Method of Stating Energy Consumption

October,2017

Outline

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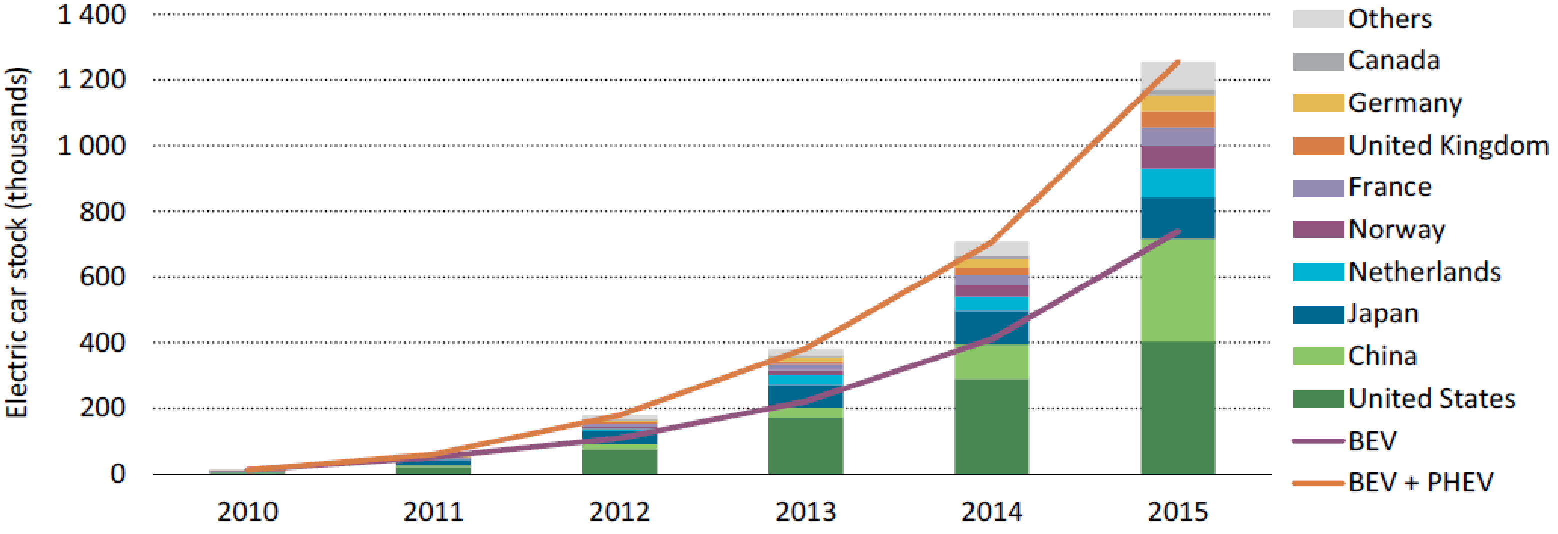
Background

- EV sales are expected to see rapid growth in the future.
- EV will transfer energy use and GHG emissions from vehicles to electricity grid.
- A standardized method for calculating and stating life-cycle energy consumption and the associated GHG emissions for electrified vehicles is recommended for consideration.
- A common method which can be used to state and compare the energy used by vehicles (i.e. MPG, L/100km, or kWh/100km, etc.) is an important environmental issue.

