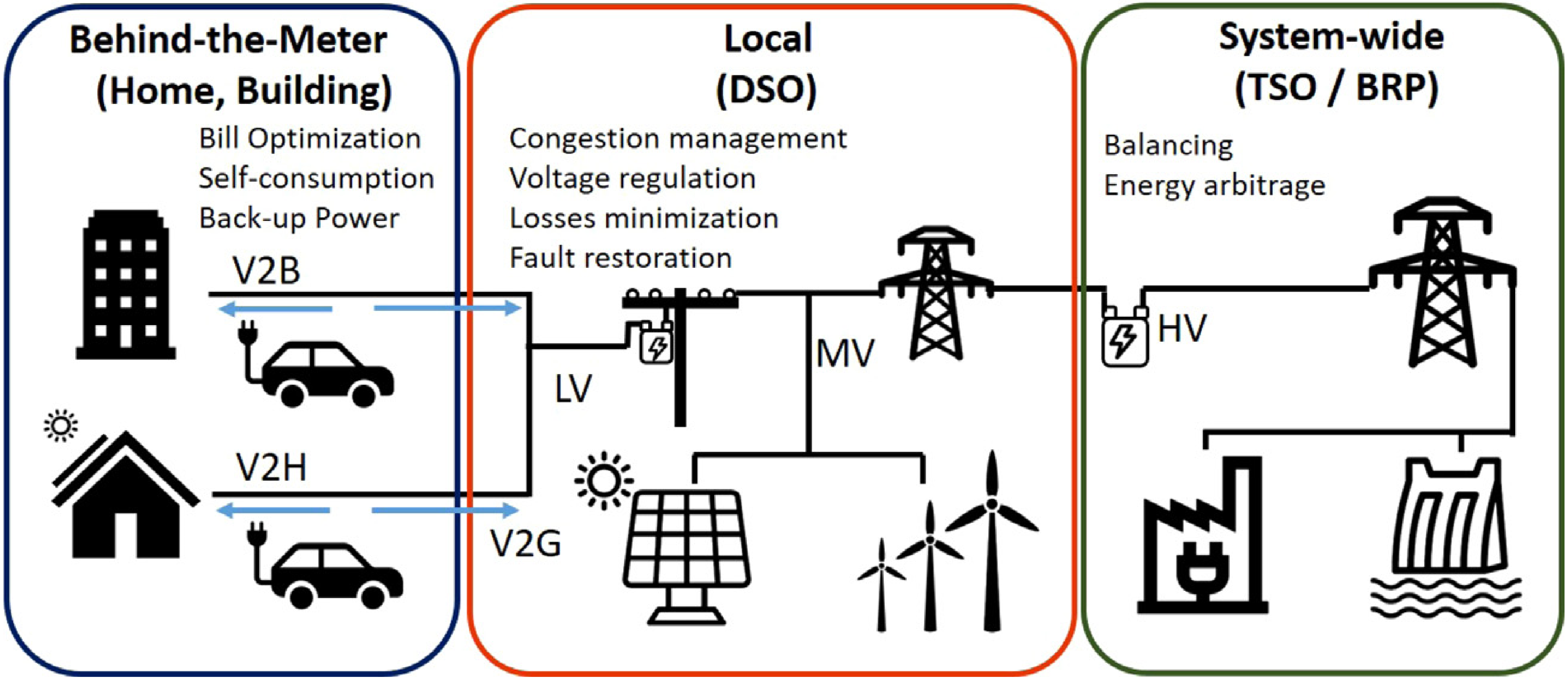


V2X:

- V2G = Vehicle-to-Grid
- V2M = Vehicle-to-Microgrid
- V2B = Vehicle-to-Building
- V2H = Vehicle-to-Home
- V2L = Vehicle-to-Load
- V2V = Vehicle-to-Vehicle

(*Source*: A.W. Thompson et al., "Vehicle-to-Everything (V2X) energy services, value streams, and regulatory policy implications", Energy Policy, 2020)

