EVKG: An interlinked and interoperable electric vehicle knowledge graph for smart transportation system

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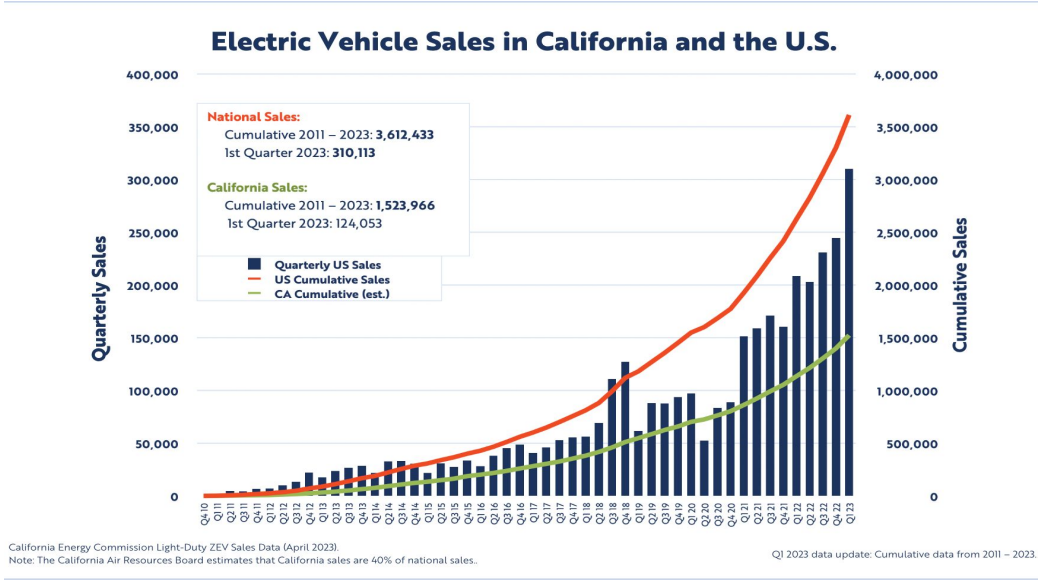
Emphatic Transition to Vehicle Electrification

- Increasing EV adoption
- Positive regulatory mandates

The FHWA has designated EV corridors on approximately 59,000 miles of the NHS



California Energy Commission Light-Duty ZEV Sales Data (April 2023).
Note: The California Air Resources Board estimates that California sales are 40% of national sales..

Q1 2023 data update: Cumulative data from 2011 – 2023.

Data Management Complexity of EV Industry

Diverse Vehicle Configurations:

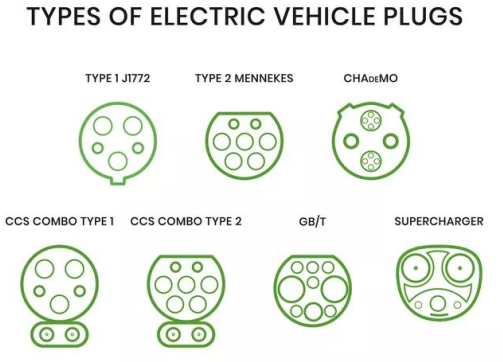
- Different EV models have different battery capacities and charger types.

Diverse EV Supply Equipments(EVSE) system:

- EV charging stations, operated by diverse providers, have different constraints.

Charging Infrastructure and Power Grid Management:

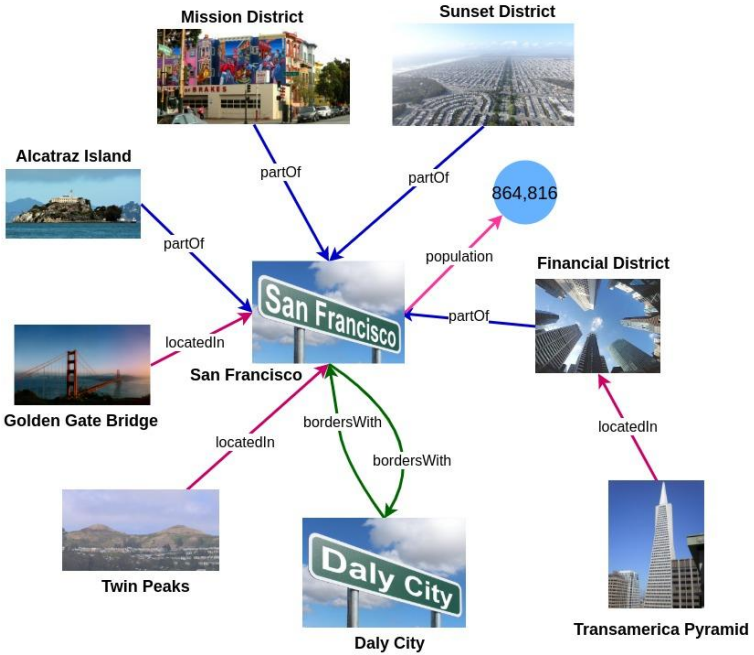
- Proper charging station site selection is crucial for power grid sustainability.



Knowledge Graphs

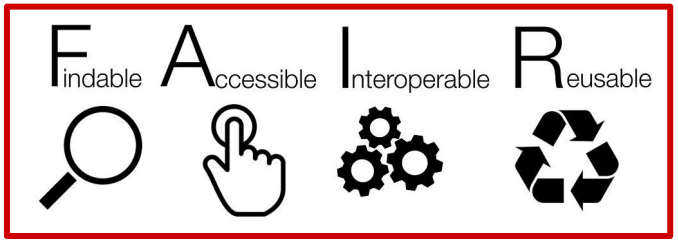
A **knowledge graph (KG)** is a data repository that stores real-world knowledge under some schema, e.g., an ontology.

- **Directed multi-graphs**
  - Nodes: entities
  - Edges: relationships between entities with relation types as labels
  - Statement: <subject, predict, object>



Why use Knowledge Graphs for EV data Management?

