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 CO2 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 CO2 intensity of a power generation mix is the average amount of CO2 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

The methods are suggested to use EXCEL tools to get life cycle analysis results.

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, and transportation, 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[©].
 - ✓ Life cycle analysis of GHG emissions situation of coal power (the share of different stages):
 - Coal mining and processing: 10.67%
 - Coal transportation:1.37%
 - Construction and decommissioning of the power plant:0.2%
 - Operation of the power plant:87.46%
 - 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)[®]:
 - ✓ Nuclear power (General situation):
 - Power production and operation: 81%
- Facility construction: 19%
- Transportation process: < 0.1%
- Backend of nuclear fuel cycle (decommissioning): data deficient, always be excluded
- ✓ Hydro power (Typical power plants in China):

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

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

• 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

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

$$E_{LC,Mixed} = \left[\frac{E_{LC,Coal}}{\eta_{Coal-to-ele}} * SH_{Coal} + \frac{E_{LC,NG}}{\eta_{NG-to-ele}} * SH_{NG} + \frac{E_{LC,Oil}}{\eta_{Oil-to-ele}} * SH_{Oil} + \sum_{k=1}^{i} E_{LC,k} * SH_{k}\right] * \frac{1}{1 - \eta_{Loss}}$$

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

$$EN_{EV} = \left[\frac{E_{LC,Coal}}{\eta_{Coal-to-ele}} * SH_{Coal} + \frac{E_{LC,NG}}{\eta_{NG-to-ele}} * SH_{NG} + \frac{E_{LC,Oil}}{\eta_{Oil-to-ele}} * SH_{Oil} + \sum_{k=1}^{i} E_{LC,k} * SH_{k}\right] * \frac{1}{1 - \eta_{Loss}} * \frac{E_{Ele,EV}}{\eta_{Charg.e}} * \frac{3.6}{100} * \frac{1}{100} * \frac{1}{$$

 \Leftrightarrow EV direct energy consumption in running stage (E_{DEV} , MJ/km):

$$E_{D,EV} = E_{Ele,EV} * \frac{3.6}{100}$$

 \Leftrightarrow EV energy consumption in upstream stage ($E_{Ups,EV}$, MJ/ km):

$$E_{Ups,EV} = EN_{EV} - E_{D,EV}$$

♦ Labelling of EV direct energy consumption :

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

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

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

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

 \Rightarrow PHEV direct energy consumption in running stage ($E_{D,PHEV}$, MJ/km):

$$E_{D,PHEV} = E_{Ele,PHEV} * SH_{Ele} * \frac{3.6}{100} + (1 - SH_{Ele}) * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100} + (1 - SH_{Ele}) * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100} + (1 - SH_{Ele}) * V_{Gasoline} * Q_{Gasoline} * \frac{1}{100} + (1 - SH_{Ele}) * V_{Gasoline} * Q_{Gasoline} * Q_{Gasoline}$$

 \diamond PHEV energy consumption in upstream stage ($E_{Ups,PHEV}$, MJ/ km):

$$E_{Ups,PHEV} = EN_{PHEV} - E_{D,PHEV}$$

♦ Labelling of PHEV direct energy consumption :

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

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

• GHG emissions

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

$$EM_{LC,Mixed} = \left[\frac{EM_{LC,Coal}}{\eta_{Coal-to-ele}} * SH_{Coal} + \frac{EM_{LC,NG}}{\eta_{NG-to-ele}} * SH_{NG} + \frac{EM_{LC,Oil}}{\eta_{Oil-to-ele}} * SH_{Oil} + \sum_{k=1}^{i} EM_{LC,k} * SH_{k}\right] * \frac{1}{1 - \eta_{Loss}} * SH_{NG} + \frac{EM_{LC,Oil}}{\eta_{Oil-to-ele}} * SH_{Oil} + \frac{EM_{LC,k} * SH_{k}}{\eta_{Oil-to-ele}} * SH_{Oil} + \frac{EM_{LC,NG}}{\eta_{Oil-to-ele}} * SH_{Oil} + \frac{EM_{LC,NG}}$$

 \Leftrightarrow EV life-cycle GHG emission (EM_{EV} ,g CO₂, e/km)

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

 \Leftrightarrow EV GHG emission in running stage ($EM_{D,EV}$, g CO₂, e/km):

$$EM_{DFV} = 0$$

 \Leftrightarrow EV GHG emission in upstream stage ($EM_{Ups,EV}$,g CO₂, e/km):

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

 \Rightarrow PHEV life-cycle GHG emission (EM_{PHEV} , g CO₂, e/km):

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

 \Leftrightarrow PHEV GHG emission in running stage ($EM_{D,PHEV}$,g CO₂, e/km):

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

 \Leftrightarrow PHEV GHG emission in upstream stage ($EM_{Ups,PHEV}$, g CO₂, e/km):

