Work of the Electric Vehicles and the Environment Informal Working Group (EVE IWG) to develop a method of stating energy consumption for electric vehicles

Presentation to the GEEE

The EVE IWG within the UNECE Framework

- The UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) is a unique worldwide regulatory forum within the institutional framework of the UNECE Inland Transport Committee
- Three (3) UN Agreements provide the legal framework allowing Contracting Parties (member countries) to establish regulatory instruments concerning motor vehicles and motor vehicle equipment
    1. UN Regulations, annexed to the 1958 Agreement
    2. United Nations Global Technical Regulations (UN GTRs), associated with the 1998 Agreement
    3. UN Rules, annexed to the 1997 Agreement
- https://www.unece.org/trans/main/wp29/introduction.html

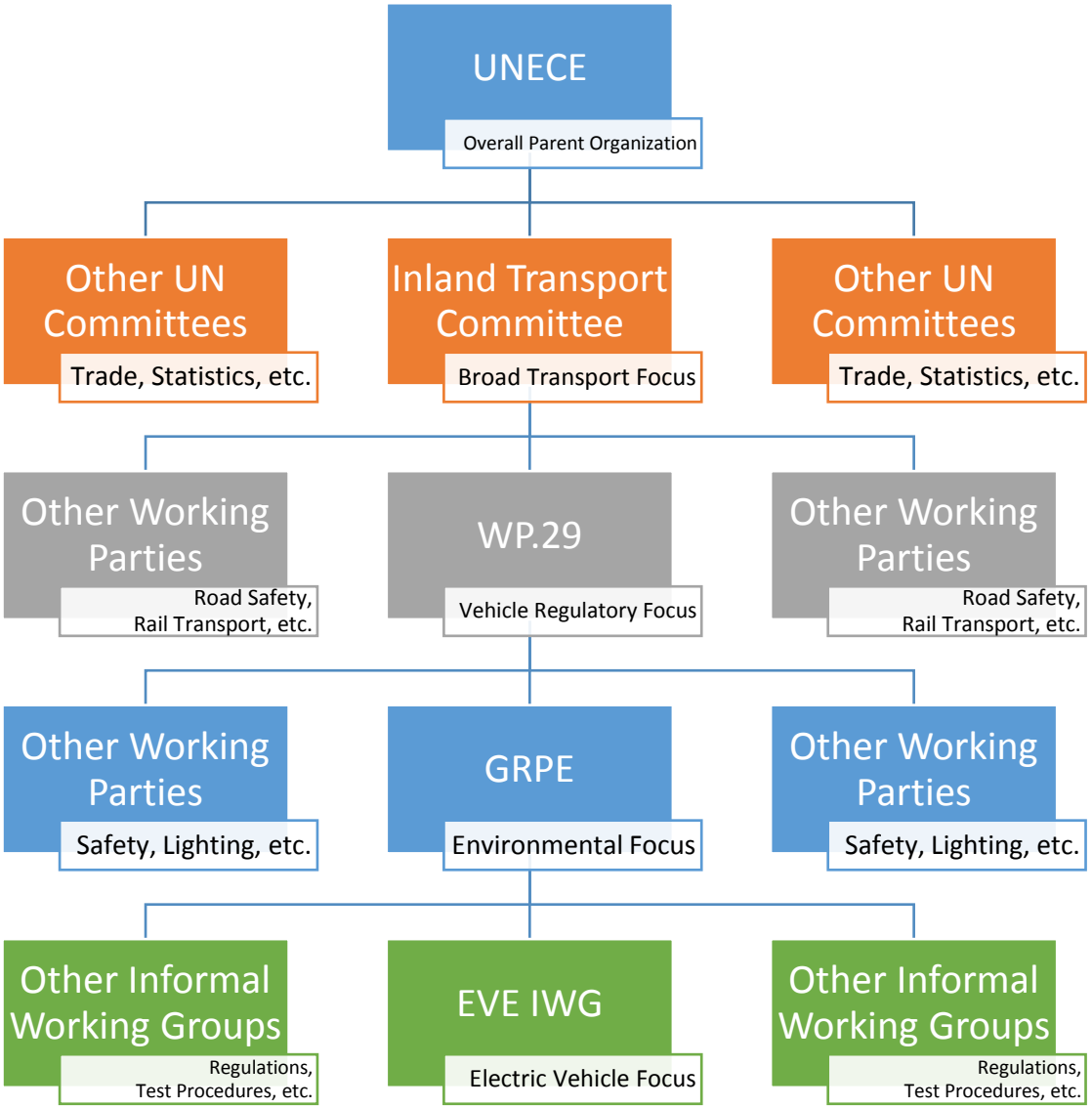
The EVE IWG within the UNECE Framework

- Various working parties exist under WP.29, focused on various vehicle performance characteristics and requirements
  - Working Party on Noise (GRB)
  - Working Party on Lighting and Light-Signalling (GRE)
  - ***Working Party on Pollution and Energy (GRPE)***
  - Working Party on Brakes and Running Gear (GRRF)
  - Working Party on General Safety Provisions (GRSG)
  - Working Party on Passive Safety (GRSP)
- The Working Party on Pollution and Energy (GRPE) is the subsidiary body of the World Forum for Harmonization of Vehicle Regulations (WP.29) that prepares regulatory proposals on pollution and energy efficiency to WP.29
- Groups of experts conduct research and analysis to develop emission and energy requirements for vehicles

The EVE IWG within the UNECE Framework

- Various informal working groups (IWGs) exist under GRPE, focused on the environmental performance characteristics and requirements of vehicles
  - ***Electric Vehicles and the Environment (EVE)***
  - Environmental and Propulsion Performance Requirements of L-category vehicles (EPPR)