Evolution of the global electric car stock, 2010-15

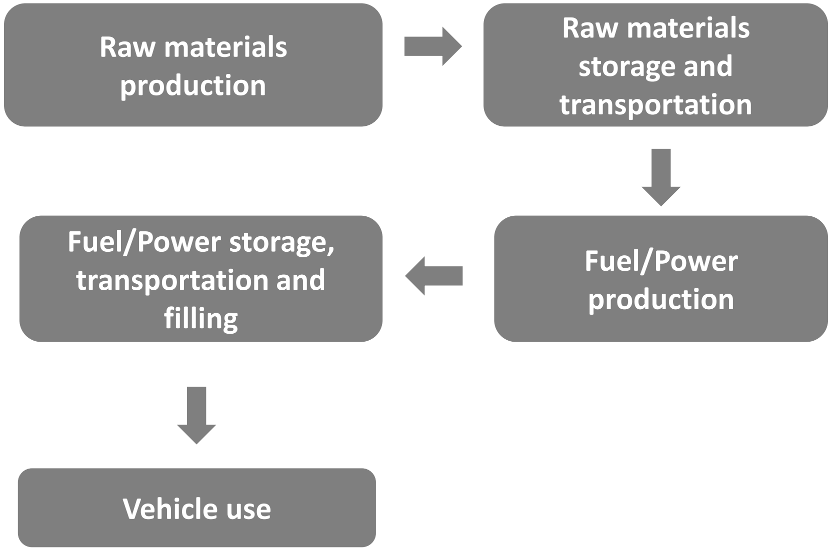


Source: Global EV Outlook, IEA,2016.

Framework

- Method of stating energy consumption are suggested to use life-cycle analysis (LCA) results.
- **key factors:** upstream stage of power supply & the fuel economy

- The energy consumed in all LC stages will be sourced to the form of three key types of primary fossil energy: **raw coal**, **raw natural gas** (NG) and **petroleum**.
- GHG emissions calculated for all the stages are measured in **CO_2** equivalents (CO_2,e) according to the global warming potential factor for each type of GHG.