- Decentralized, but standardized (e.g., W3C, OGC)
- Semantically rich, and diverse (ontology engineering and alignment)
- Extensible and flexible
- Human and machine readable
- foster interoperability across different domains



TABLE

M	D	ER
36417	1883	KRA
57	1980	MSH
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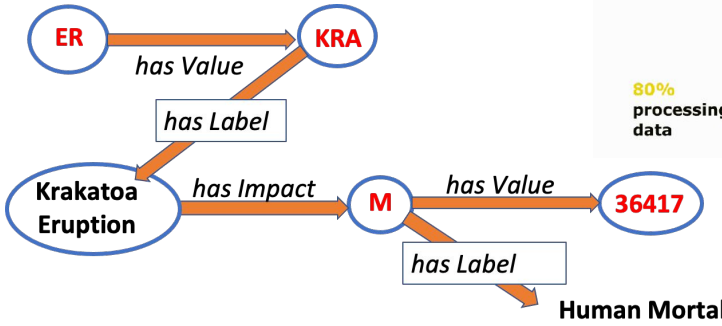
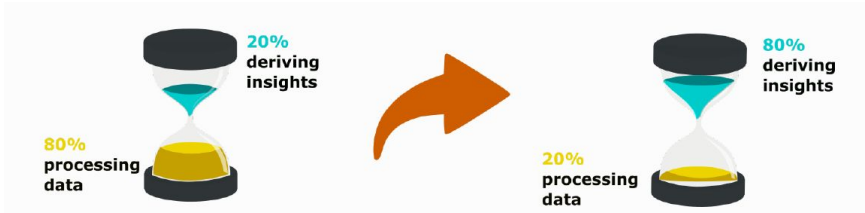
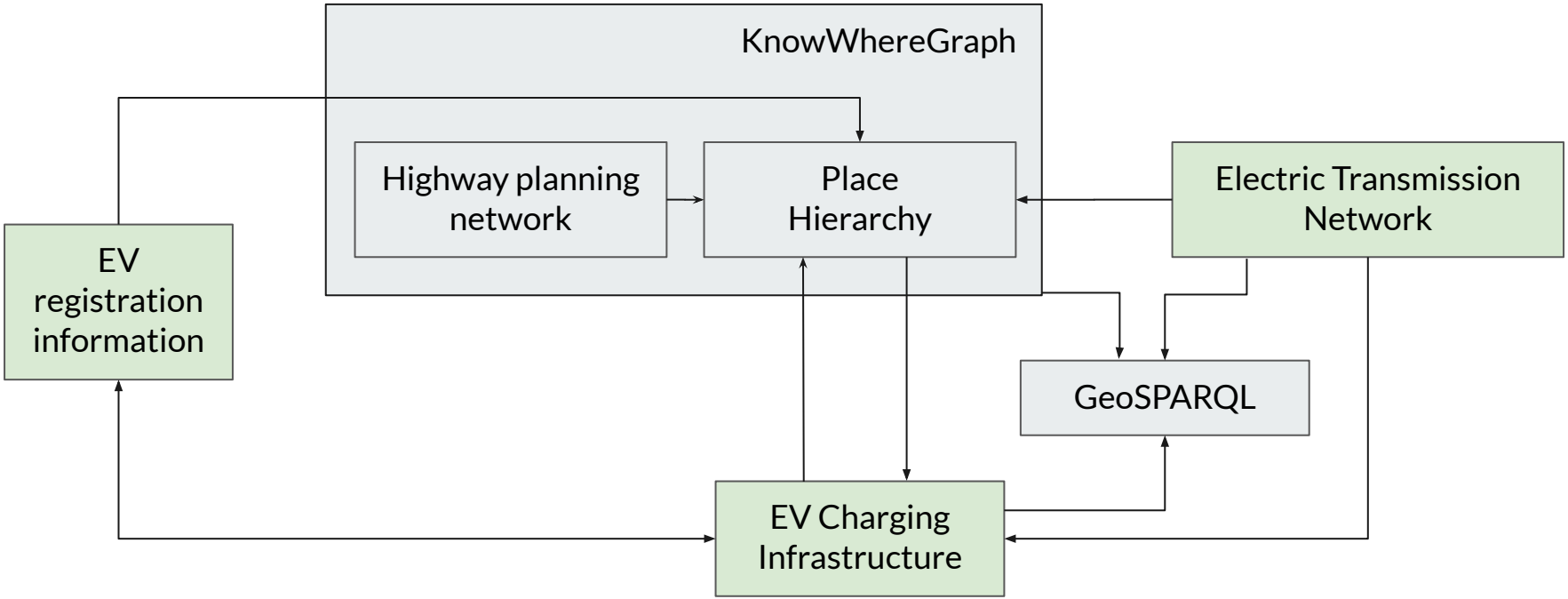
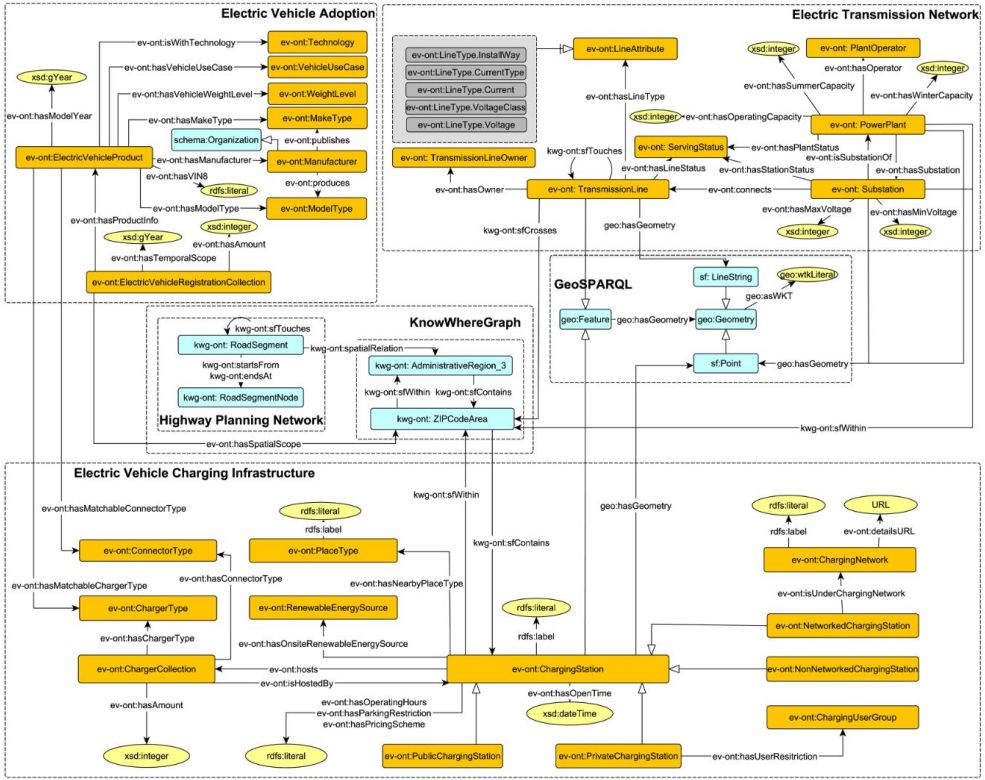




