Paris Session 2022

Assessment of Life Cycle Emissions from Battery Electric (BEV) as compared with DME-fuelled Compression Ignition Vehicles

SC C3 – PS 1
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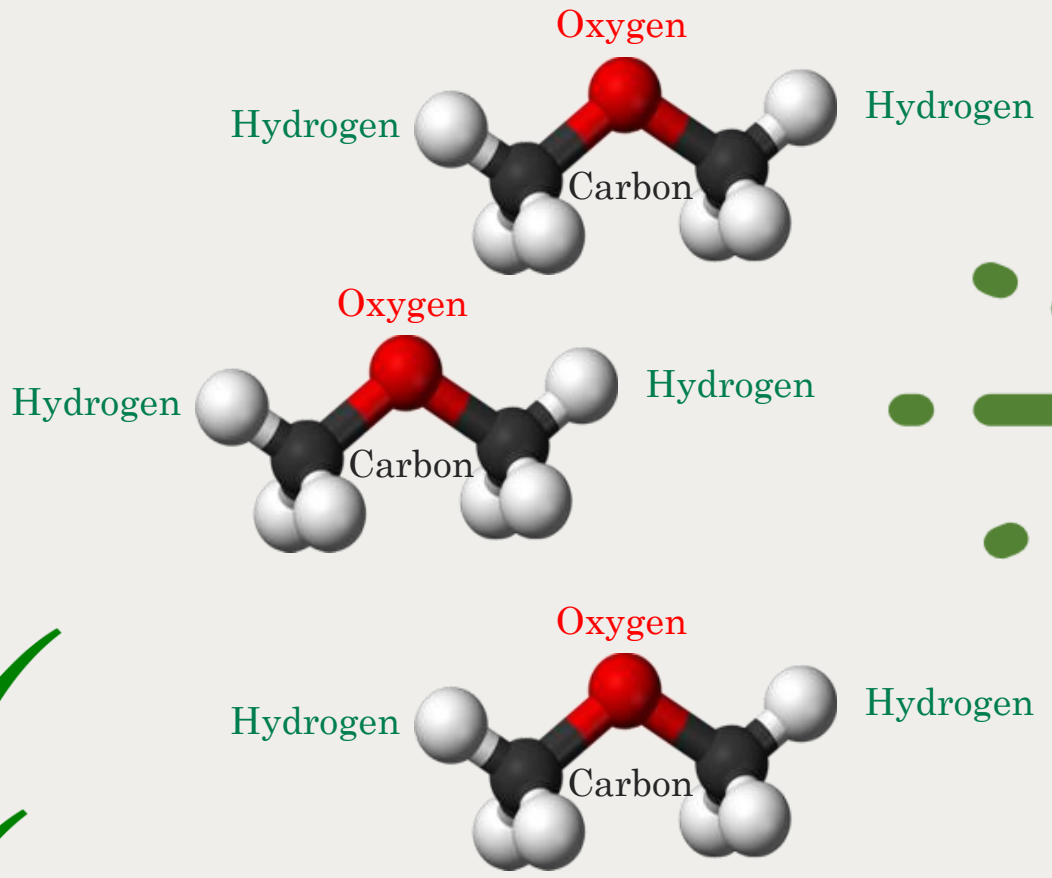
What is DME?

$$CH_3OCH_3$$

- Non-toxic ✓
- Non-carcinogenic ✓
- Non-teratogenic ✓

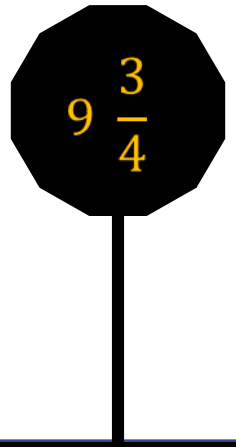


	Methane	Methanol	DME	Ethanol	Gasoline	Diesel
Formula	CH_4	CH_3OH	CH_3OCH_3	CH_3CH_2OH	C_7H_{16}	$C_{14}H_{30}$
Molecular Weight (g/mol)	16.04	32.04	46.07	46.07	100.2	198.4
Density (g/cm^3)	0.00072	0.792	0.661	0.785	0.737	0.856
Normal Boiling Point (°C)	-162	64	-24.9	78	38 – 204	125 – 400
LHV (kJ/cm^3)	0.0346	15.82	18.92	21.09	32.05	35.66
LHV (kJ/g)	47.79	19.99	28.62	26.87	43.47	41.66
Cetane Number	75	5	55-60	12	93-97	46-55
Exergy (MJ/kg)	51.76	22.36	30.75	29.4	47.46	46.94
Carbon Content (wt. %)	74	37.5	52.2	52.2	85.5	87
Sulfur Content (ppm)	~7 - 25	0	0	0	~200	~250
Ignition Temperature (°C)	600	440	350	376	280	177-329

