Submitted by the IWG on EVE

Informal document **WP.29-170-29**
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agenda item 19.2)

Updated information for the section of *Method of Stating Energy Consumption*

Part 1: Literature review

Based on the literature review, there are four observations:

1) **Many papers were related to the assessment of energy saving and GHG emission reductions of EVs in different countries/districts;**
   - ✓ For EU and its members
     - Rangaraju et al. (2015); Buekers et al. (2014); Donateo et al. (2015); Ma et al. (2012); Millo et al. (2014); Sánchez et al. (2013); Brouwer et al. (2013); Jochem et al. (2015); Faria et al. (2013); Holdway et al. (2010); Smith (2010)
   - ✓ For US
     - Huo et al. (2015); Holdway et al. (2010); Millo et al. (2014); Thomas (2012a,b); Kim et al. (2014) ; Yang (2013)
   - ✓ For China
     - Huo et al. (2015); Millo et al. (2014); Zhou et al. (2013); Ou et al. (2010)
   - ✓ For Others (i.e. Japan)
     - Millo et al. (2014); Zhang et al. (2013)

2) **The upstream stage of power supply should be covered in the assessment of EV energy consumption;**

The emissions from EVs depend on their own energy consumption and on the CO_2 intensity of the power generation mix from which the EV's energy should obtained. The energy consumption is the amount of energy used per unit distance traveled. The CO_2 intensity of a power generation mix is the average amount of CO_2 emitted per unit of electrical energy generated by all of the power production processes in a mix weighted by the amount of power obtained from each of those processes.

3) **Data about the electricity mix and upstream emissions factors of different power supplies can be collected from most countries;**

4) **Therefore, a standardized method for calculating and stating energy consumption and the associated GHG emissions for EVs is recommended for consideration.**

It is recommended that a method be developed rather than attempt to establish a common value.

Part 2: Calculation methods suggested

1) Methods overview

- Electricity chains and vehicle running are considered in the calculation, that is, upstream and operation stages are both covered in life cycle consumption and emissions.

- Data for fossil fuel and non-fossil fuel to power:

  ✧ Three kinds of fossil fuels including Coal, Oil and Natural gas are used as feedstock in power generation. Energy consumption and emissions include the upstream stages, such as feedstock exploration, transportation, fuel production , in addition to the energy consumption emissions occurring in the fuel utilization; but the facility construction and vehicle manufacturing stages are excluded for their little effect on the life cycle energy consumption and emission. Take coal power for example[①].

  ✓ Life cycle analysis of GHG emissions situation of coal power (the share of different stages):

  - Coal mining and processing:10.76%
  - Coal transportation:1.36%
  - Construction and decommissioning of the power plant:0.2%
  - Operation of the power plant:87.56%
  - Power transmission:0.3%

  GHG emission the of the construction and decommissioning stage only accounts for 0.2%, so it has little effect on the life cycle emission and often be ignored.

  ✧ Non-fossil fuels includes Hydro, Nuclear, Solar, Wind and other types. The energy consumption and emission during facility manufacturing and factory construction stages are allocated to the total power supplying during the whole life time of those power stations for they account for a very large proportion. Life cycle analysis of GHG emissions situation of different power(the share of different stages)[②]:

  ✓ Nuclear power (General situation):

  - Uranium mining and metallurgy: 20%
  - Uranium conversion and enrichment: 10%
  - Fuel element fabrication: 2%
  - Facility construction and operation: 20%
  - Transportation process:＜0.1%，always be negligible
  - Backend of nuclear fuel cycle: 44%.
  - Waste disposal: 4%

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① Reference: China Academy of Engineering. 2015. Greenhouse gas emissions of different power energy in China [M]. Beijing: Atomic Energy Press.

② Reference: China Academy of Engineering. 2015. Greenhouse gas emissions of different power energy in China [M]. Beijing: Atomic Energy Press.

- Facility decommissioning: Rarely be conducted in China and always be estimated about 30%-50% of the construction stage

✓ Hydro power (Typical power plants in China):

- Material and facility production: 4.3%
- Material and facility transportation: 2.1%
- Civil engineering construction: 70.2%
- Power production plant: 23.4%

✓ Solar power(Polycrystalline silicon solar photovoltaic):

- Material and facility production: 84.14%
- Power production and operation: 0.08%
- Power transmission: 5.5%
- Decommissioning of the power plant: 10.28%

✓ Wind power(A typical power plant in China):

- Manufacturing stage: 71.42%
- Material transportation: 10.73%
- Power plant operation and maintenance: 10.71%
- Wind power plant decommissioning: 7.14%