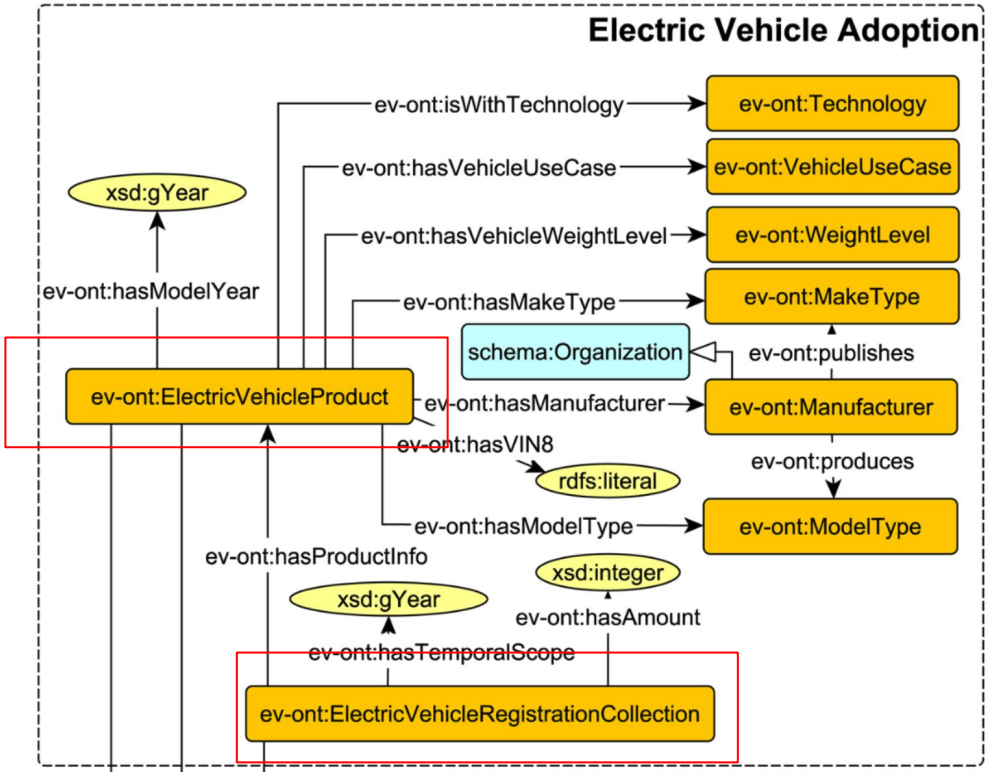
Core Modules of EVKG



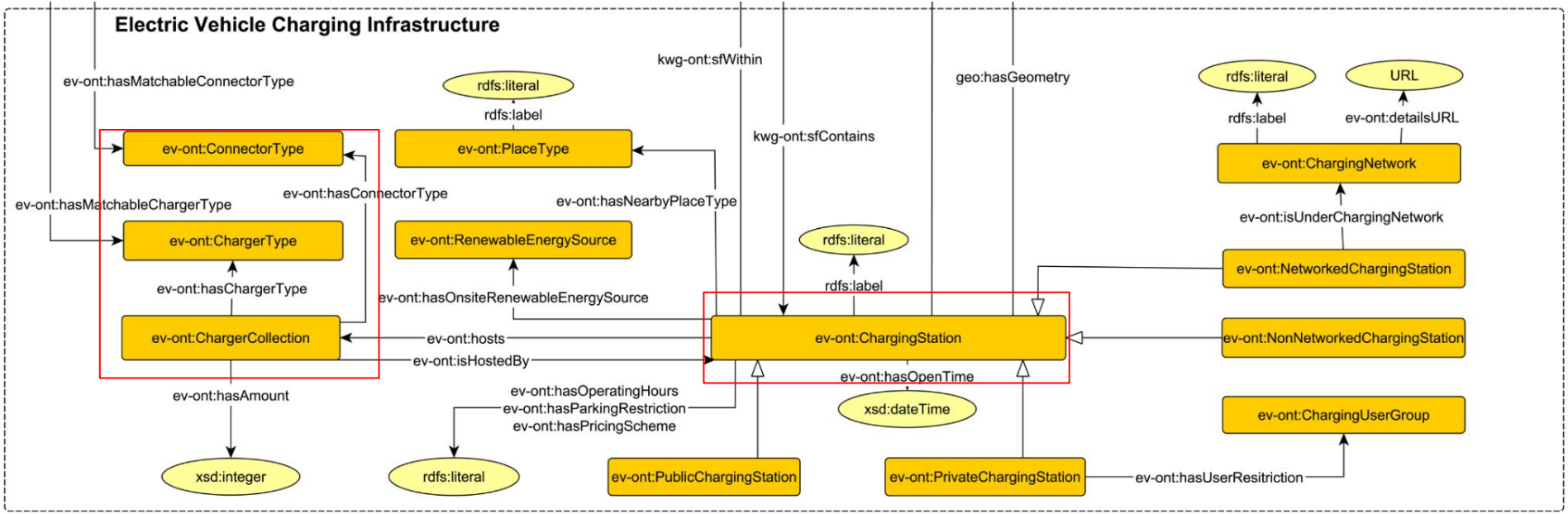
Ontology Design for the EVKG



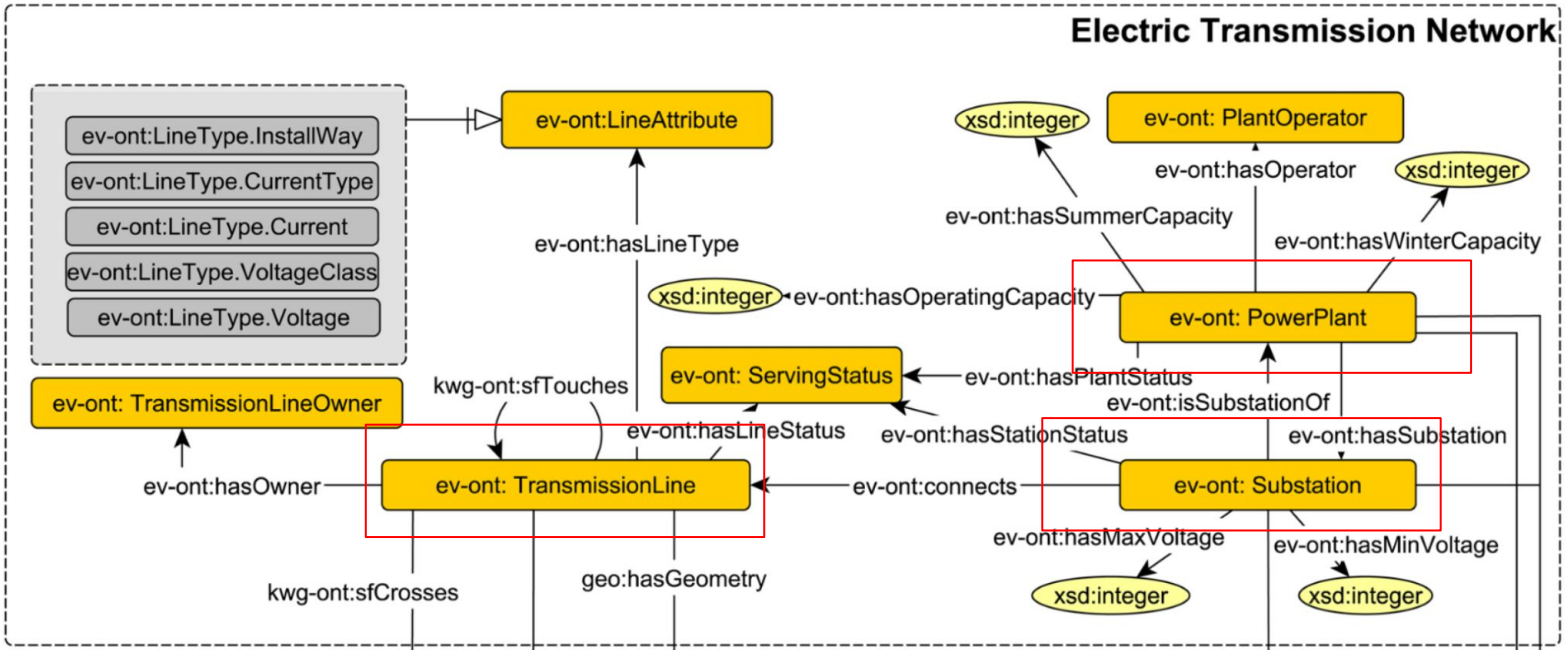
Submodule of EV Adoption



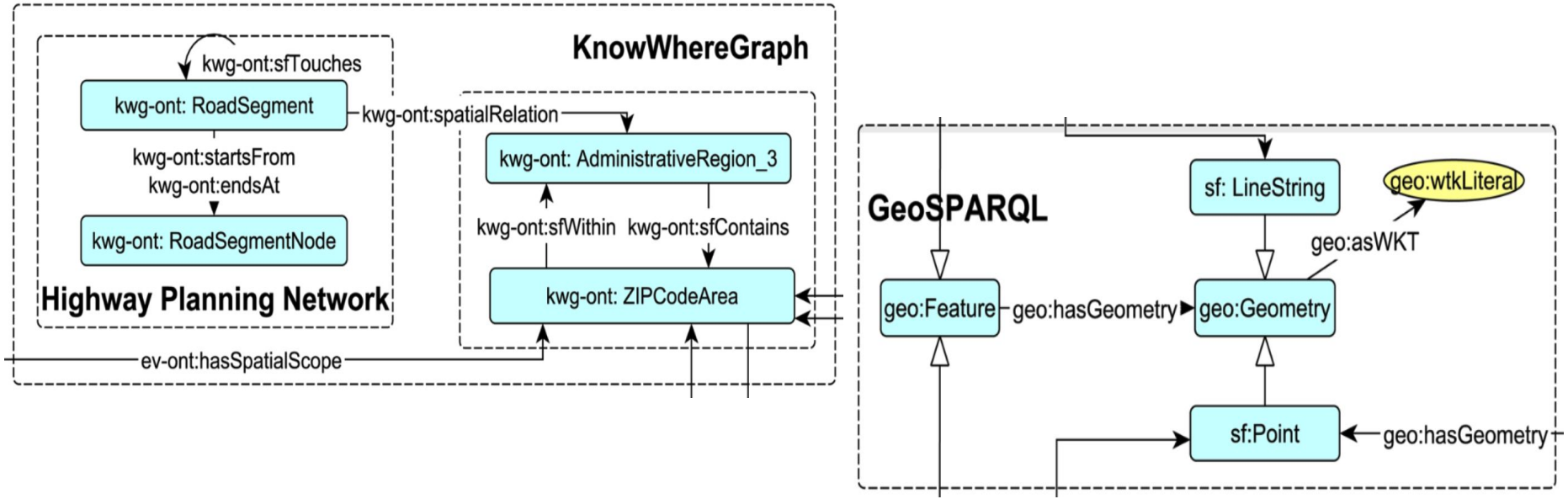
Submodule of EV Charging Infrastructure



Submodule of Electric Transmission Network



Reused Submodule From KWG and GeoSPARQL



