

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 be 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^①.
 - ✓ 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)^②:
 - ✓ 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):

^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.

- 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):

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

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

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

- ✧ EV direct energy consumption in running stage ($E_{D,EV}$, MJ/ km):

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

- ✧ 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 :

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

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

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

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

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

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

✧ 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 :

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

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

● GHG emissions

✧ Life cycle GHG emission for mixed electricity generation and supply ($EM_{LC,Mixed}$, g CO_{2,e} /MJ power supplying):

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

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

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

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

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

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

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

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

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

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

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

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.	$E_{LC,Coal}$	MJ/MJ	Life cycle energy consumption for coal production and distribution
	$EM_{LC,Coal}$	g CO ₂ , e/MJ	Life cycle GHG emission for coal production and distribution
	$\eta_{Coal-to-ele}$	%	Coal power electricity generation efficiency
	SH_{Coal}	%	The share of coal power in the total electricity supplying of regional electrical grids
	$E_{LC,Oil}$	MJ/MJ	Life cycle energy consumption for oil production and distribution
	$EM_{LC,Oil}$	MJ/MJ	Life cycle GHG emission for oil production and distribution
	$\eta_{Oil-to-ele}$	%	Oil power electricity generation efficiency
	SH_{Oil}	%	The share of oil power in the total electricity supplying of regional electrical grids
	$E_{LC,NG}$	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

	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
Parameters	$V_{Gasoline}$	Liter/100km	Energy consumption of PHEV driven by gasoline in running stage
	$Q_{Gasoline}$	32 MJ/L ^③	Calorific value of gasoline
	$EM_{Gasoline}$	67.91 g CO ₂ , e/MJ ^④	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.

A	B	C	D	E	F	G	H	I
Note	Input data			Notes				
	Output data			Label				

• 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 (%).

^③ Averaged value . $Q_{Gasoline} = Q \cdot D / 1000$, Q : gasoline calorific value, 43.07 MJ/kg (GB/T 2589-2008); D : gasoline density, 720-775 kg/m³ (GB 17930-2013).

^④ $EM_{Gasoline} = 44/12 \cdot FCO \cdot CEF$, 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 .)

A Data for fossil fuel to power				
A.1 •Life cycle energy consumption and GHG emissions situation for fossil fuel production and distribution stages				
•Fuel type	•MJ/MJ fuel obtained	•g CO ₂ e /MJ fuel obtained		Life-cycle
Coal as feedstock	$E_{LC, Coal}$	$EM_{LC, Coal}$		Life-cycle
Heavy oil as feedstock	$E_{LC, Oi1}$	$EM_{LC, Oi1}$		Include:
Gas as feedstock	$E_{LC, NG}$	$EM_{LC, NG}$		Based on
A.2 •Electricity generation efficiency				
•Fuel type	•%			Based on
Coal as feedstock	$\eta_{Coal-to-ele}$			
Heavy oil as feedstock	$\eta_{Oil-to-ele}$			
Gas as feedstock	$\eta_{NG-to-ele}$			

✧ 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				
•technology	•MJ/MJ power supplying	•g CO ₂ e /MJ power supplying		The ener
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_{Oi1}			
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			Based on
	$E_{ELE, EV}$			
E.3 Energy consumption for PHEV running				
	•kWh /100 km	•liter /100 km	•Range share by el	
	$E_{ELE, PHEV}$	$V_{Gasoline}$	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 CO _{2,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 gasoline production and utilization			
Mixed electricity	•MJ/MJ fuel obtained and used $E_{LC, Mixed}$	•g CO _{2,e} /MJ fuel obtained an used $EM_{LC, Mixed}$	
G.2 Energy consumption for pure Battery EV			
	•MJ/ km driven EN_{EV}		
G.3 GHG emissions for pure Battery EV			
	•g CO _{2,e} / km driven EN_{EV}		
G.4 Energy consumption for PHEV			
	•MJ/ km driven EN_{PHEV}		
G.5 GHG emissions for PHEV			
	•g CO _{2,e} / km driven EN_{PHEV}		

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

H Labelling						
H.1 •for BEV						
Direct energy consumption	$E_{E, EV}$	kWh /100 km	or	$E_{V, EV}$	Liter (gasoline equivalent)/ 100 km	
		energy consumption		percentile	GHG emissions	percentile
Vehicle running stage	$E_{D, EV}$	MJ/km		#VALUE!	$EM_{D, EV}$	g CO _{2, e} / #VALUE!
Upstream stage	$E_{Up, EV}$	MJ/km		#VALUE!	$EM_{Up, EV}$	g CO _{2, e} / #VALUE!
H.2 •for PHEV						
Direct energy consumption	$E_{E, PHEV}$	kWh /100 km	or	$E_{V, PHEV}$	Liter (gasoline equivalent)/ 100 km	
		energy consumption		percentile	GHG emissions	
Vehicle running stage	$E_{D, PHEV}$	MJ/km		#VALUE!	$EM_{D, PHEV}$	g CO _{2, e} / #VALUE!
Upstream stage	$E_{Up, PHEV}$	MJ/km		#VALUE!	$EM_{Up, PHEV}$	g CO _{2, e} / #VALUE!

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 CO_{2,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 CO_{2,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

Fuel Type	Life cycle energy consumption and GHG emissions situation for fossil fuel production and distribution stages		Electricity generation efficiency (%)
	Energy Consumption** (MJ/MJ fuel obtained)	GHG Emissions*** (g CO _{2,e} /MJ fuel 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.

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

*** Life-cycle emission intensity (g CO_{2,e}/MJ)

2) Data for non-fossil 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 CO _{2,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)

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

Wind Power	
Others(please add)	

4) Electricity transmission loss

Electricity transmission loss (%)	
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5) Life cycle energy consumption and GHG emissions situation for gasoline production and utilization

	Energy Consumption (MJ/MJ fuel obtained and used)	GHG Emission (g CO ₂ e /MJ fuel obtained an used)
Gasoline		