Raw materials production

Raw materials storage and transportation

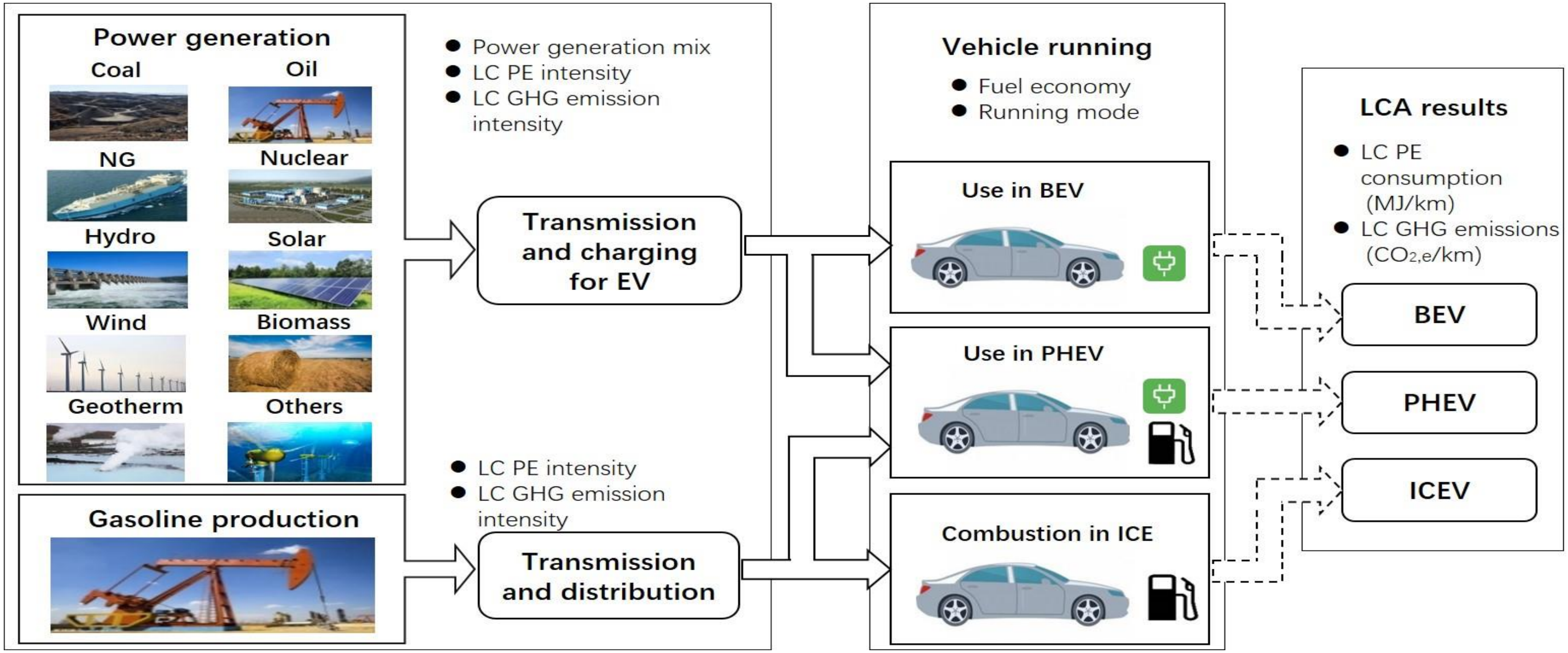
Fuel/Power production

Fuel/Power storage, transportation and filling

Vehicle use

Framework

- The life-cycle analysis was conducted with the functional unit of 1 kilometer driven by an EV/PHEV/ICEV under real-world driving conditions .



Upstream stage

Operation stage

Calculation formula

■ Life-cycle primary fossil fuel consumption (MJ) of BEV/PHEV driven by 1 km

$$EN_{EV} = \left[\sum_{k=1}^{i} E_{LC,k} * SH_k \right] * \frac{1}{1-\eta_{Loss}} * \frac{E_{Ele,EV}}{\eta_{Charge}} * \frac{3.6}{100}$$

$$EN_{PHEV} = \left[\sum_{k=1}^{i} E_{LC,k} * SH_k \right] * \frac{1}{1-\eta_{Loss}} * \frac{E_{Ele,PHEV}}{\eta_{Charge}} * \frac{3.6}{100} * SH_{Ele} + (1 - SH_{Ele}) * E_{LC,Gasoline} * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100}$$

- k: The type of power technologies from 1 to i mean: Coal, Oil, NG, Hydro, Nuclear, Solar, Wind ,Biomass, Geothermal, Others…
- SH_k: The share of type k in the total electricity supplying of regional electrical grids(%)
- $E_{LC,K}$: Life cycle energy consumption for electricity generation and supply of type k (MJ/MJ power supplying)
- η_{Loss}: Electricity transmission loss rate (%)
- η_{Charge}: Charging Efficiency (%)
- $E_{Ele,EV}$: Direct energy consumption of EV (kWh/100km)
- $E_{Ele,PHEV}$: Direct energy consumption of PHEV (kWh/100km)
- SH_{Ele}: The range share by electricity(%)
- Q_{Gasoline}: Calorific value of gasoline (32 MJ/L)
- $E_{LC,\text{Gasoline}}$: Life cycle energy consumption for gasoline production and utilization(MJ/MJ)
- V_{Gasoline}: Energy consumption of PHEV driven by gasoline in running stage(Liter/100km)

Calculation formula

- Life-cycle GHG emissions (g CO₂,e) of BEV/PHEV driven by 1 km

$$EM_{EV} = \left[\sum_{k=1}^{i} EM_{LC,k} * SH_k \right] * \frac{1}{1-\eta_{Loss}} * \frac{E_{Ele,EV}}{\eta_{Charge}} * \frac{3.6}{100}$$

$$EM_{PHEV} = \left[\sum_{k=1}^{i} EM_{LC,k} * SH_k \right] * \frac{1}{1-\eta_{Loss}} * \frac{E_{Ele,PHEV}}{\eta_{Charge}} * \frac{3.6}{100} * SH_{Ele} + (1-SH_{Ele}) * EM_{LC,Gasoline} * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100}$$