2) Calculation formula

● Energy consumption

✧ Life cycle energy consumption for mixed electricity generation and supply ($E_{LC,Mixed}$, MJ/ MJ power supplying):

$$E_{LC,Mixed} = \left[\sum_{k=1}^{i} E_{LC,k} * SH_k\right] * \frac{1}{1-\eta_{Loss}}$$

✧ EV life-cycle energy consumption (EN_{EV} , MJ/ km):

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

✧ Labelling of EV direct energy consumption:

✓ $E_{E,EV} = E_{D,EV} * 100 / 3.6$, (kWh/ 100km)

✓ $E_{V,EV} = E_{D,EV} * 100 / Q_{Gasoline}$, (liter/ 100km)

✧ PHEV life-cycle energy consumption (EN_{PHEV} , MJ/ km):

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

✧ Labelling of PHEV direct energy consumption :

✓ $E_{E,PHEV} = E_{D,PHEV} * 100 / 3.6$, (kWh/ 100km)

✓ $E_{V,PHEV} = E_{D,PHEV} * 100 / Q_{Gasoline}$, (liter/ 100km)

✧ Gasoline ICEV life-cycle energy consumption (EN_{ICEV} , MJ/ km):

$$EN_{ICEV} = E_{LC,Gasoline} * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100}$$

- **GHG emissions**

✧ Life cycle GHG emission for mixed electricity generation and supply ($EM_{LC,Mixed}$,g CO2,e /MJ power supplying):

$$EM_{LC,Mixed} = \left[\sum_{k=1}^{i} EM_{LC,k} * SH_k \right] * \frac{1}{1-\eta_{Loss}}$$

✧ EV life-cycle GHG emission (EM_{EV} ,g CO_2, e/km)

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

✧ EV GHG emission in running stage ($EM_{D,EV}$, g CO_2, e/km):

$$EM_{D,EV} = 0$$

✧ EV GHG emission in upstream stage ($EM_{Ups,EV}$,g CO_2, e/km):

$$EM_{Ups,EV} = EM_{EV} - EM_{D,EV}$$

✧ PHEV life-cycle GHG emission (EM_{PHEV} ,g CO_2, e/km):

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

✧ PHEV GHG emission in running stage ($EM_{D,PHEV}$,g CO_2, e/km):

$$EM_{D,PHEV} = (1-SH_{Ele}) * V_{Gasoline} * Q_{Gasoline} * EM_{Gasoline} * \frac{1}{100}$$

✧ PHEV GHG emission in upstream stage ($EM_{Ups,PHEV}$,g CO_2, e/km):

$$EM_{Ups,PHEV} = EM_{PHEV} - EM_{D,PHEV}$$

✧ Gasoline ICEV life-cycle GHG emission (EM_{ICEV} ,g CO_2, e/km):

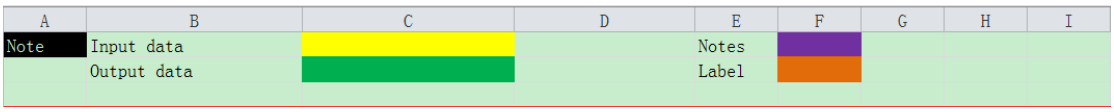
$$EM_{ICEV} = EM_{LC,Gasoline} * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100}$$

Where:

	Symbol	Unit	Description
Input Variables: The input data based on annual statistical data books or formal report vary from country to country in the calculation, and they can be collected from most countries.	k		The type of power technologies from 1 to i mean : Coal, Oil, NG, Hydro, Nuclear, Solar, Wind ,Biomass, Geothermal, Others……
	$E_{LC,k}$	MJ/MJ	Life cycle energy consumption for electricity generation and supply of type k
	$EM_{LC,k}$	g CO_2, e/MJ	Life cycle GHG emission for electricity generation and supply of type k
	SH_k	%	The share of type k in the total electricity supplying
	η_{Loss}	%	Electricity transmission loss rate
	$E_{Ele,EV}$	kWh/100km	Direct Energy consumption of EV in running stage
	η_{Charge}	%	Charging efficiency
	$E_{Ele,PHEV}$	kWh/100km	Energy consumption of PHEV driven by power in running stage
	SH_{Ele}	%	The range share by electricity
	$E_{LC,Gasoline}$	MJ/MJ	Life cycle energy consumption for gasoline production and utilization
	$EM_{LC,Gasoline}$	g CO_2, e/MJ	Life cycle GHG emission for gasoline production and utilization
	$V_{Gasoline}$	Liter/100km	Energy consumption of PHEV driven by gasoline in running stage
Parameters	$Q_{Gasoline}$	32 MJ/L③	Calorific value of gasoline
	$EM_{Gasoline}$	67.91 g CO_2, e/MJ④	GHG emission intensity for gasoline

Part 3: Operating manual

The methods are based on EXCEL tools to get life cycle analysis results. Based on the data of different regions and countries input in the Yellow Cell, the results will be showed in the output cell (the Green Cell) and the labelling is presented in the Orange Cell. The data is explained in the Purple Cell.