Group 1: Semantic and geospatial questions

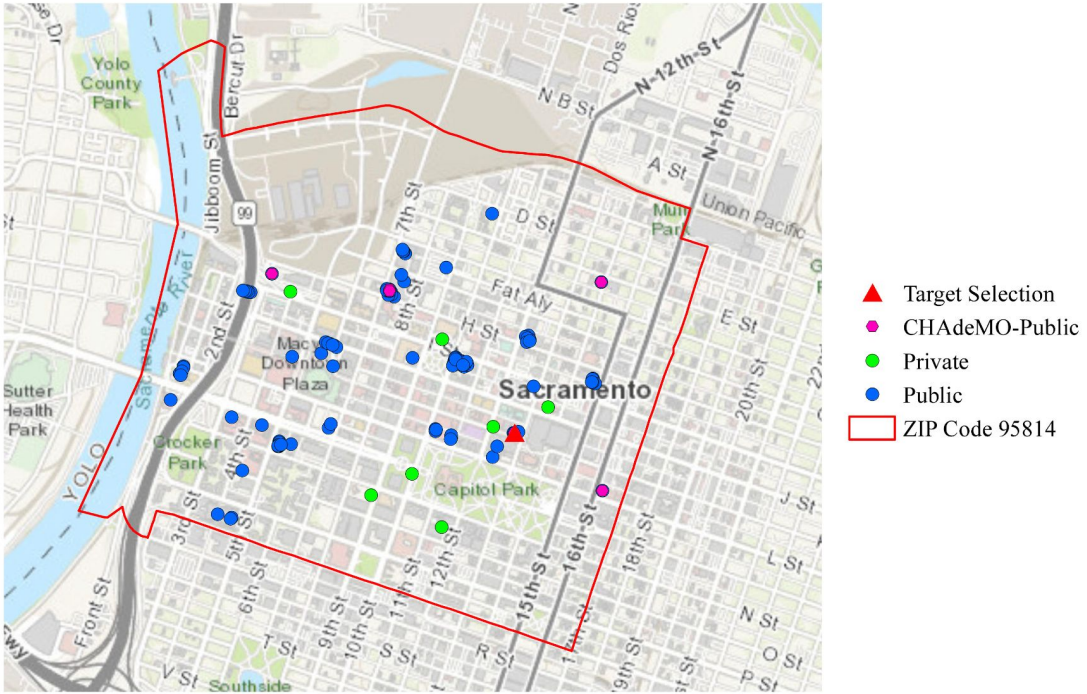
Q1. Semantic Questions
Which [*electric vehicle products]* have charging cables that match the ***[CHADeMO connector type]***?

Q2. Geospatial Questions
Which *[charging stations/road segments/transmission lines/power plants/ substations]* are ***[located in/pass through] [King county]***?