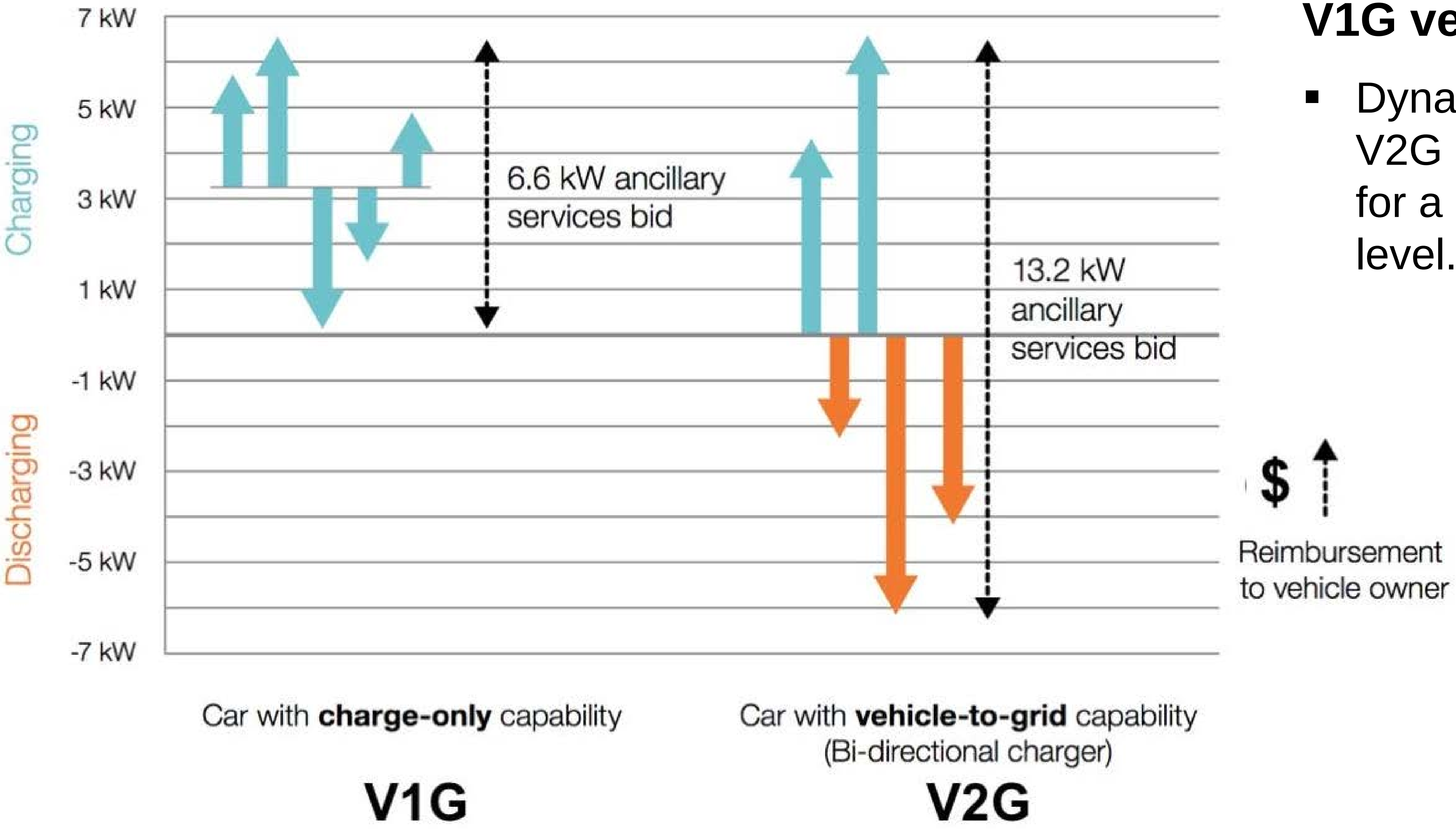
EV as DER ▶ Flexibility Services at Different Grid Levels



(*Source*: F.G. Venegas et. al., "Active integration of electric vehicles into distribution grids: Barriers and frameworks for flexibility services", Renewable and Sustainable Energy Reviews, Vol.145, July 2021)

Note: DSO = Distribution System Operator, TSO = Transmission System Operators, BRP = Balance Responsible Party