  - Particle Measurement Program (PMP)
  - Vehicle Interior Air Quality (VIAQ)
  - Worldwide harmonized Light vehicles Test Procedure (WLTP)
- The Electric Vehicles and the Environment Informal Working Group (EVE IWG) brings together experts in electric vehicle performance to assess the performance of electrified vehicles, and when instructed by WP.29 and GRPE, develop Global Technical Regulations (GTRs)
- https://wiki.unece.org/pages/viewpage.action?pageId=917779

The EVE IWG within the UNECE Framework



EVE Past Mandate

- Mandate from November 2014 – November 2016 had 4 primary tasks
- Topics to research and recommend whether a Global Technical Regulation (GTR) is appropriate for
  a) Electrified vehicle battery performance and durability
     Outcome was that more research was needed
  b) Determining the powertrain performance of electrified vehicles (maximum power and torque)
     Outcome was that a GTR can and should be developed
- Topics to research for information sharing only
  a) Method of stating energy consumption of electrified vehicles
     Outcome was that experts in electricity generation and distribution need to be involved, and ideally should lead
     WP.29 felt that upstream emissions are not a vehicle performance topic
  b) Battery recycling/recyclability
     Outcome was that battery recycling is not a vehicle performance issue, and should be dealt with via other forums

EVE Current Mandate

- Mandate from November 2016 - November 2018 has 3 primary tasks

a) Continue research on whether a Global Technical Regulation for electrified vehicle battery performance and durability can and/or should be developed
b) Develop Global Technical Regulation (GTR) for determining the powertrain performance of electrified vehicles (maximum power and torque)
c) Find another suitable organization to lead work on developing a method of stating energy consumption of electrified vehicles, with the support of the EVE as experts in the field of the performance of electrified vehicles