- k: The type of power technologies from 1 to i mean: Coal, Oil, NG, Hydro, Nuclear, Solar, Wind ,Biomass, Geothermal, Others…
- $EM_{LC,K}$: Life cycle GHG emission for electricity generation and supply of type k (g CO2, e/MJ power supplying)
- SH_k: The share of type k in the total electricity supplying(%)
- η_{Loss}: Electricity transmission loss rate (%)
- η_{Charge}: Charging Efficiency (%)
- $E_{Ele,EV}$: Direct energy consumption of EV (kWh/100km)
- $E_{Ele,PHEV}$: Direct energy consumption of PHEV (kWh/100km)
- SH_{Ele}: The range share by electricity(%)
- Q_{Gasoline}: Calorific value of gasoline (32 MJ/L)
- $EM_{LC,\mathrm{Gasoline}}$: Life cycle GHG emission for gasoline production and utilization(67.91 g CO2, e/MJ)
- V_{Gasoline}: Energy consumption of PHEV driven by gasoline in running stage(Liter/100km)

Research findings

- The life-cycle energy consumption of EV/PHEV/ICEV was assessed by primary energy consumption :

  **MJ /km

- The associated GHG emissions were estimated by equivalent CO_2 intensity:

  **g CO_2, e/km

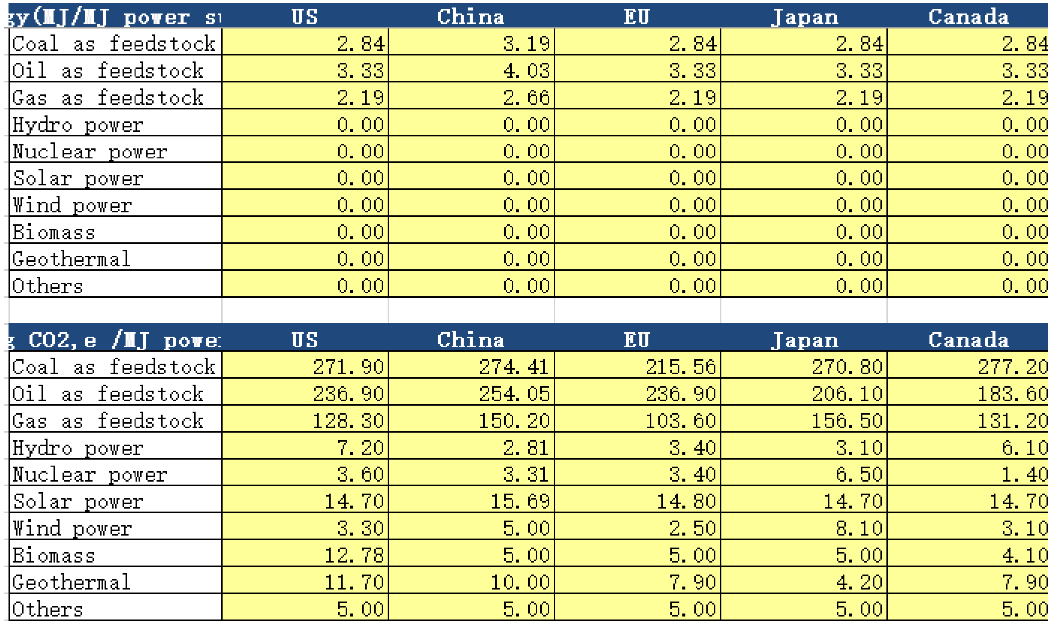
- The tool states the fuel consumption of EV/PHEV/ICEV in two forms and labelling together:

  ** kWh /100 km

  ** Liter (gasoline equivalent)/100 km

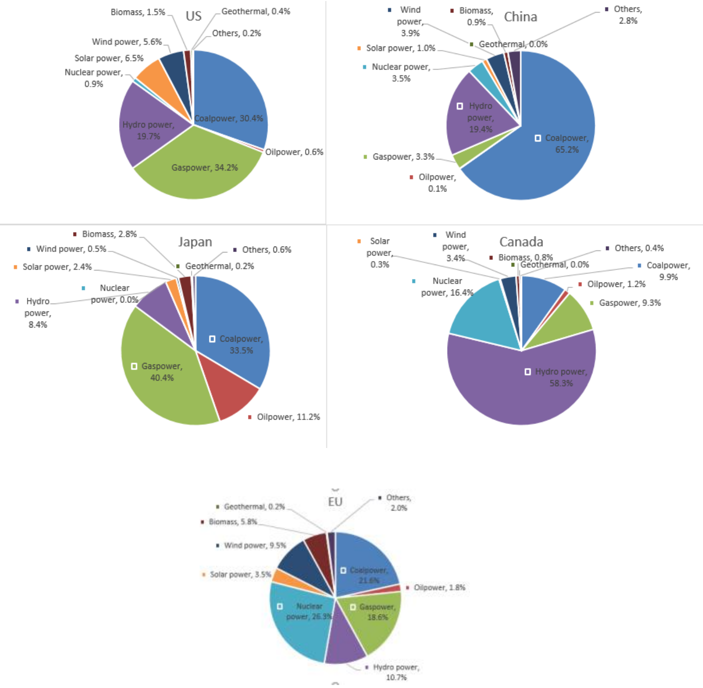
Research findings

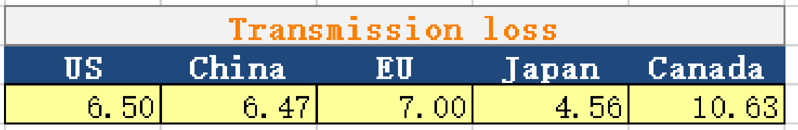
- In order to help make the model more broadly applicable, a database was established containing electricity mix data and upstream emissions factors for different power sources in some countries and regions (China, USA, EU, Japan and Canada). But the database need to be modified once updated statistics are available.



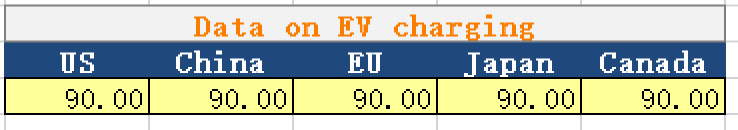
gy(MJ/MJ power s	US	China	EU	Japan	Canada
Coal as feedstock	2.84	3.19	2.84	2.84	2.84
Oil as feedstock	3.33	4.03	3.33	3.33	3.33
Gas as feedstock	2.19	2.66	2.19	2.19	2.19
Hydro power	0.00	0.00	0.00	0.00	0.00
Nuclear power	0.00	0.00	0.00	0.00	0.00
Solar power	0.00	0.00	0.00	0.00	0.00
Wind power	0.00	0.00	0.00	0.00	0.00
Biomass	0.00	0.00	0.00	0.00	0.00
Geothermal	0.00	0.00	0.00	0.00	0.00
Others	0.00	0.00	0.00	0.00	0.00

g CO2,e /MJ powe	US	China	EU	Japan	Canada
Coal as feedstock	271.90	274.41	215.56	270.80	277.20
Oil as feedstock	236.90	254.05	236.90	206.10	183.60
Gas as feedstock	128.30	150.20	103.60	156.50	131.20
Hydro power	7.20	2.81	3.40	3.10	6.10
Nuclear power	3.60	3.31	3.40	6.50	1.40
Solar power	14.70	15.69	14.80	14.70	14.70
Wind power	3.30	5.00	2.50	8.10	3.10
Biomass	12.78	5.00	5.00	5.00	4.10
Geothermal	11.70	10.00	7.90	4.20	7.90
Others	5.00	5.00	5.00	5.00	5.00





Transmission loss				
US	China	EU	Japan	Canada
6.50	6.47	7.00	4.56	10.63



Data on EV charging				
US	China	EU	Japan	Canada
90.00	90.00	90.00	90.00	90.00

Problem encountered

- The development of such a method is very challenging. It requires expertise in the composition of regional electrical grids, knowledge of the energy consumed both in electricity generation and in distribution.