EV as DER ▶ V1G & V2G Capabilities for Grid Flexibility

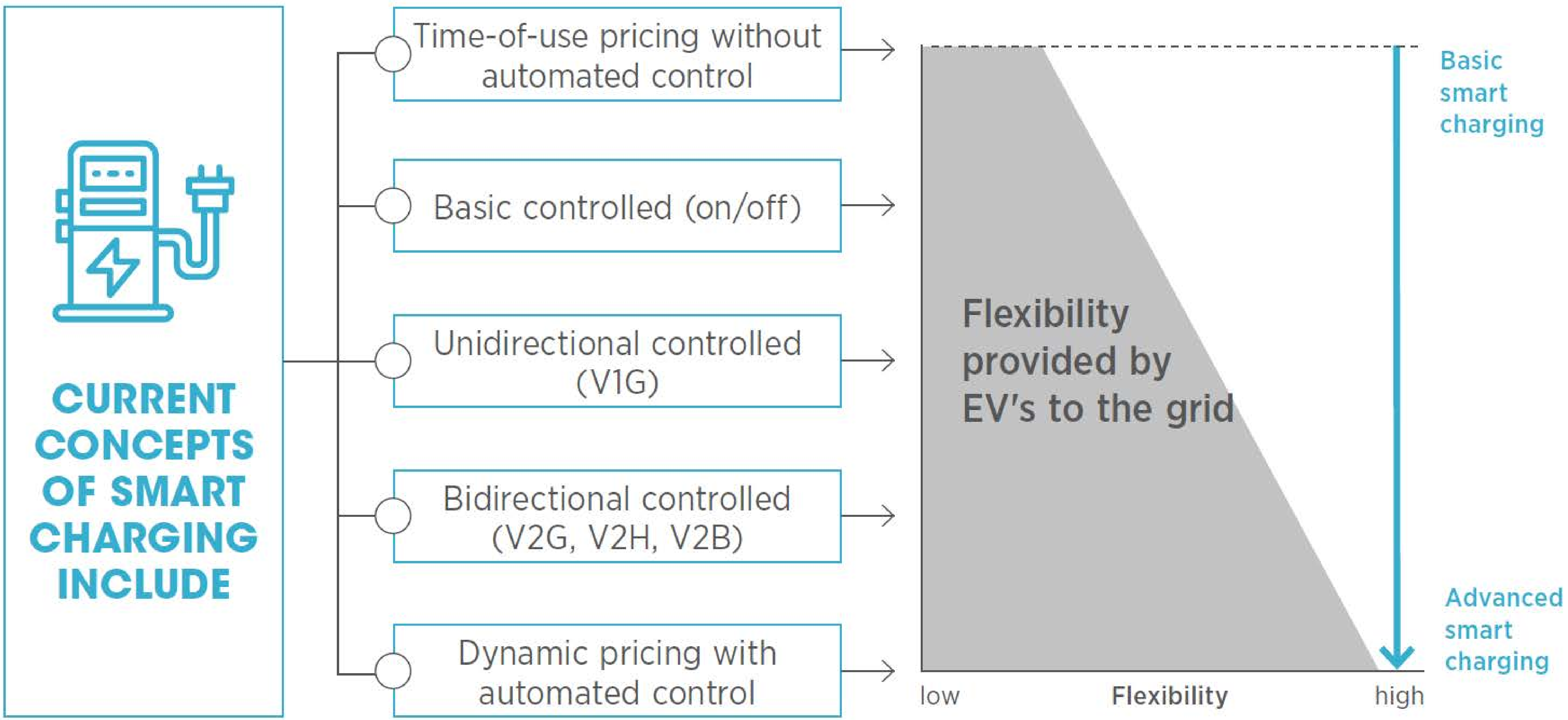


V1G versus V2G:

- Dynamic power range of V2G is twice that of V1G for a specified charging level.

(**Source**: *Jeffery Greenblatt et al., "Quantifying the Potential of Electric Vehicles to Provide Electric Grid Benefits in the MISO Area", 2019*)

EV as DER ▶ Grid Flexibility at Different EV Control Schemes



(*Source: IRENA, Innovation landscape brief: Electric-vehicle smart charging, 2019*)

EV as DER ▶ Examples of Available EV Models for V2L/V2H/V2G

Electric Vehicles with bidirectional charging capability 🚗🔌🔋⚡🔛 *List of V2G, V2H, V2L compatible electric cars.* Source: zecar

Vehicle	🔋 size (kWh)	Days storage	Port	V2L	V2G	V2H	Availability
Nissan Leaf (ZE1)	36-62	1.7-3	Chademo	❌	✅	✅	Yes
Mitsubishi Outlander (plug-in)	13.8	0.7	Chademo	✅	✅	✅	Yes
Ford F-150 Lightning	98-130	4.7-6.2	CCS	✅	✅	✅	July 2022 (US)
Hyundai Ioniq 5	54-77.4	2.6-3.7	CCS	✅	TBC	TBC	Yes
Kia EV6	54-77.4	2.6-3.7	CCS	✅	TBC	TBC	Yes
BYD Atto 3	50.1-60.4	2.4-2.9	CCS	✅	TBC	TBC	July 2022 (Aus)
MG ZS EV (2022)	49-68	2.3-3.2	CCS	✅	TBC	TBC	July 2022 (UK)
Porsche Taycan	71-83.7	3.3-3.9	CCS	TBC	TBC	TBC	TBC