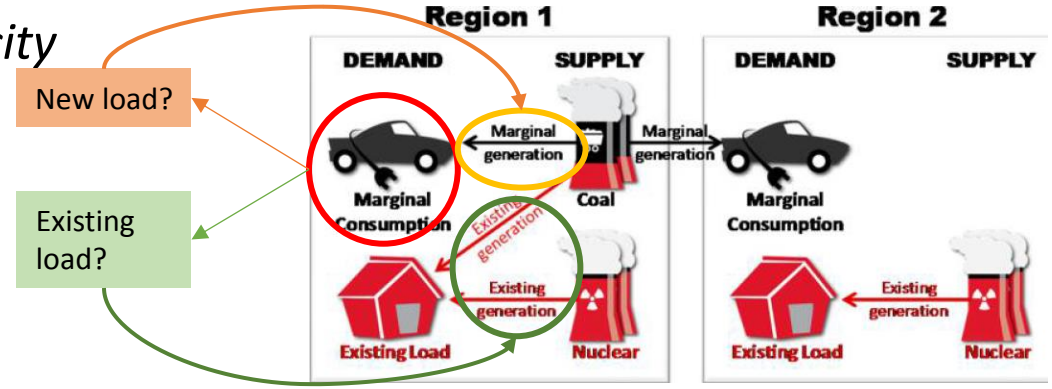
- Formal mandate: https://www.unece.org/fileadmin/DAM/trans/doc/2016/wp29/ECE-TRANS-WP29-2016-116e.pdf

Work to Date on a Method of Stating Energy Consumption

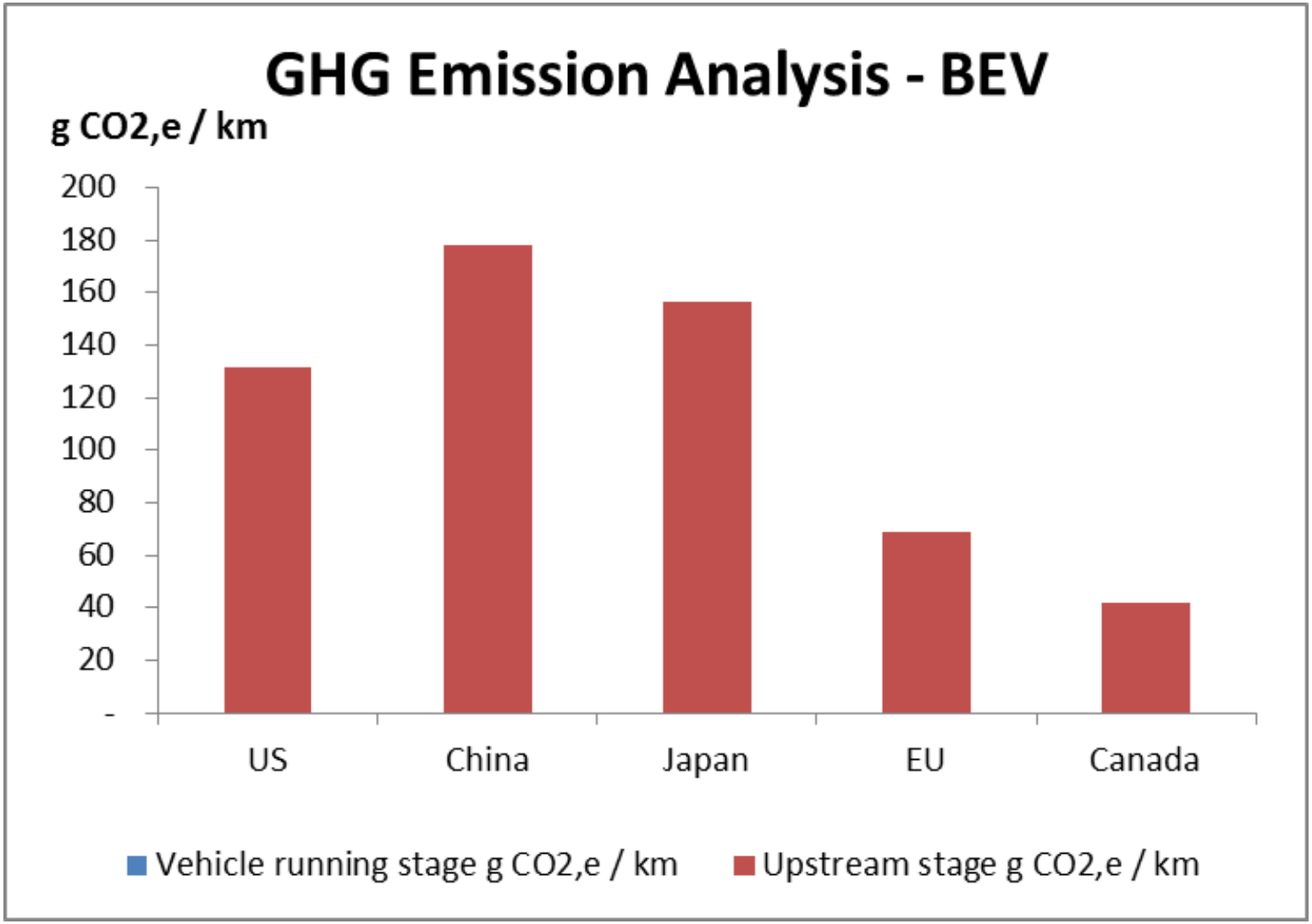
- EVE IWG made significant initial progress when developing a method of stating energy consumption
- Work was largely led by China, and included an Excel based model and associated informative/explanatory documentation
- Documents WP.29-170-29 is the information document about the Excel based model https://www.unece.org/fileadmin/DAM/trans/doc/2016/wp29/WP29-170-29e.pdf
- Document WP.29-170-30 is the Excel based model developed for this work https://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/geninf170.html
- Document WP.29-170-31 is the final Status report of the most recently completed EVE mandate https://www.unece.org/fileadmin/DAM/trans/doc/2016/wp29/WP29-170-31e.pdf