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

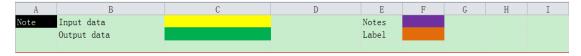
Where:

	Symbol	Unit	Description
	$E_{LC,Coal}$	МЈ/МЈ	Life cycle energy consumption for coal production and distribution
	$EM_{\scriptscriptstyle LC,Coal}$	g CO ₂ , e/MJ	Life cycle GHG emission for coal production and distribution
Input Variables: The input	$\eta_{\scriptscriptstyle Coal-to-ele}$	%	Coal power electricity generation efficiency
data based on annual statistical data books or formal report	$SH_{\it Coal}$	%	The share of coal power in the total electricity supplying of regional electrical grids
vary from country to country in the calculation, and they	$E_{\scriptscriptstyle LC,Oil}$	МЈ/МЈ	Life cycle energy consumption for oil production and distribution
can be collected from most countries.	$EM_{LC,Oil}$	MJ/MJ	Life cycle GHG emission for oil production and distribution
	$\eta_{\scriptscriptstyle Oil-to-ele}$	%	Oil power electricity generation efficiency
	$SH_{\it Oil}$	%	The share of oil power in the total electricity supplying of regional electrical grids
	$E_{\scriptscriptstyle LC,NG}$	MJ/MJ	Life cycle energy consumption for NG production and distribution
	$EM_{LC,NG}$	g CO ₂ , e/MJ	Life cycle GHG emission for NG production and distribution
	$\eta_{_{NG-to-ele}}$	%	NG power electricity generation efficiency
	SH_{NG}	%	The share of NG power in the total electricity supplying of regional electrical grids
	k		The type of non-fossil fuel power from 1 to i mean : Hydro, Nuclear, Solar, Wind ,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 non-fossil fuel type k in the total electricity supplying

	$\eta_{{\scriptscriptstyle Loss}}$	%	Electricity transmission loss rate
	$E_{{\scriptscriptstyle Ele},{\scriptscriptstyle EV}}$	kWh/100km	Direct Energy consumption of EV in running stage
	$\eta_{{\it Ch}{ m arg}{\it e}}$	%	Charging efficiency
	$E_{{\scriptscriptstyle Ele,PHEV}}$	kWh/100km	Energy consumption of PHEV driven by power in running stage
	$SH_{{\scriptscriptstyle Ele}}$	%	The range share by electricity
	$E_{\scriptscriptstyle LC,Gasoline}$	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
	$V_{\it Gasoline}$	Liter/100km	Energy consumption of PHEV driven by gasoline in running stage
	$Q_{\it Gasoline}$	32 MJ/L [®]	Calorific value of gasoline
Parameters	EM _{Gasoline}	67.91 g CO ₂ , e/MJ [®]	GHG emission intensity for gasoline

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.

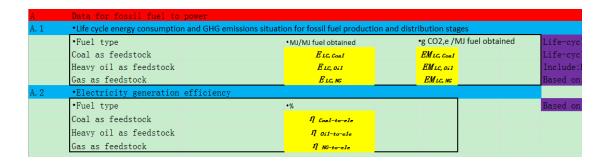


Upstream stage

★ Table A presents the data for different fossil fuel to power. A.1 is life cycle energy consumption (primary fossil energy intensity for secondary energy, MJ/MJ) and GHG emissions(g CO2, e/MJ) situation for fossil fuel production and distribution stages. A.2 presents the electricity generation efficiency (%).

[®] Averaged value . $Q_{Gasoline} = \mathbf{Q} \cdot \mathbf{D}/1000$, \mathbf{Q} : gasoline calorific value, 43.07 MJ/kg (GB/T 2589-2008); \mathbf{D} : gasoline density, 720-775 kg/m³ (GB 17930-2013).

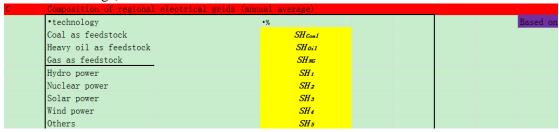
[®] EM _{Gasoline} =44/12*FCO*CEF, FCO: fuel oxidation rate, 0.98; CEF: carbon emission factor, 18.9 g/MJ. (Reference: China Academy of Engineering. 2015. Greenhouse gas emissions of different power energy in China [M]. Beijing: Atomic Energy Press.)



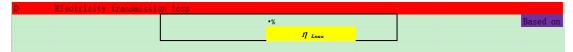
→ Table B presents the data for non-fossil fuel to power.