Group 1: Semantic and geospatial questions

Q3. Semantic and Geospatial Questions

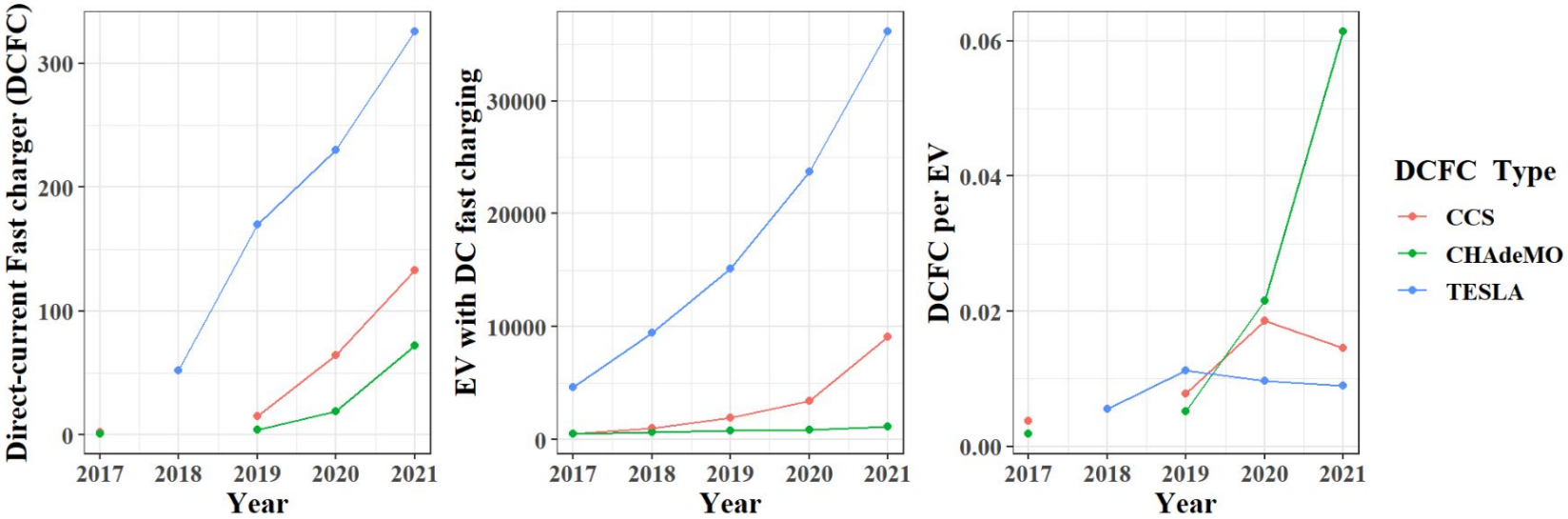
Which and **where** are the ***[public charging stations]*** operating ***["24 hours daily"]*** that a ***[Nissan Leaf 2021]*** vehicle with a membership of the ***[ChargePoint]*** network can use for ***[fast charging]*** within ZIP code ***[95814]***?