Why is EVE IWG Reaching out to GEEE?

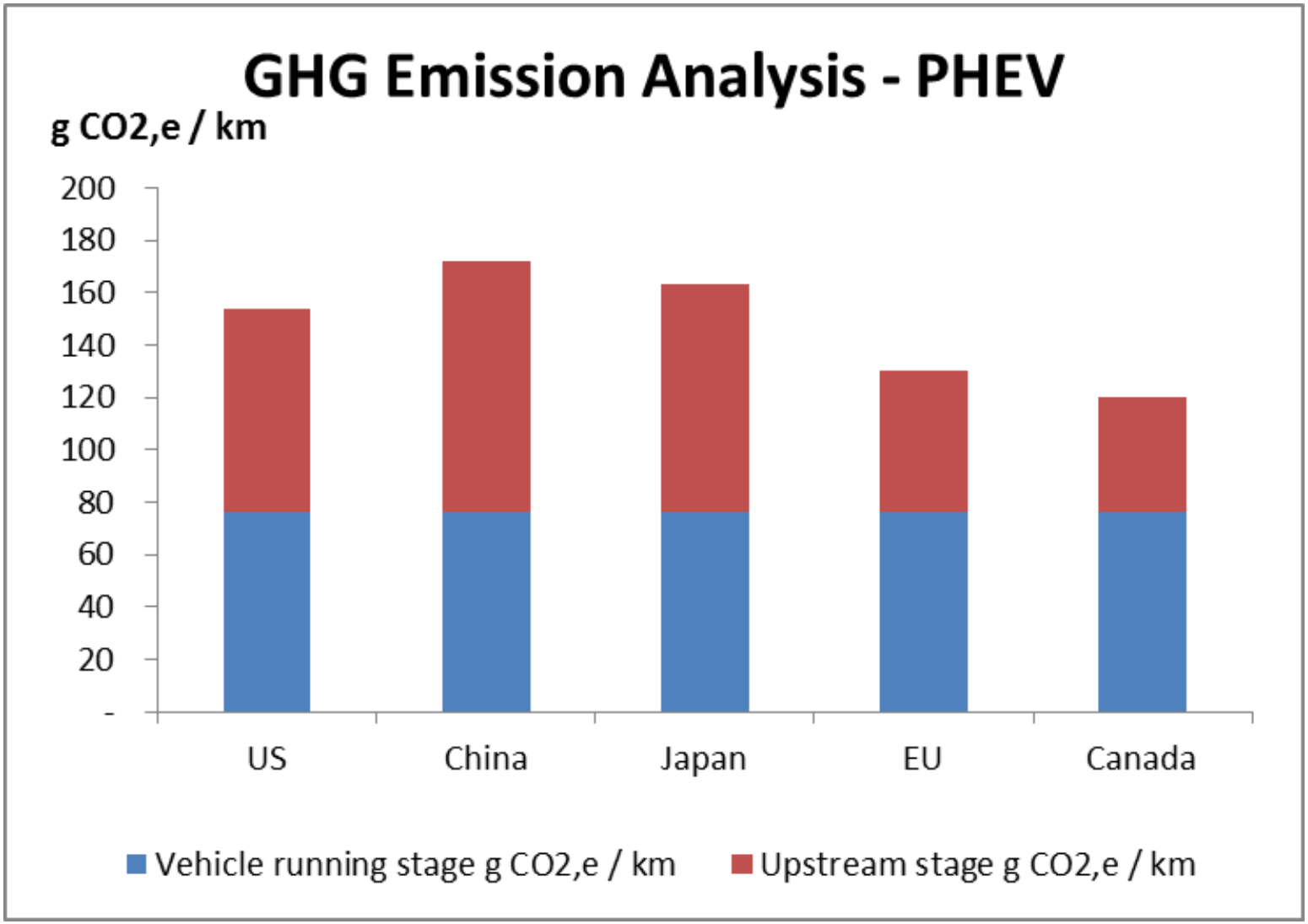
- EVE has built a suitable, simple Excel based model which can estimate the emissions from a single electrified vehicle with electricity supplied by any combination of power sources desired by the model user
- When considering ways to make the model more broadly applicable, the EVE realized that it did not possess the required expertise related to the generation and distribution of electricity to make the more broadly applicable
  - *How should the model account for emissions associated with construction and decommissioning of power plants?*
  - *Should EVs be considered incremental loads which only draw power from incremental generation, or should EVs be considered normal loads which have the same average upstream emissions as other loads?*
  - *How to account for electricity bought from and sold to other jurisdictions?*