① System boundaries

Life-cycle energy consumption and GHG emission data in different electricity generation stages are incomplete in current database. Energy consumption and GHG emission of various power plants in different stages, including fuel production and distribution, facility manufacturing and factory construction operation and de-commission, should be clearly collected.

② Energy efficiency

Energy efficiency (including energy consumption and GHG emission) associated with the upstream production of electricity can vary depending on the method of power generation and source of raw input energy (heavy fuel, gas, biofuel, wind, solar, hydro etc.).

Problem encountered

② Energy efficiency (continued)

$$EN_{PHEV} = \left[\sum_{k=1}^{i} \overset{a}{E_{LC,k}} * \overset{b}{SH_k}\right] * \frac{1}{1-\underset{c}{\eta_{Loss}}} * \frac{E_{Ele,PHEV}}{\underset{d}{\eta_{Charge}}} * \frac{3.6}{100} * SH_{Ele} + (1-SH_{Ele}) * E_{LC,Gasoline} * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100}$$

$$EM_{PHEV} = \left[\sum_{k=1}^{i} EM_{LC,k} * SH_k\right] * \frac{1}{1-\eta_{Loss}} * \frac{E_{Ele,PHEV}}{\eta_{Charge}} * \frac{3.6}{100} * SH_{Ele} + (1-SH_{Ele}) * EM_{LC,Gasoline} * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100}$$

Data related to the following aspects should be further analyzed:

a. Source of raw input energy in the process of power generation; The energy efficiencies associated with the upstream production of electricity

b. Regional energy consumption and GHG emissions can be affected by marginal emission factors, average emission factors or influence of the load on the whole grid

c. The energy loss during electricity transmission

d. The energy loss during charging

Problem encountered

- In order to better formulate this method, The EVE IWG is reaching out to ask the GEEE to consider taking up the work of developing a method of assessing the energy consumption of electrified vehicles, including upstream emissions with the full support of the EVE IWG as experts in the performance of electrified vehicles.

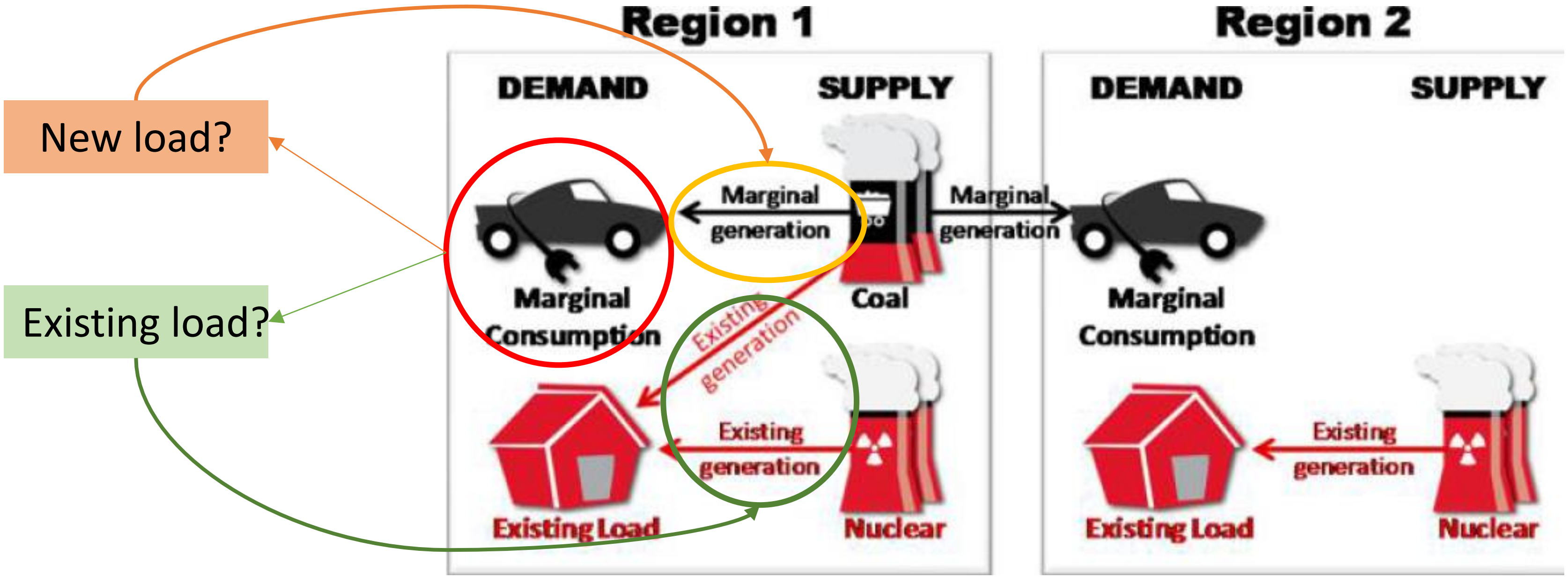
Thanks for your attention!