Group 2: Spatial and temporal aggregation questions

Q4. Temporal Aggregation Questions

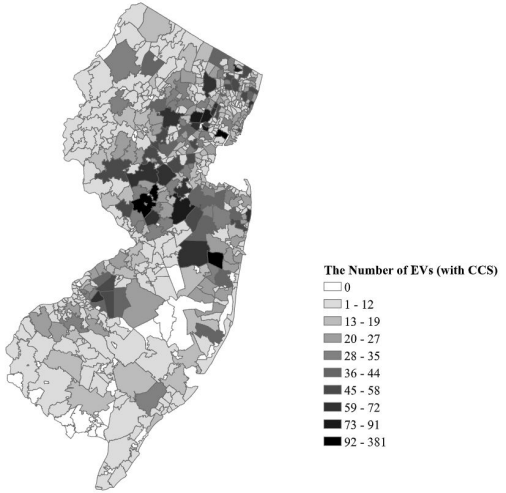
How does the fast charging resource of the ***[CCS], [CHAdeMO]***, and ***[TESLA]*** types per matchable electric vehicle evolve over the temporal scope in ***[New Jersey]***?



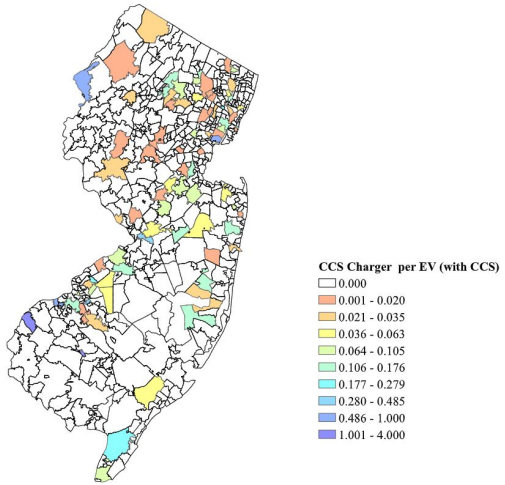
Group 2: Spatial and temporal aggregation questions

Q5. Spatial Aggregation Queries

How many registered electric vehicles equipped with the ***[CCS]*** type connector are there in each ***[ZIP code areas]*** of ***[New Jersey]*** in ***[2021]***? How many ***[CCS chargers]*** are there in those ***[ZIP code areas]***? What about the CCS Charger per EV with CCS-type connectors in each ***[ZIP code area]***?