Sample results from Excel Model

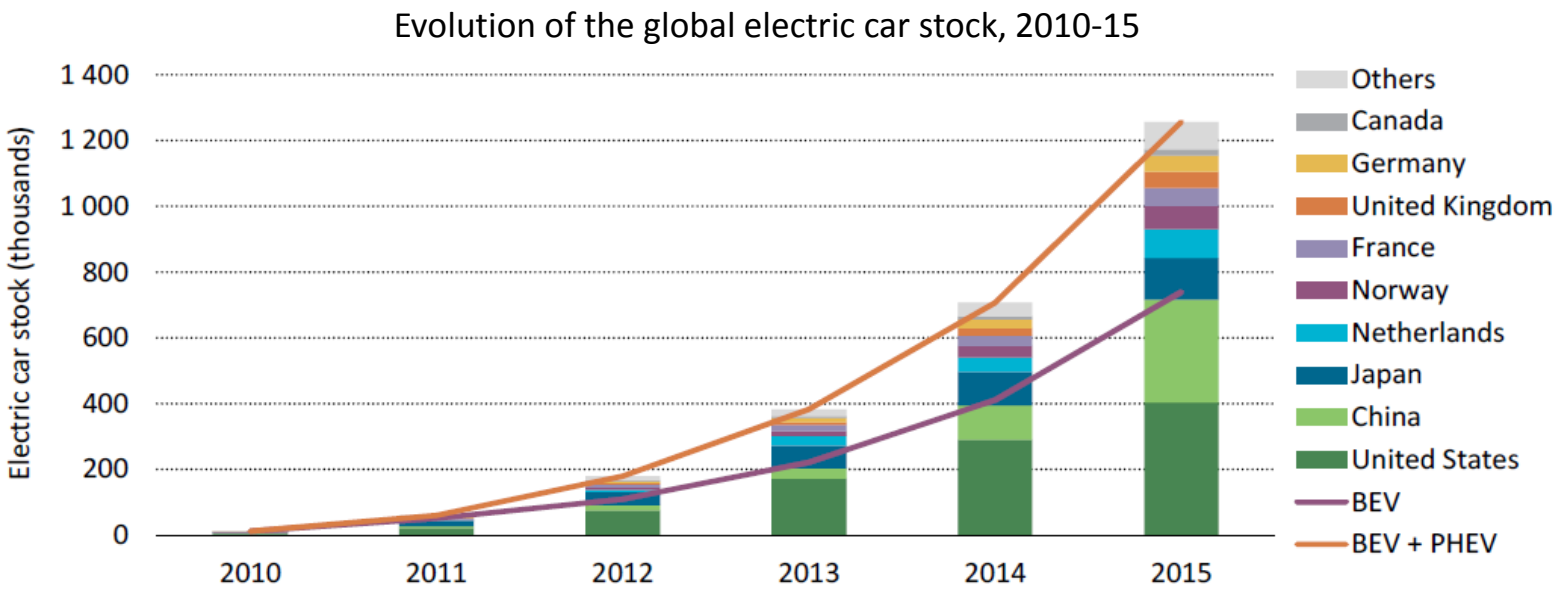


Sample results from Excel Model



Why Might This be a Priority for GEEE?

- EV sales are expected to see rapid growth in the future
- EVs 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 may be broadly beneficial for UNECE member States



Source: Global EV Outlook, IEA,2016.

Next Steps

- EVE IWG has been given a mandate to look for another organization within the UNECE framework to assume leadership of developing a method of stating consumption of electrified vehicles
- The EVE IWG intends to fully support this work as desired by the new leadership group, given the EVE IWG's access to experts in the field of the performance of electrified vehicles
- This new leadership could build on the existing work of the EVE IWG, or could develop their own tools, models and methods as desired
- The new leadership will need to consider broader policy questions such as:
  - *Should EVs be considered new or existing loads?*