Note: CCS = Combined Charging System, TBC = To Be Confirmed

EV as DER ▶ Examples of Available EV Models for V2L/V2H/V2G

ELECTRIFICATION T&DWorld

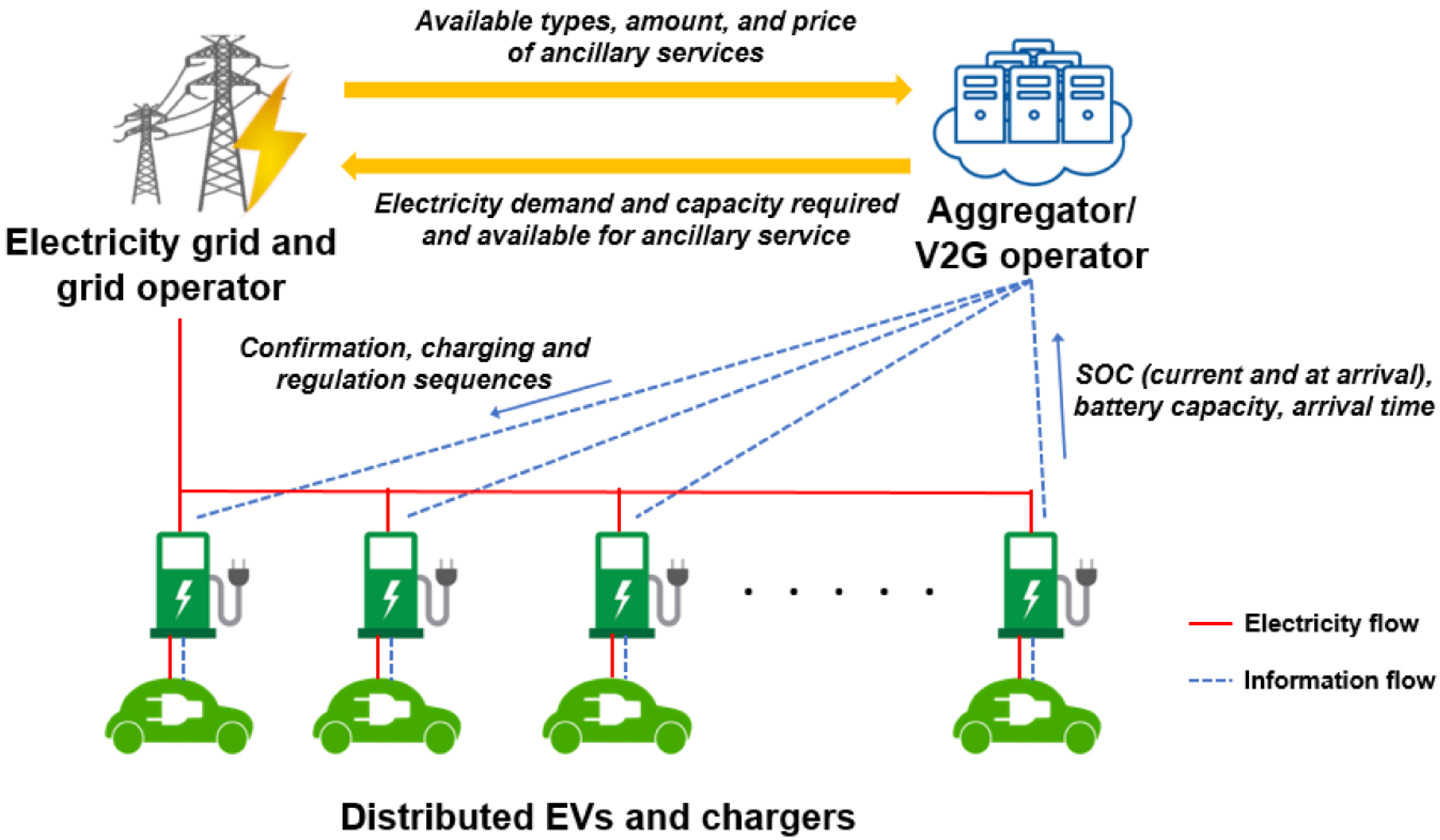
Duke Energy to Explore How Ford F-150 Lightning Electric Trucks Can Serve as Grid Resource

Aug. 23, 2022

Powerful Ford F-150 Lightning all-electric truck batteries have vehicle-to-grid two-way charging capabilities.

(**Source**: *https://electrek.co/2022/03/01/ford-launches-bi-directional-home-charging-station-surprisingly-good-price/*)

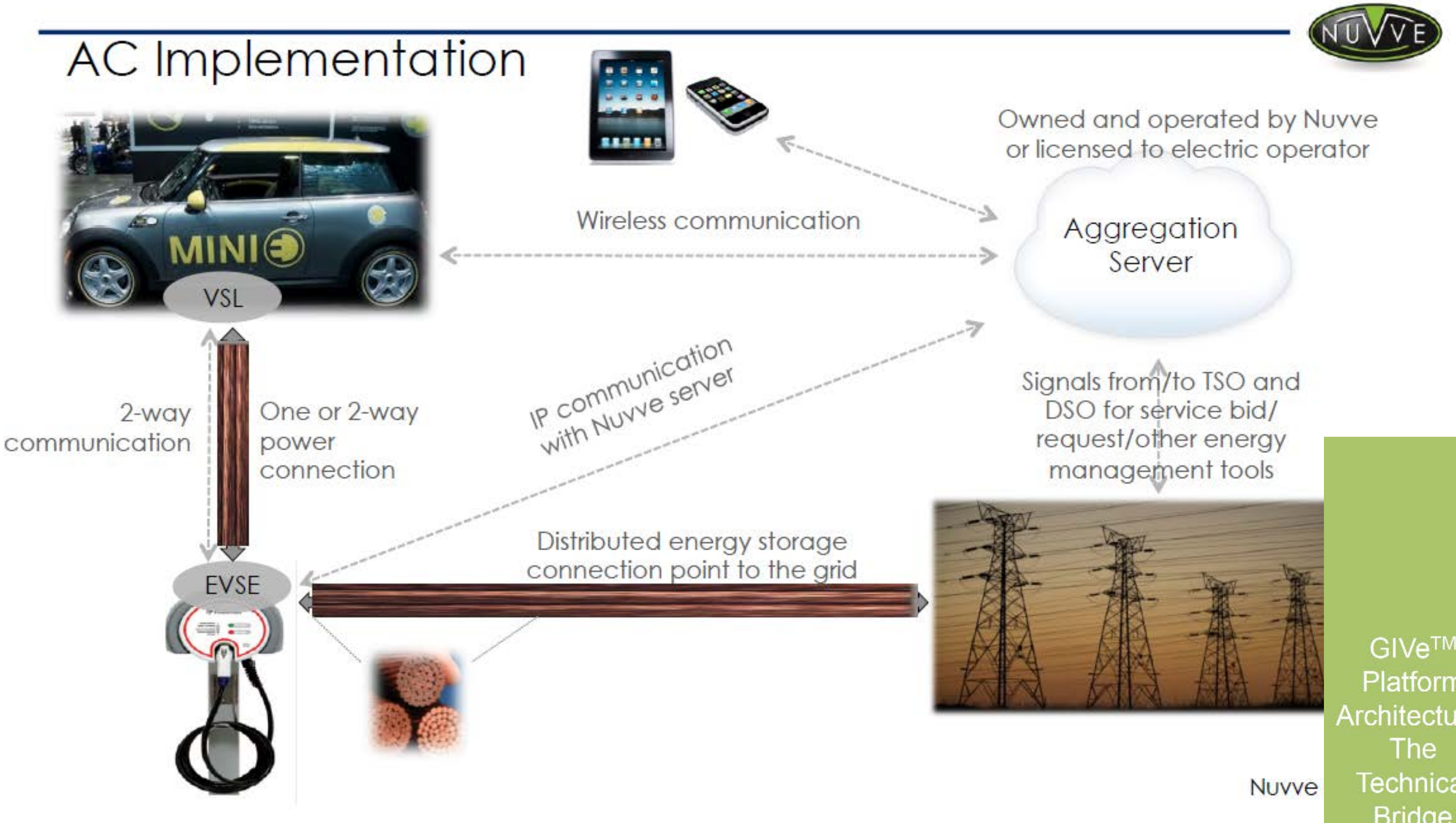
EV as DER ▶ Aggregator's Role for Grid Services