[Semelsberger, 2006 & Sinor, 1997]


SKIP

1. Does a DME vehicle emit more Emissions & use more Energy than an EV?
2. What can be done to Optimise these fuel-type vehicles.



PLEASE MIND THE **RESEARCH GAP** BETWEEN THE PLATFORM AND THE TRAIN

Thesis Objectives

1. Understand Fuel & Vehicle Pathways

2. Quantify their Emission and Energy Intensities

3. Approach Optimised Technologies through the Introduction of Variances

1. Understanding Fuel & Vehicle Pathways

Barriers to Entry

Refining & Processing

Existing Infrastructure

Raw Material Extraction

Alternative Processes

Usage & Combustion

Future Outlook

Storage & Distribution

Current Applications

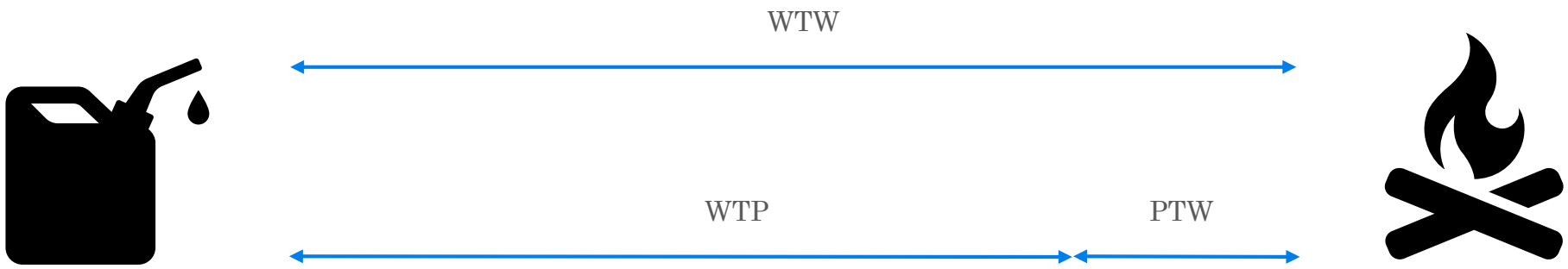
Transportation

Manufacturing processes

End of life recycling

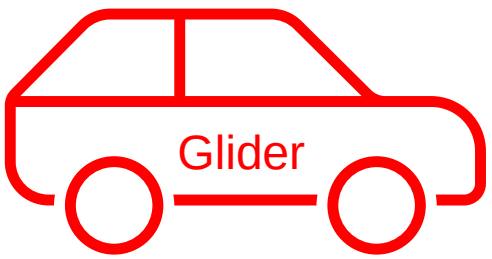
2. Quantifying Emissions & Energy Intensities

GREET ® + Excel = LCA



Base Scenarios (BS)

$$\text{BS Design} = (\text{WTW})_{\text{Fuel}} + (\text{WTW})_{\text{Glider Attributes}} + (\text{WTW})_{\text{Bespoke Vehicle Attributes}}$$