В	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 CO2,e /MJ power supplying						
	Hydro power	E 1.C, 1	EM LC, 1				
	Nuclear power	E 1.C, 2	EM LC, 2				
	Solar power	E LC, 3	EM LC, 3				
	Wind power	E LC, 4	EM LC, 4				
	Others	E 1.C, 5	EM LC, 5				

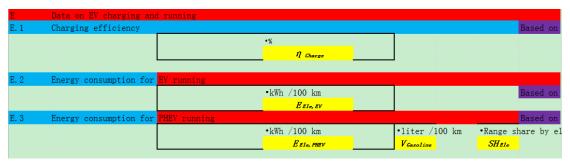
→ Table C presents the data for composition of regional electrical grids (annual average).



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



Running stage



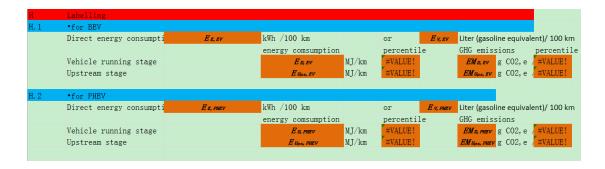
→ Table F presents the data on vehicle fuel life-cycle energy consumption and GHG emissions situation for gasoline production and utilization.

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						
			•MJ/MJ fuel obtained and u	used	•g CO2,e /	MJ fuel obtained a	n used
	Gasoline		ELC, Gasoline		EM LC, Gasolin	ie.	Based on

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

C	life evelo enclusis nos	v1+a						
G. 1	Life_cycle_analysis_results *Life cycle energy consumption and GHG emissions situation for gasoline production and utilization							
J. 1	the cycle energy consumption a		•MJ/MJ fuel obtained and u		•g CO2,e /MJ	fuel obtained	d an used	
	Mixed electricity		ELC, Mixed		EN LC, Mixed			
G. 2	Energy consumption for	pure Battery EV						
			•MJ/ km driven					
			EN zv					
G. 3	GHG emissions for pure	Battery EV						
			g CO2,e / km driven					2 2.
			Ell ev					calculted
G. 4	Energy consumption for	PHEV						
			•MJ/ km driven					
			EN prev					
G. 5	GHG emissions for PHEV							
			g CO2,e / km driven					
			EM puev					

• Table **H** presents the **labelling**.



Part 3: Data to collect

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

- 1) Data on electricity chains
 - Life cycle energy consumption and GHG emissions situation for fossil fuel production and distribution stages of power generation(Coal, Oil, Gas)
 - ♦ MJ/MJ fuel obtained
 - ♦ g CO2,e /MJ fuel obtained
 - Electricity generation efficiency of fossil fuel (by type, %)
 - Life cycle energy consumption and GHG emissions situation for non-fossil

fuel power generation and supplying (Hydro, Nuclear, Solar, Wind and others)

- ♦ MJ/MJ power supplying
- ♦ g CO2,e /MJ power supplying
- Composition of regional electrical grids (Coal, Oil, Gas, Hydro, Nuclear, Solar, Wind 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 (%)

Part 4: Stating Methods suggested

About the stating methods, some rules are suggested.

- 1) Labelling together
 - kWh /100 km
 - Liter (gasoline equivalent)/ 100 km
- 2) Considering energy consumption by upstream and operation stages
 - Upstream (percentile)
 - Operation (percentile)
- 3) Comparing GHG emissions to conventional gasoline vehicle
 - Total
 - By stages

Part 5: Supports are welcomed from contracting parties

- 1) The data listed in Part 3 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 labeling methods in other specific regions.

Appendix I: Data Collection Table

1) Data for fossil fuel to power

	Life cycle energy co			
	emissions situat	Electricity generation		
Fuel Type	production and	efficiency		
Fuel Type	Energy Consumntion**	GHG Emissions***		
	Energy Consumption**	(g CO2,e /MJ fuel	(%)	
	(MJ/MJ fuel obtained)	obtained)		
Coal as feedback				
Heavy oil as feedback*				
Gas as feedback				
Others(please add)				

^{*}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.

2) Data for non-fossil fuel to power

Data for non-rossif fact to power					
	Life cycle energy consumption and GHG emissions situation for				
Technology	power generation and supplying*				
	Energy Consumption	GHG Emissions			
	(MJ/MJ power supplying)	(g CO2,e /MJ power supplying)			
Hydro Power					
Nuclear Power					
Solar Power					
Wind Power					
Others(please add)					

^{*}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.

3) Composition of regional electrical grids (annual average)

	<u> </u>
Fuel Type /	Percentage (%)
Technology	Torontage (10)
Coal as feedback	
Heavy oil as feedback	
Gas as feedback	
Wind Power	
Hydro Power	
Nuclear Power	
Solar Power	

^{**}Life-cycle primary fossil energy intensity for secondary energy (MJ/MJ)

^{***} Life-cycle emission intensity (g CO2,e/MJ)

	Others(please add)	
1)	Electricity transmissio	n loss

Wind Power

Electricity		
transmission loss (%)		

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

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