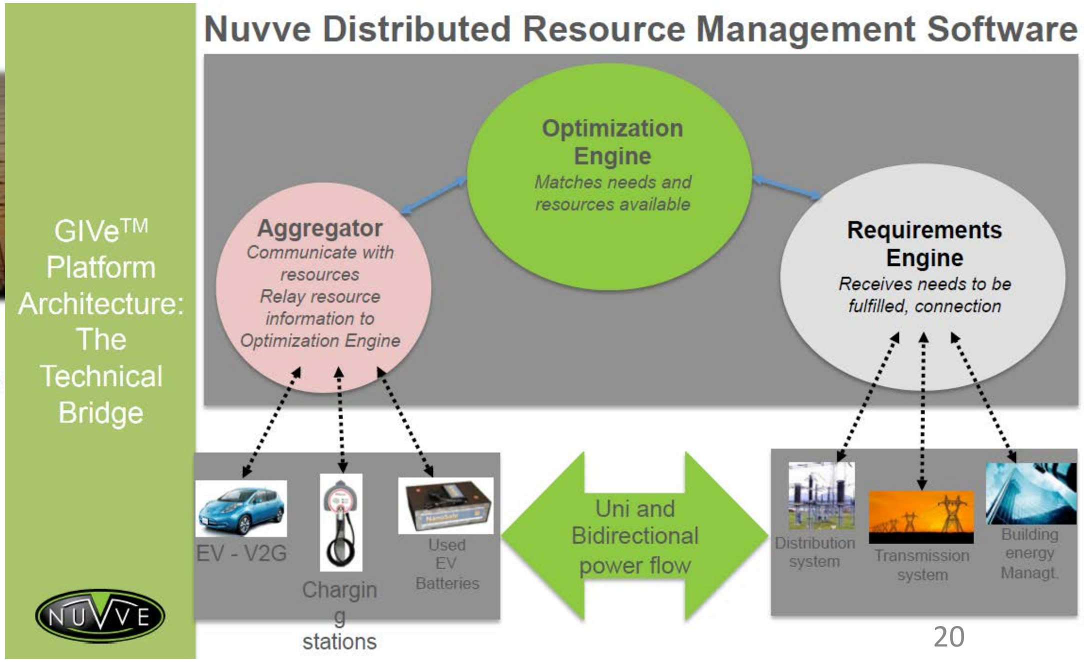
(**Source**: *Sai S. Ravi et al., "Utilization of Electric Vehicles for Vehicle-to-Grid Services: Progress and Perspectives", Energies, 2022*)

Practical Use Cases : Vehicle-Grid Integration (Aggregator Platform)

Grid Flexibility Services Provided by Electric Vehicles (EVs)



(**Source**: NUVVE: V2G & Deployments, 2017)



Practical Use Cases : Vehicle-Grid Integration (Grid Services)

Grid Flexibility Services Provided by Electric Vehicles (EVs) in US, Denmark, UK

UD "Demand-side Resource"
PJM regulation: $1,200 / EV / year

Energinet.dk Primary reserves market, earning €1,600/EV/year

Testing 3-phase charging standards at National Renewable Energy Lab, Golden, CO

Examples of GIV Systems in Operation

UK, Commercial GIV Fleets, multiple grid services – installed 2019/2020

V2G Manufacturers:

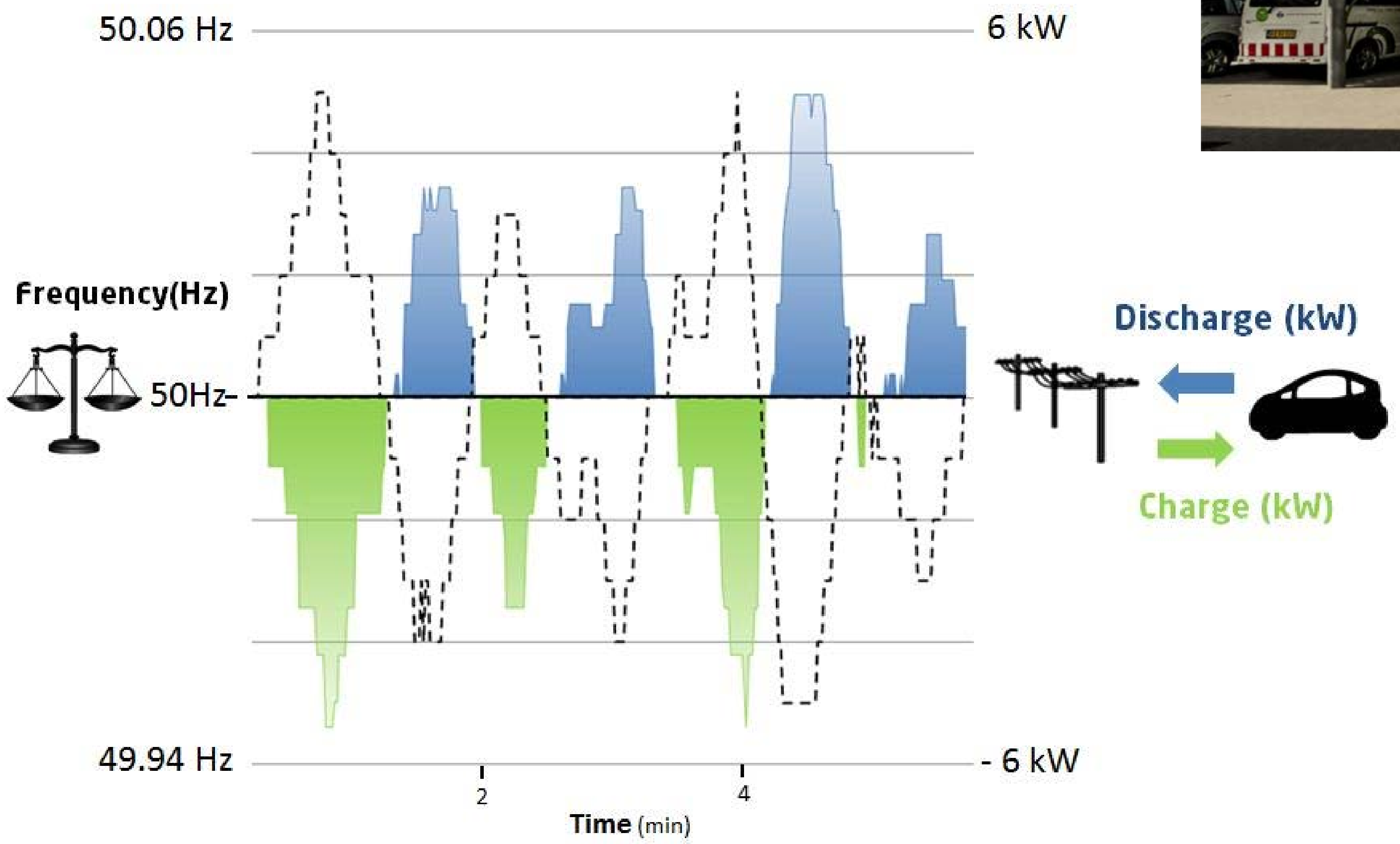
- **BMW** (demonstrations)
- **Honda** (Pre-production EVs with AC V2G built-in)
- **Nissan Europe** (selling Leafs & eNV200s warranted for V2G via DC)
- **The Lion Electric** (selling AC V2G busses)
- **BYD** (40 kW AC V2G demonstration, 28 transit buses)
- **Bluebird** (DC V2G buses, pre-production)
- **Renault** (mass produced AC V2G capable vehicle)

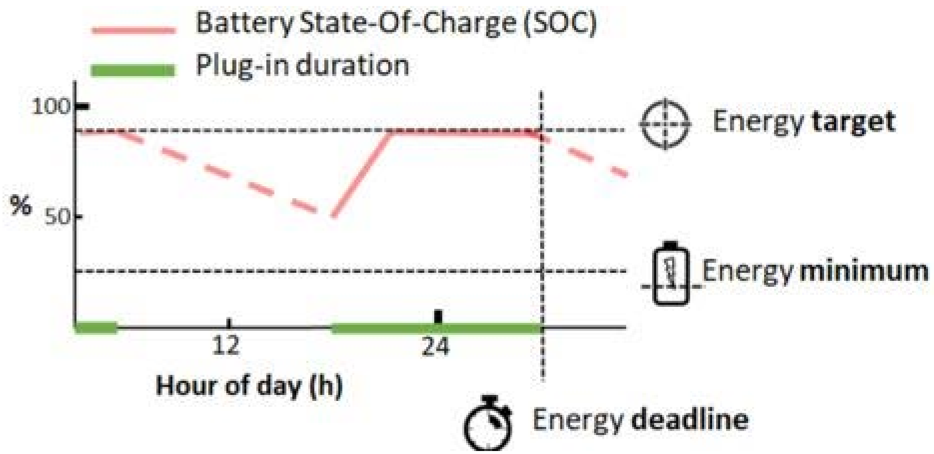
(*Source*: Sara Parkison, "Electric Vehicles as Grid Assets: GIV Technology and Policy Considerations", Electric Vehicle Grid Integration Policy Summit, 2020)

Practical Use Cases : Vehicle-Grid Integration (Frequency Control)

Grid Flexibility Services Provided by Electric Vehicles (EVs) in Denmark

- 10 x Nissan eNV200 electric vans
- 10 x ENEL V2G units (bi-directional 10 kW)
- Usage hours = Working days from 7 AM to 4 PM