③ Average value. $Q_{Gasoline}$ =**Q*****D**/1000, **Q**: gasoline calorific value, 43.07 MJ/kg (GB/T 2589-2008); **D**: gasoline density, 720-775 kg/ m^3 (GB 17930-2013).

④ $EM_{Gasoline}$ =44/12***FCO*****CEF**, **FCO**: fuel oxidation rate, 0.98; **CEF**: carbon emission factor, 18.9 g/MJ. (Reference: China Academy of Engineering. 2015. Greenhouse gas emissions of different power energy in China [M]. Beijing: Atomic Energy Press.)

- **Upstream stage**

- In original model Table A presents the data for different fossil fuel to power, while in the new model Table A is deleted, and it's packaged into Part B.1

✧ Table **B** presents the data for fossil and non-fossil fuel to power.

B	Data for non-fossil fuel to power		
B. 1	•Life cycle energy consumption and GHG emissions situation for power generation and supplying		
	•technology	•MJ/MJ power supplying	•g CO_2,e /MJ power supplying
	Coal as feedback		256.33
	Oil as feedback		254.05
	Gas as feedback		146.8
	Hydro power	0	2. 81
	Nuclear power	0	3. 31
	Solar power	0	15. 69
	Wind power	0	5
	Biomass	0	0
	Geothermal	0	0
	Others	0	5. 9

✧ Table **B** presents the data for non-fossil fuel to power.

B	Data for non-fossil fuel to power			
B. 1	•Life cycle energy consumption and GHG emissions situation for power generation and supplying			The energ
	•technology	•MJ/MJ power supplying	•g CO_2,e /MJ power supplying	
	Hydro power	$E_{LC,1}$	$EM_{LC,1}$	
	Nuclear power	$E_{LC,2}$	$EM_{LC,2}$	
	Solar power	$E_{LC,3}$	$EM_{LC,3}$	
	Wind power	$E_{LC,4}$	$EM_{LC,4}$	
	Others	$E_{LC,5}$	$EM_{LC,5}$	

✧ Table **C** presents the data for composition of regional electrical grids (annual average).

C	Composition of regional electrical grids (annual average)		
	•technology	•%	Based on
	Coal as feedstock	SH_{Coal}	
	Heavy oil as feedstock	SH_{Oil}	
	Gas as feedstock	SH_{NG}	
	Hydro power	SH_1	
	Nuclear power	SH_2	
	Solar power	SH_3	
	Wind power	SH_4	
	Others	SH_5	

✧ Table **D** presents the data on electricity transmission loss.

D	Electricity transmission loss	
	•%	Based on
	η_{Loss}	

- **Running stage**

✧ Table **E** presents the data on EV and HPEV charging and running. **E.1** presents the charging efficiency; **E.2** presents the energy consumption for EV running; **E.3** presents the energy consumption for PHEV running, two different running modes are presented in the modulates, including driven independently by power consumption (kWh /100 km) and gasoline consumption (liter/100 km).

E	Data on EV charging and running			
E. 1	Charging efficiency			Based on
		•% η_{Charge}		
E. 2	Energy consumption for EV running			
		•kWh /100 km $E_{Ele, EV}$		Based on
E. 3	Energy consumption for PHEV running			Based on
		•kWh /100 km $E_{Ele, PHEV}$	•liter /100 km $V_{Gasoline}$	•Range share by el SH_{Ele}

✧ Table **F** presents the data on vehicle fuel life-cycle energy consumption and GHG emissions situation for gasoline production and utilization.

F	Data on vehicle fuel life-cycle energy consumption and GHG emission			
F. 1	•Life cycle energy consumption and GHG emissions situation for gasoline production and utilization			
	Gasoline	•MJ/MJ fuel obtained and used $E_{LC, Gasoline}$	•g CO2,e /MJ fuel obtained an used $EM_{LC, Gasoline}$	Based on

- Table **G**. presents the **calculated results.**

G	Life cycle analysis results				
G. 1	•Life cycle energy consumption and GHG emissions situation for mixed electricity generation and supplying				calculted
	Mixed electricity	•MJ/MJ fuel obtained and used $EN_{LC. Mixed}$	•g CO2,e /MJ fuel o $EM_{LC. Mixed}$	•g CO2,e /kWh fuel obtained an used #VALUE!	
G. 2	Energy consumption for pure Battery EV				
		•MJ/ km driven EN_{EV}			
G. 3	GHG emissions for pure Battery EV				
		•g CO2,e / km driven EM_{EV}			
G. 4	Energy consumption for PHEV				
		•MJ/ km driven EN_{PHEV}			
G. 5	GHG emissions for PHEV				
		•g CO2,e / km driven EM_{PHEV}			
G. 5	Energy consumption for gasoline ICEV				
		•MJ/ km driven EN_{ICEV}			
G. 5	GHG emissions for for gasoline ICEV				
		•g CO2,e / km driven EM_{ICEV}			

- Table **H** presents the **labelling**.