Appendix

Problem encountered

Regional grid energy and emission factors

Variations in grid energy and emission factors are important ingredients to estimate regional energy consumption and GHG emissions. Therefore regional marginal emission factors or average emission factors for electricity production should be clearly defined.



New load?

Existing load?

Source: Mili-Ann M. Tamayao.2015.

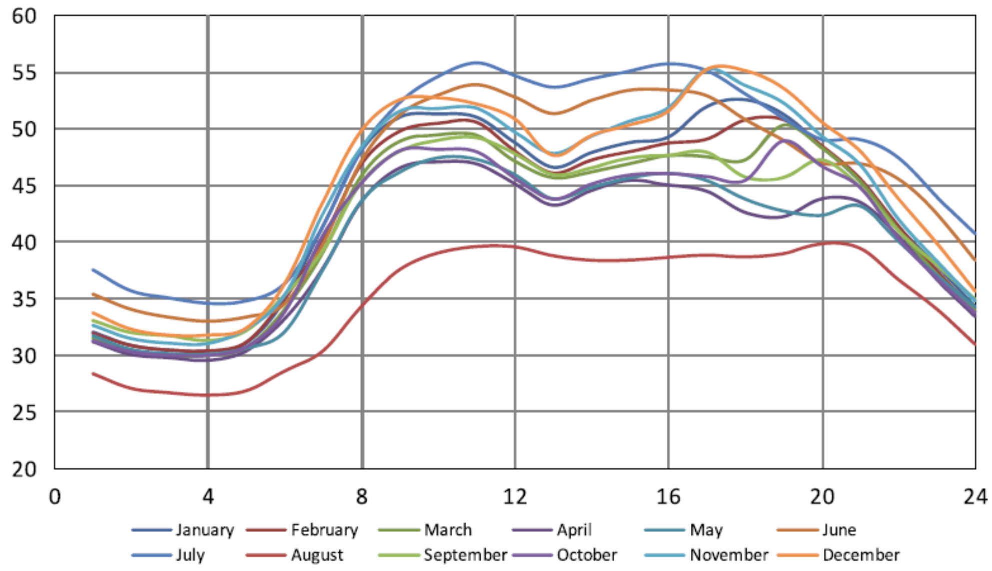
Problem encountered

Influence of the load (caused by EV charging) on the whole grid

Charging time has a significant impact on energy and emission factor of regional grid. EVs charging will lead to a new load at a given time and location. However, the influence of the load on the whole grid always changes with regional character over time. Therefore, it would be good to know more about the characteristics of seasonal or hourly electrical grids, including generation mix and emissions factors.

For example:

The figure on the right was the electric power demand during a normal day(GW) on Italian grid per each month. It changed with time. So the generation mix also changed



Source: Terna.2007.