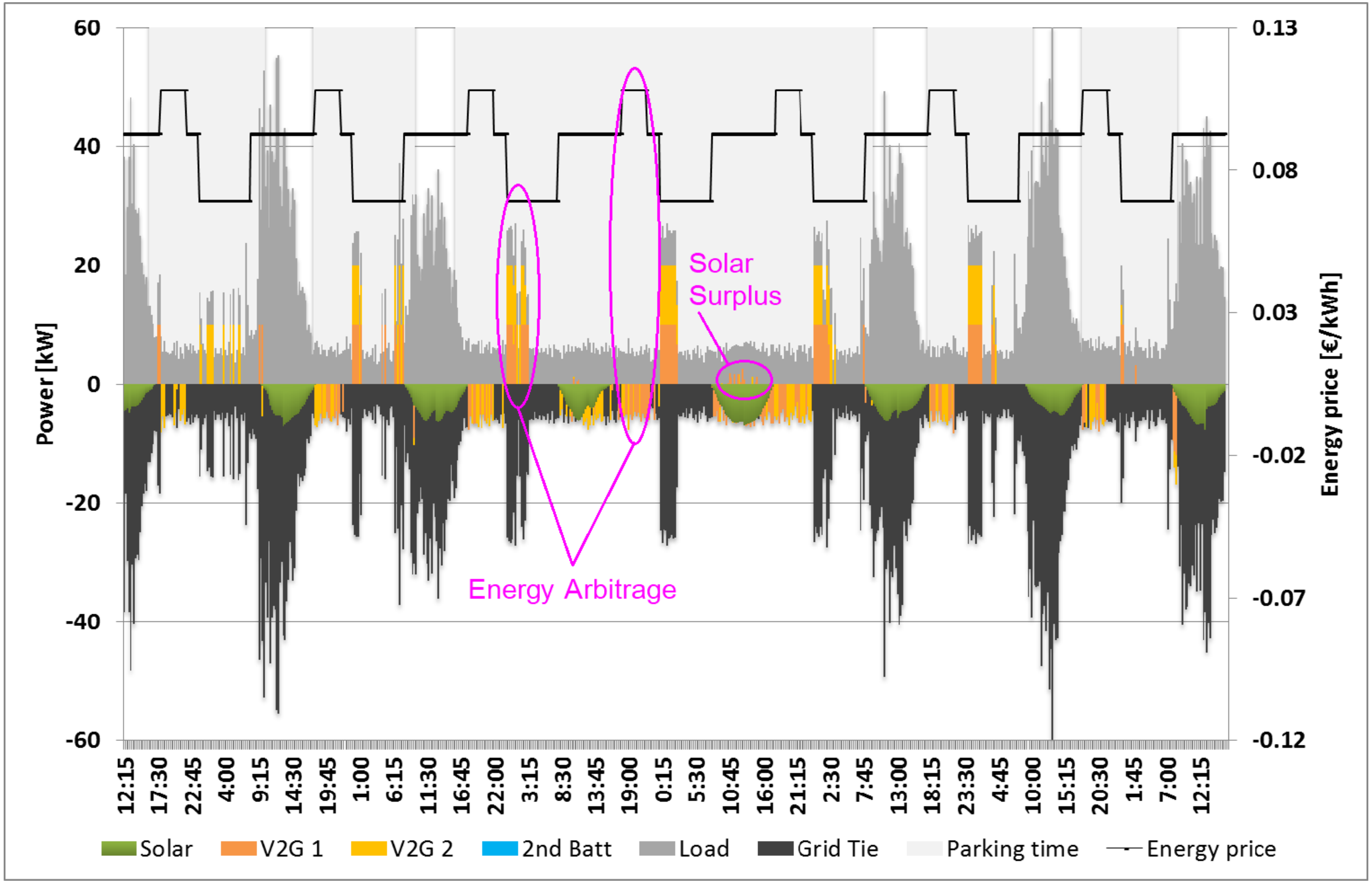


Energy target and time setting

Potential earning with 10kW V2G units = 120 Euro/Month per Vehicle

(**Source**: P.B. Andersen, "The Parker Project in Denmark - First Results", 5th International Conference on Electromobility: Challenging Issues, 2017)

Practical Use Cases : V2G Tests at Nissan offices in Barcelona



(**Source**: *Cristina Corchero et al., "Optimal energy management system for V2G chargers combined with PV and ESS in a real environment", 2019*)

Food for Thought ▶ Energy Independence and Resilience

Source: zecar

Energy Fact	
Average household consumption	21.5kWh
Tesla Powerwall 2	13.5kWh
Nissan Leaf e+ 🔋	62.0kWh

Annual degradation analysis

	Distance	Energy	Degradation
Driving 🚗	13,260 km	2,130 kWh	0.3%
Energy storage 🔋		3,524 kWh	0.6%