H	Labelling							
H. 1	•for BEV							
	Direct energy consumptio	$E_{E. EV}$	kWh /100 km	or	$E_{V, EV}$	Liter (gasoline equivalent)/ 100 km		
			Life cycle energy comsumption			Life cycle GHG emis		percentile
			EN_{EV}	MJ/km	Vehicle running st	$EM_{D, EV}$	g CO2, e /	#VALUE!
					Upstream stage	$EM_{UPs, EV}$	g CO2, e /	#VALUE!
H. 2	•for PHEV							
	Direct energy consumptio	$E_{E. PHEV}$	kWh /100 km	or	$E_{V, PHEV}$	Liter (gasoline equivalent)/ 100 km		
			Life cycle energy comsumption			Life cycle GHG emissions		
			EN_{PHEV}	MJ/km	Vehicle running st	$EM_{D, PHEV}$	g CO2, e /	#VALUE!
					Upstream stage	$EM_{UPs, PH}$	g CO2, e /	#VALUE!

Part 4: Data to collect

The following data are encouraged to submit for the calculation mentioned above:

1) Data on electricity chains

- Electricity generation efficiency of fossil fuel (by type, %)

- Life cycle energy consumption and GHG emissions situation for fossil and non-fossil fuel power generation and supplying (Coal, Oil, Gas, Hydro, Nuclear, Solar, Wind, Biomass, Geothermal and others)
  - ✧ MJ/MJ power supplying
  - ✧ g CO2,e /MJ power supplying

- Composition of regional electrical grids (Coal, Oil, Gas, Hydro, Nuclear, Solar, Wind, Biomass, Geothermal and others, %)

- Electricity transmission loss (%)

- Composition of regional electrical grids (Coal, Oil, Gas, Hydro, Nuclear, Solar, Wind, Biomass, Geothermal and others, %)

- Electricity transmission loss (%)

2) Data on EV and PHEV charging and running

- Charging efficiency (%)

- Energy consumption for EV running (kWh /100 km)

- Energy consumption for PHEV running driven by electricity(kWh /100 km)

- Energy consumption for PHEV running driven by gasoline(Liter /100 km)

- The range share by electricity for PHEV (%)

Part 5: Stating Methods suggested

About the stating methods, some rules are suggested.

1) Labelling together
   - ** kWh /100 km
   - ** Liter (gasoline equivalent)/ 100 km
2) Comparing energy consumption by primary energy
3) Comparing GHG emissions to conventional gasoline vehicle
   - Total
   - By stages

Part 6: Supports are welcomed from contracting parties

1) The data listed in Part 4 should be collected with clear sources such as statistical book or formal report. The data format please see Appendix I;
2) Modifications suggestion for our suggested methods, with the presentation about the experiences of current calculation and labelling methods in EU, US and other specific regions.

Appendix I: Data Collection Table

1) Data for fuel to power

Technology	Life cycle energy consumption and GHG emissions situation for power generation and supplying*	
	Energy Consumption (MJ/MJ power supplying)	GHG Emissions (g CO2,e /MJ power supplying)
Coal as feedstock		
Oil as feedstock		
Gas as feedstock		
Hydro Power		
Nuclear Power		
Solar Power		
Wind Power		
Biomass		
Geothermal		
Others(please add)		

* For the fossil fuel(Coal, Oil, NG), data include: Energy consumption and emissions occurring in upstream stages, such as feedstock exploration, transportation, fuel production, and transportation, in addition to the energy consumption emissions occurring in the fuel utilization; the facility construction and vehicle manufacturing stages are excluded. For the non-fossil fuel, the energy consumption and emission during facility manufacturing and factory construction stages are allocated to the total power supplying during the whole life time of those power stations.

2) Composition of regional electrical grids (annual average)

Fuel Type / Technology	Percentage (%)
Coal as feedstock	
Heavy oil as feedstock	
Gas as feedstock	
Wind Power	
Hydro Power	
Nuclear Power	
Solar Power	
Wind Power	

Biomass	
Geothermal	
Others(please add)	

3) Electricity transmission loss

Electricity transmission loss (%)	

4) Life cycle energy consumption and GHG emissions situation for gasoline production and utilization

	Energy Consumption (MJ/MJ fuel obtained and used)	GHG Emission (g CO2,e /MJ fuel obtained an used)
Gasoline		

5) EV and PHEV Charging efficiency

Charging efficiency (%)	