20-year lifetime

150,000 km

Plastics

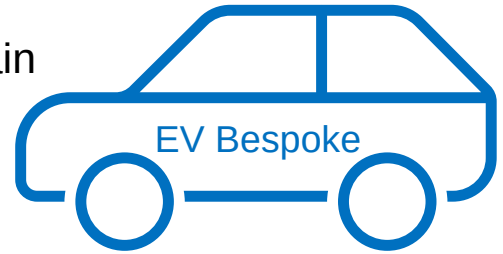
Chassis w/o Battery

Fluids

Body

Tyre Replacement

Transmission



480 km/charge

Li-ion BOM

Battery Management System

Electronic Controller

Powertrain

Glycerol

Traction Motor

Copper, Aluminium, Steel

100 kWh Battery

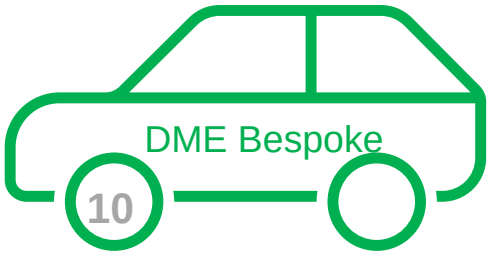
Aluminium

Lead Acid Battery

Powertrain

Copper Wiring & Harnessing

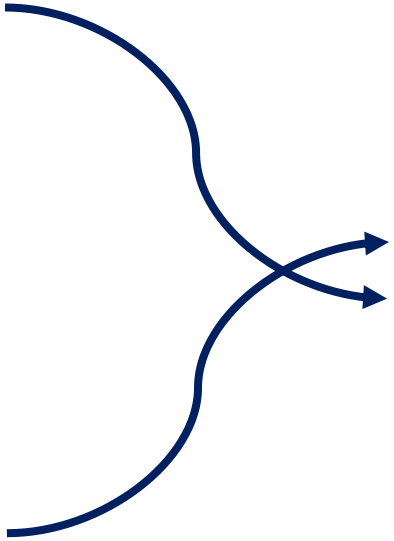
Coolant (Fatty Acid)



Base Scenarios (BS)

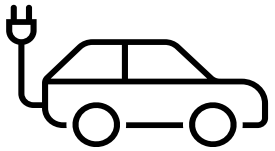
BS1
BS3

BS2
BS4

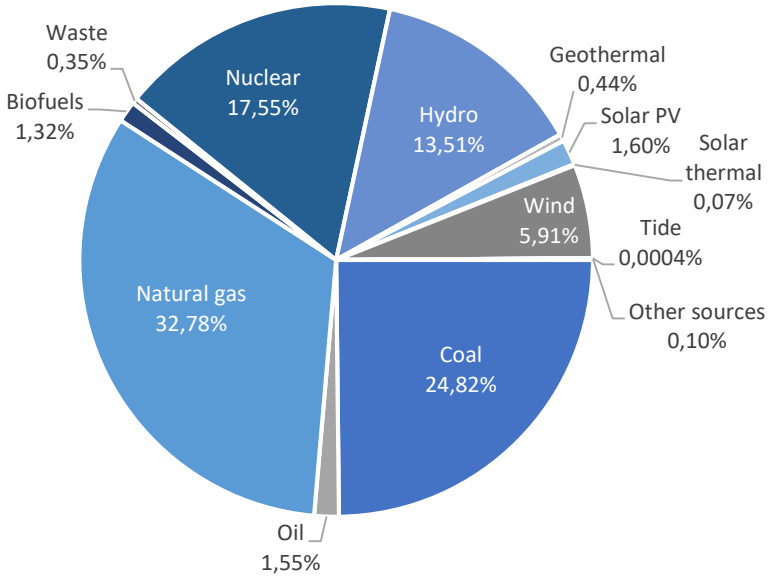


BS1 & BS2

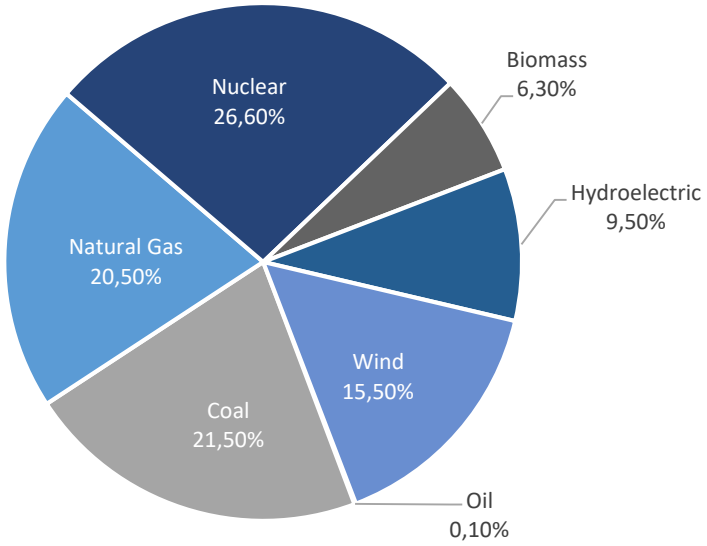
NA Average Electricity Mix Generation → Electric Transmission and Distribution →