(a) The distribution of CCS-EV registrations

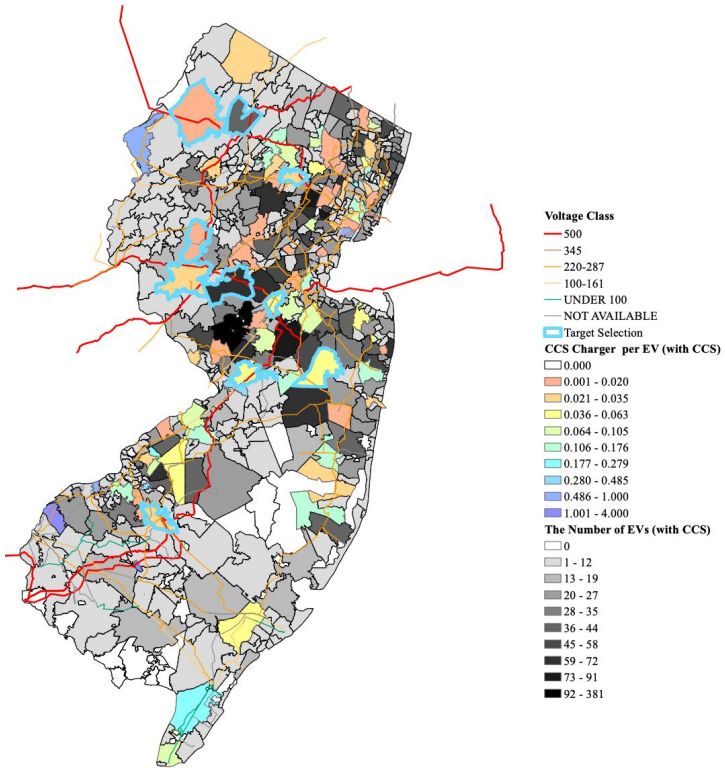


(b) The average CCS-charger share per CCS-EV

Group 3: Cross-domain questions

Q6. Cross-Domain Complex Questions

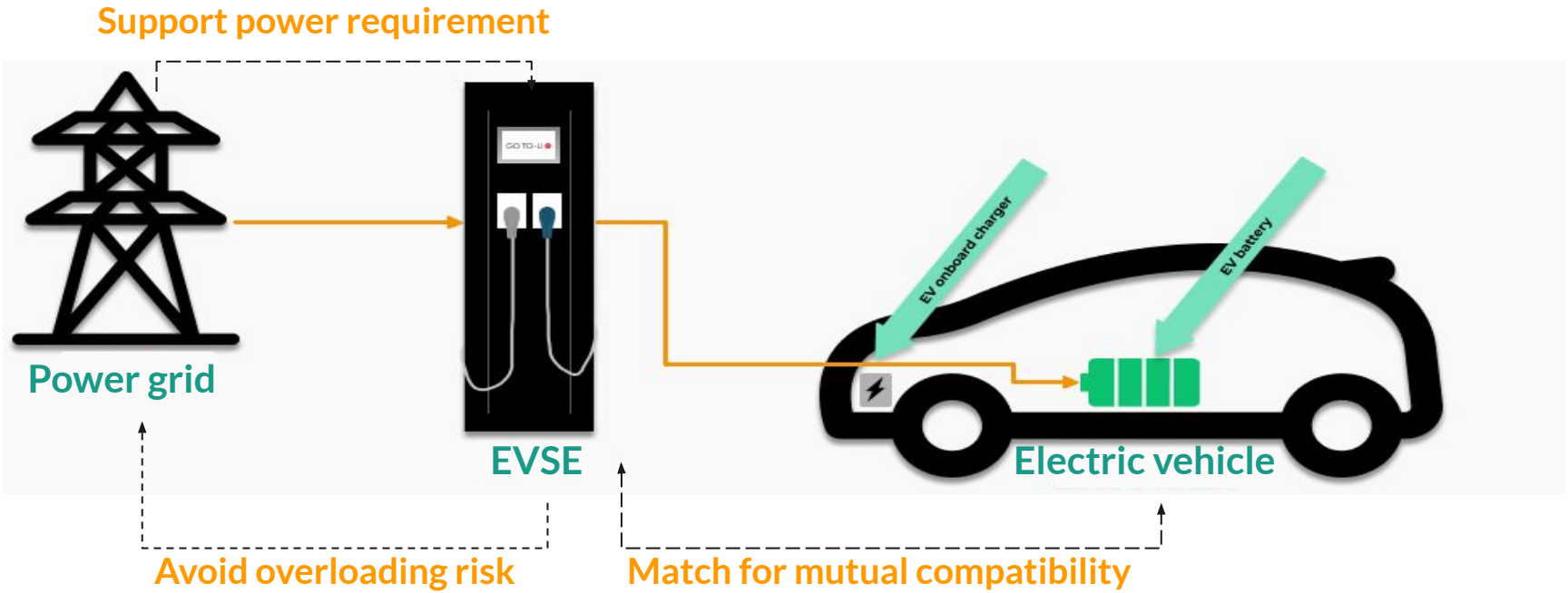
Which ZIP code areas in the ***[New Jersey]*** State with **significant charging resource shortage** can potentially take advantage of the **high-voltage transmission lines** that pass through for installing the direct electricity source for **DCFC** stations?



Conclusions

- Inadequate data sharing and integration hinder vehicle electrification success.
- The EVKG integrates critical aspects of EVs, charging infrastructure, and electricity networks.
- The EVKG serves as a comprehensive knowledge management system for efficient EV charging and infrastructure planning.
- Future plans include expanding data integration, integrating with other knowledge repositories, and enhancing data quality and multidisciplinary insights.

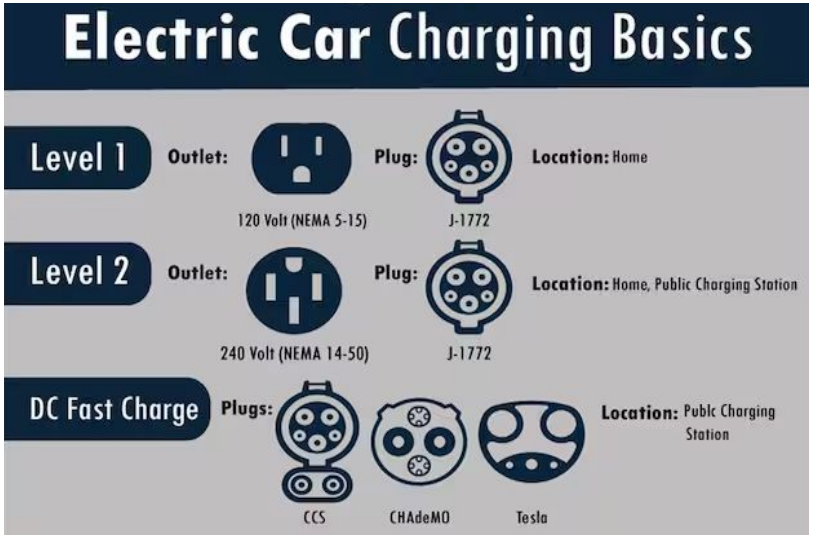
Core components for the EV charging System



Data Management Complexity of EV Industry

- **EV charging capacity diversity**
  - Abundance of emerging EV models
  - Onboard charging cables limited to specific compatible chargers

- **EVSE incompatibility & heterogeneity**
  - No universal charger/connector standard applicable for all EVs
  - Various additional onsite requirements



- **Dependence on the power grid**
  - EV replenishment replying on power grid sustainability

Data Silo Issues for Smart Transportation System

- **EV Travelers - Smart E-mobility**
  - Both of **spatial location** & **semantic contexts** matter much
  - **Isolated** in conventional GIS environment

- **Urban Infrastructure Planners - EVSE location selection**
  - Necessitates information integration of
    - EV adoption
    - EVSE distribution
    - Electricity network
  - **No interoperability** and **extensibility** across the available data sources

Data Management Complexity of EV Industry

Diverse Vehicle Configurations:

- EV manufacturers offer unique models with varied battery capacities and charger types.
- Compatibility issues arise due to lack of universal charger or connector type.

Diverse Electric Vehicle Supply Equipments(EVSE) system:

- EV charging stations, operated by diverse providers, have different constraints.
- Heterogeneous data formats hinder data sharing and integration.

Charging Infrastructure and Power Grid Management:

- High demand from EVSEs can overload the electricity system, leading to blackouts.
- Proper charging station site selection is crucial for power grid sustainability.