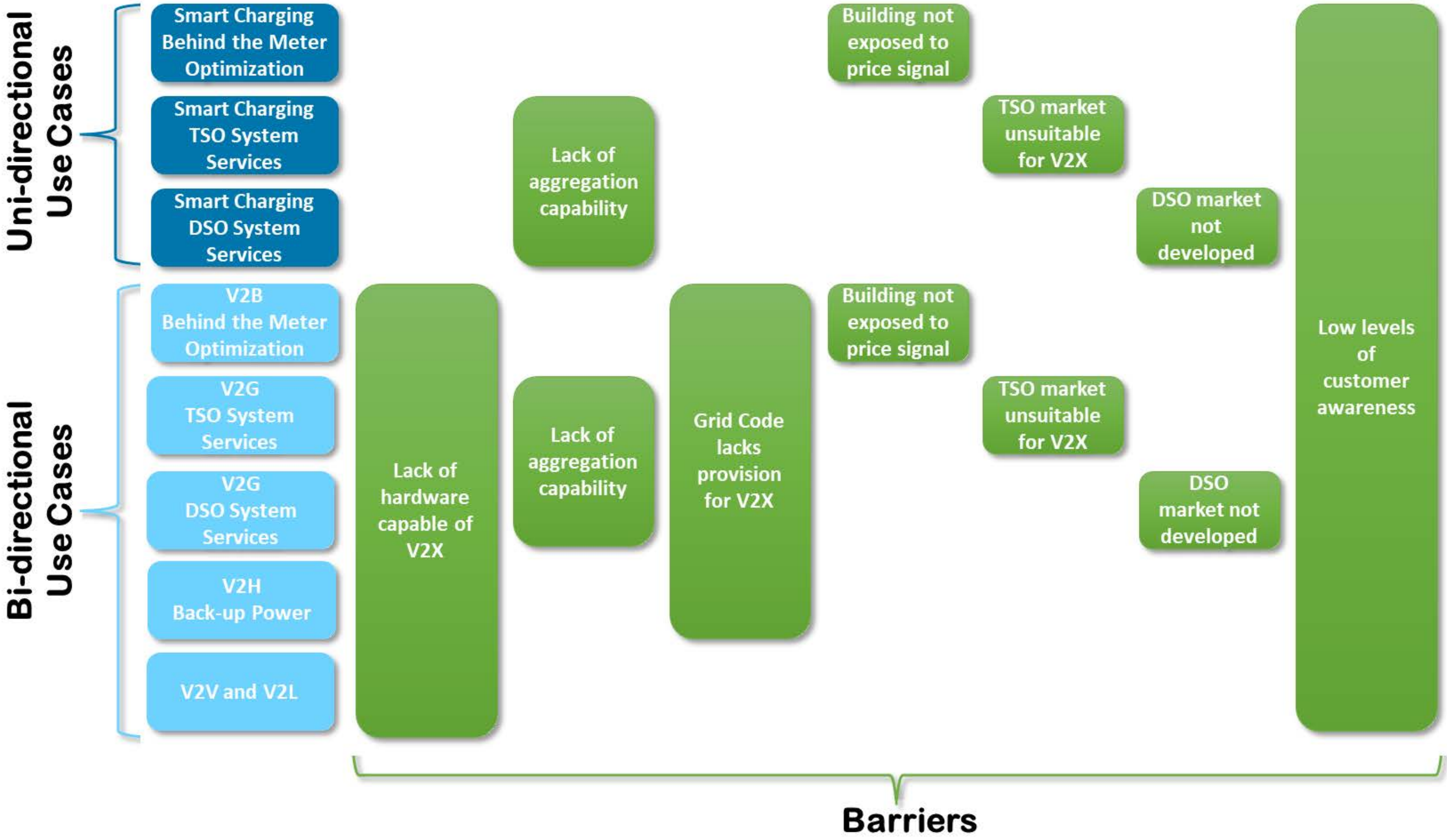
Degradation comparison after 8-years

	Battery SoH	capacity loss (kWh)	Range loss (km)
Driving 🚗	97.9%	1.5	9.6
V2H 🔋	93.4%	3.3	20.5

The price per additional kWh between a '*standard range*' and '*extended range*' of the car models is $300 per kWh approximately.

✓ The economic cost of degradation is approximately $1,000. With V2H expected to save an additional $5,000 over the 8-year ownership period (in reduced electricity bills), the economic case for V2H here is strong.

Food for Thought ▶ Vehicle-Grid Integration Barriers



V2G @ Warwick, UK

***Source**: https://transportandenergy.com/*

V2G charge points can improve the battery life of EVs, project finds

TRANSPORT +ENERGY

June 8, 2022 · Alec Peachey · 902 Views

Vehicle-to-grid (V2G) can balance the calendar and cycling aging (both of which affect the rate of battery degradation) to optimise the battery condition and improve its health by 8.6 – 12.3% over one-year's operation, compared to conventional charging alone – equivalent to one extra year of use.

***The EV-elocity Project**, funded by Innovate UK*

(**Source**: *Cristina Corchero et al., "V2X Roadmap", IREC, 2019*)

Conclusions

- EVs fit well into all the three categories of DERs: generator, storage, demand mgmt.
- More EVs mean more microgrid/nanogrid capabilities. ▶ Reliability & Resilience
- EVs can provide all-in-one flexibility to power grids. ▶ Local & Global benefits
- Full utilization of V2G required effective regulatory & financial incentives to facilitate:
  - Grid codes / Grid services / Aggregator platforms
  - Bi-directional chargers: on-board / off-board
  - Time-of-Use (ToU) / Electrical outlet with IoT metering at office parking lots
- Understanding of EVs' battery life (battery degradation) affected by V2G services is also another important factor for extensive consumers' adoption.

Thank You Very Much for Your Attention !!

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