  - *How should emissions from construction and decommissioning of electricity generation facilities be considered?*
  - *Are there concerns about shifting pollution that is currently dispersed across large segments of the population (anyone who is near a vehicle tailpipe) and concentrating pollution near smaller populations (anyone who is near power plant emissions?*

Would the GEEE be interested in assuming leadership of the work of developing a method of stating energy consumption of electrified vehicles, with the support of the EVE IWG desired by the GEEE?

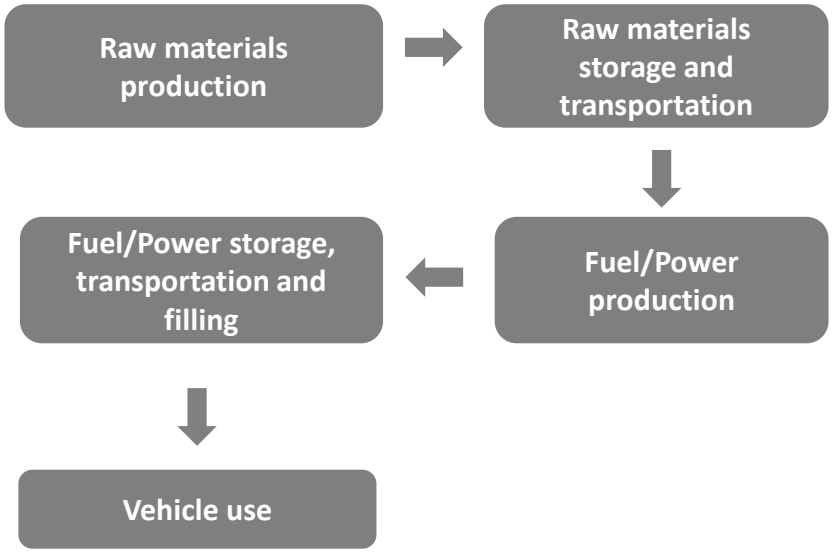
Additional Information About the Excel Based Model

- Questions can be sent to EVE leadership team:
- Chair: Mr. Michael Olechiw (United States of America) olechiw.michael@epa.gov
- Vice-Chair: Mr. Tetsuya NIIKUNI (Japan) niikuni@ntsel.go.jp
- Vice-Chair: Ms. Chen Chunmei (China) chencm@miit.gov.cn
- Secretariat: Mr. Andrew Giallonardo (Canada) andrew.giallonardo@canada.ca