Knowledge Graphs

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Col0	Col1	Col2
A	1883	…
B	1980	…
…	…	…

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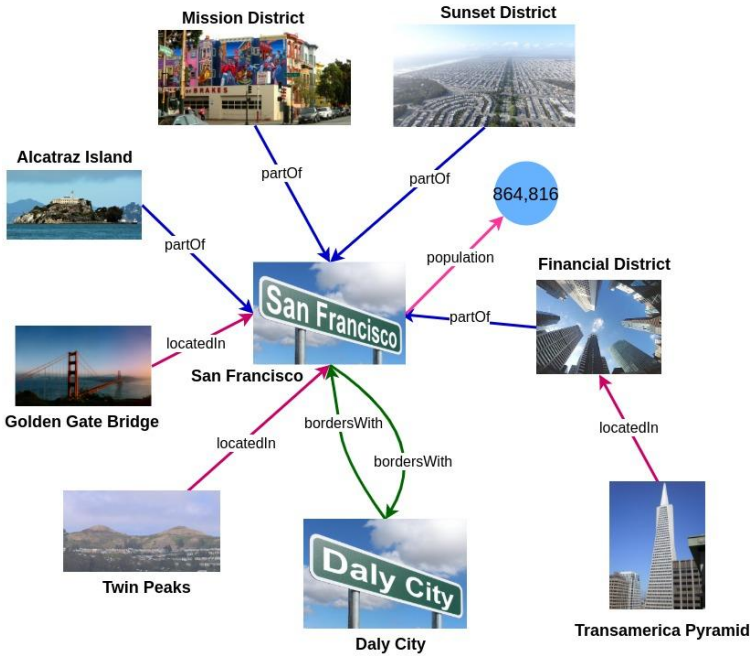

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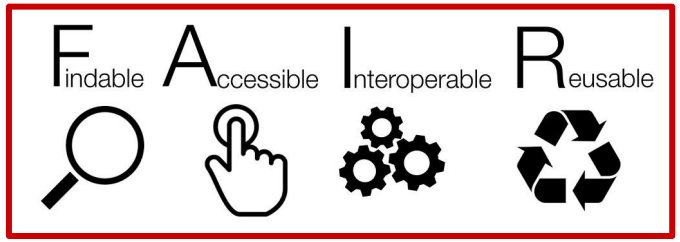

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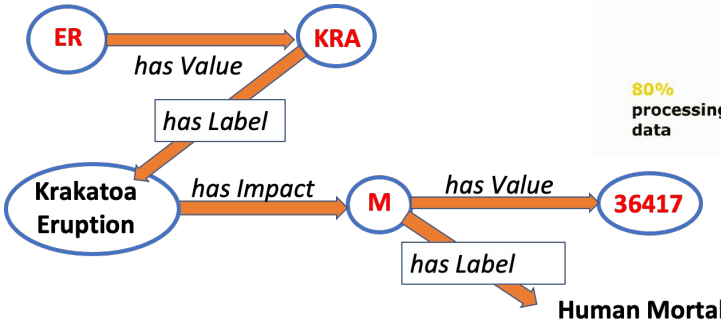
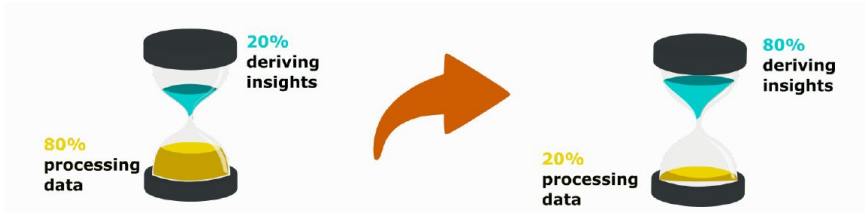
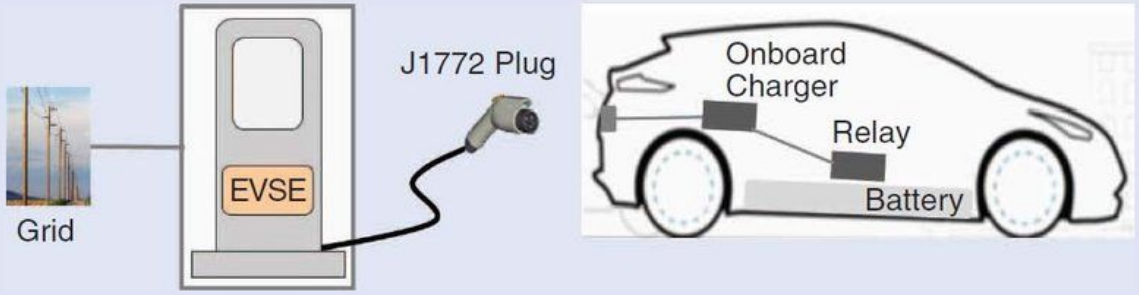
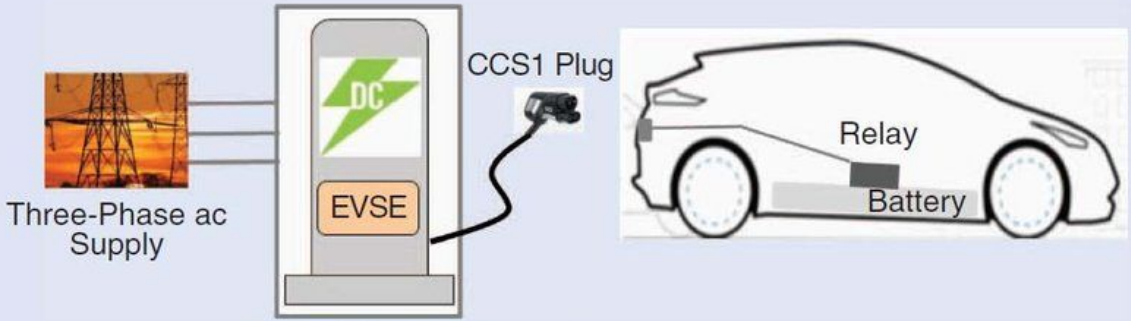






— Monitoring Power Flow
— Safety Monitoring

(a)



— ac–dc Off Board Conversion
— Monitoring Power Flow
— Safety Monitoring

(b)