Model Logic

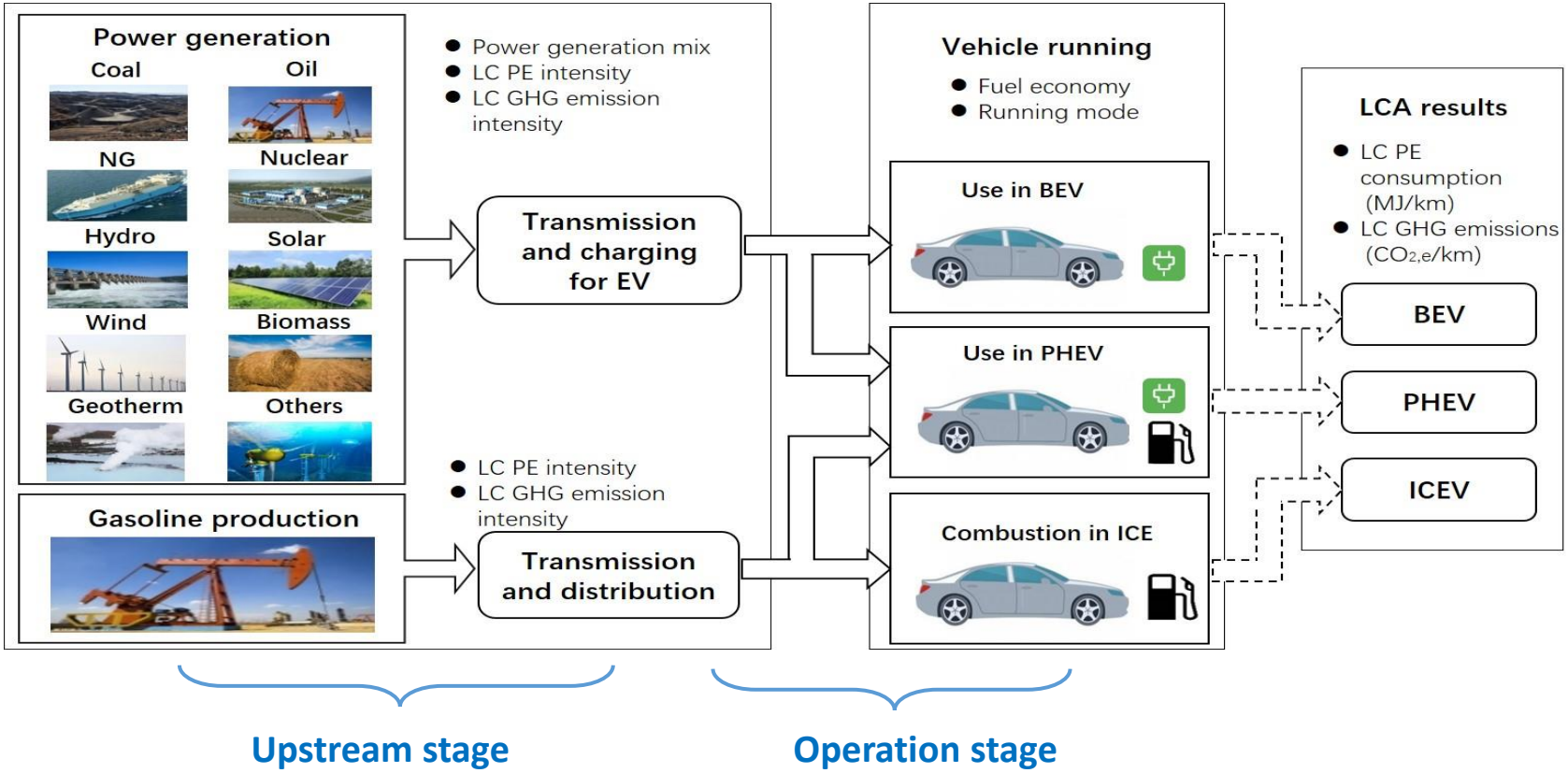
- Method of stating energy consumption are suggested to use life-cycle analysis (LCA) results.
- **key factors:** upstream stage of power supply & the fuel economy

- 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



Model 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



Model Formulas

■ 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)
- $E_{LC,\mathrm{Gasoline}}$: 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)

Model Formulas

■ Life-cycle GHG emissions (g CO_2,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)

Model Results

- 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

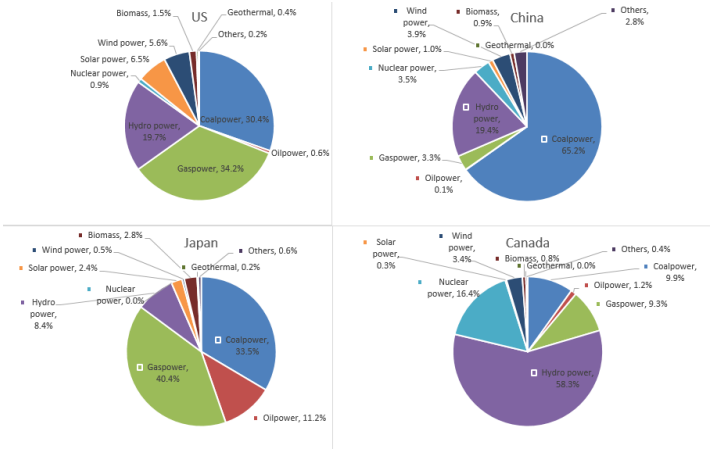
  ** Liter (gasoline equivalent)/100 km

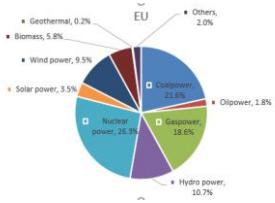
Initial Research on Upstream Emissions

- 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)
- Database will 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

Specific Concerns for the Model

- Development of such a method is very challenging, and will require 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 the 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-commissioning should be gathered

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.)

Specific Concerns for the Model

② Energy efficiency (continued)

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

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

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

Specific Concerns for the Model

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.

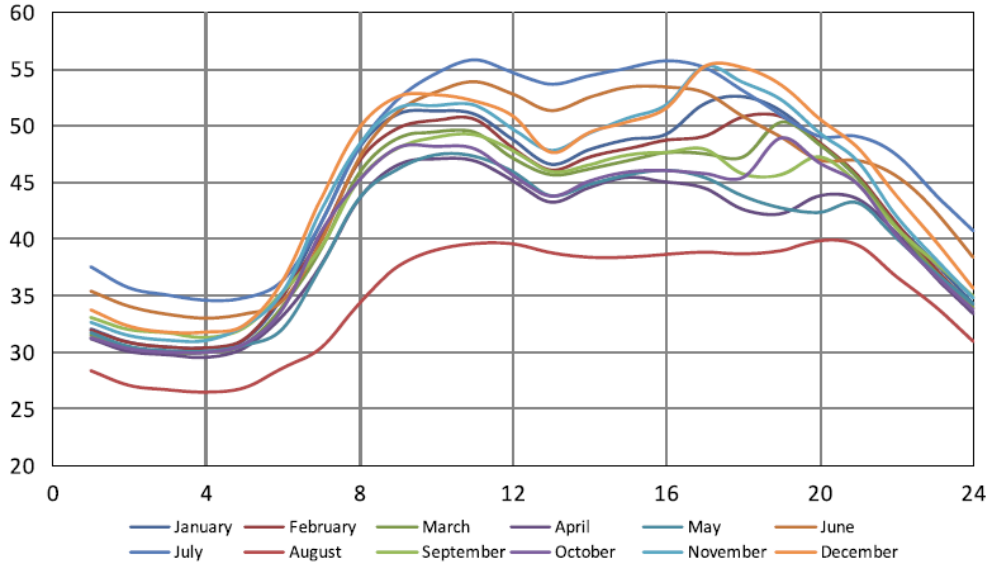
Specific Concerns for the Model

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.