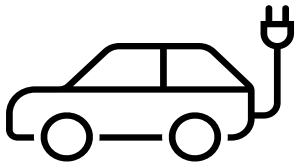


NA Average Electricity Mix 2020



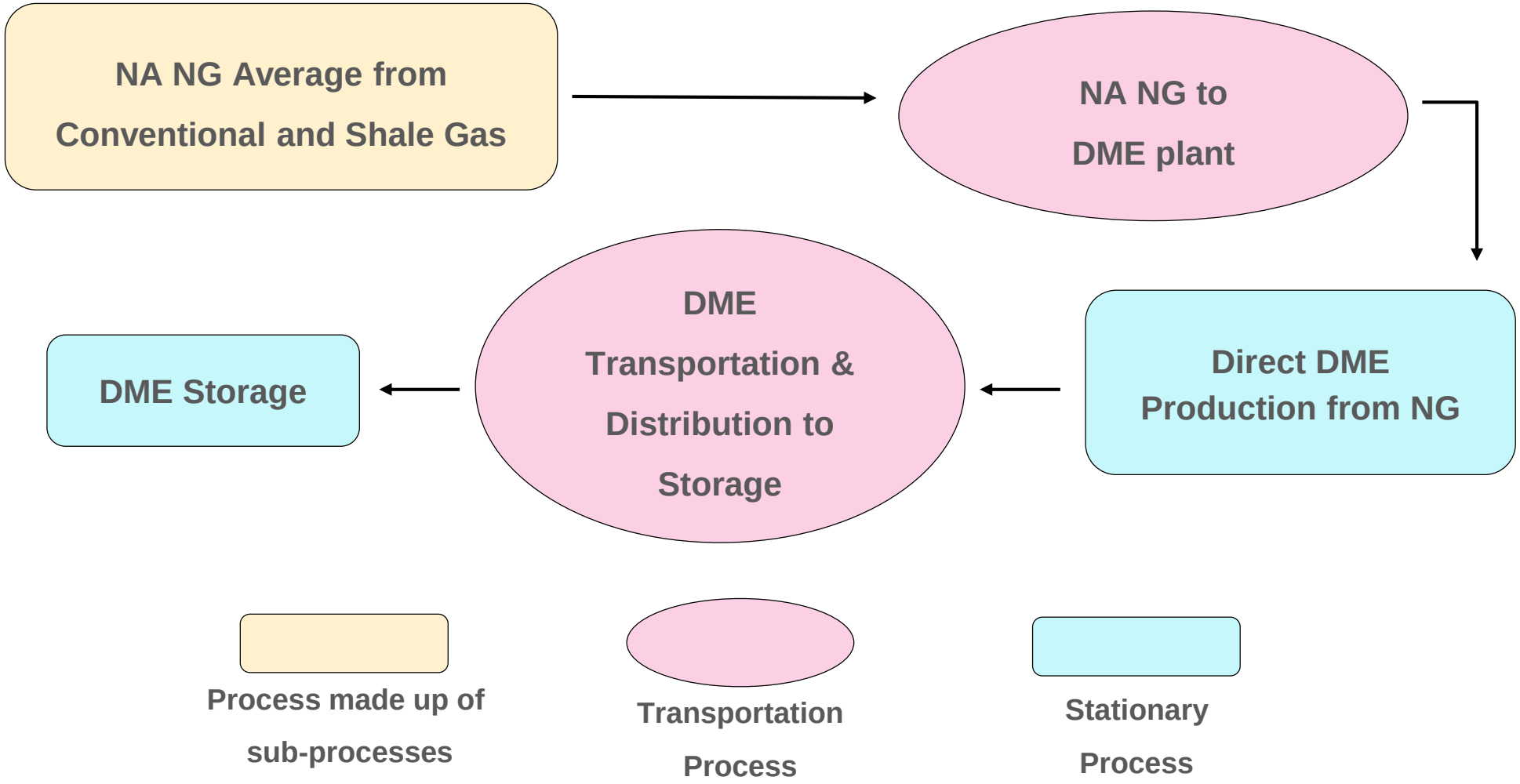
European Average Electricity Mix 2020



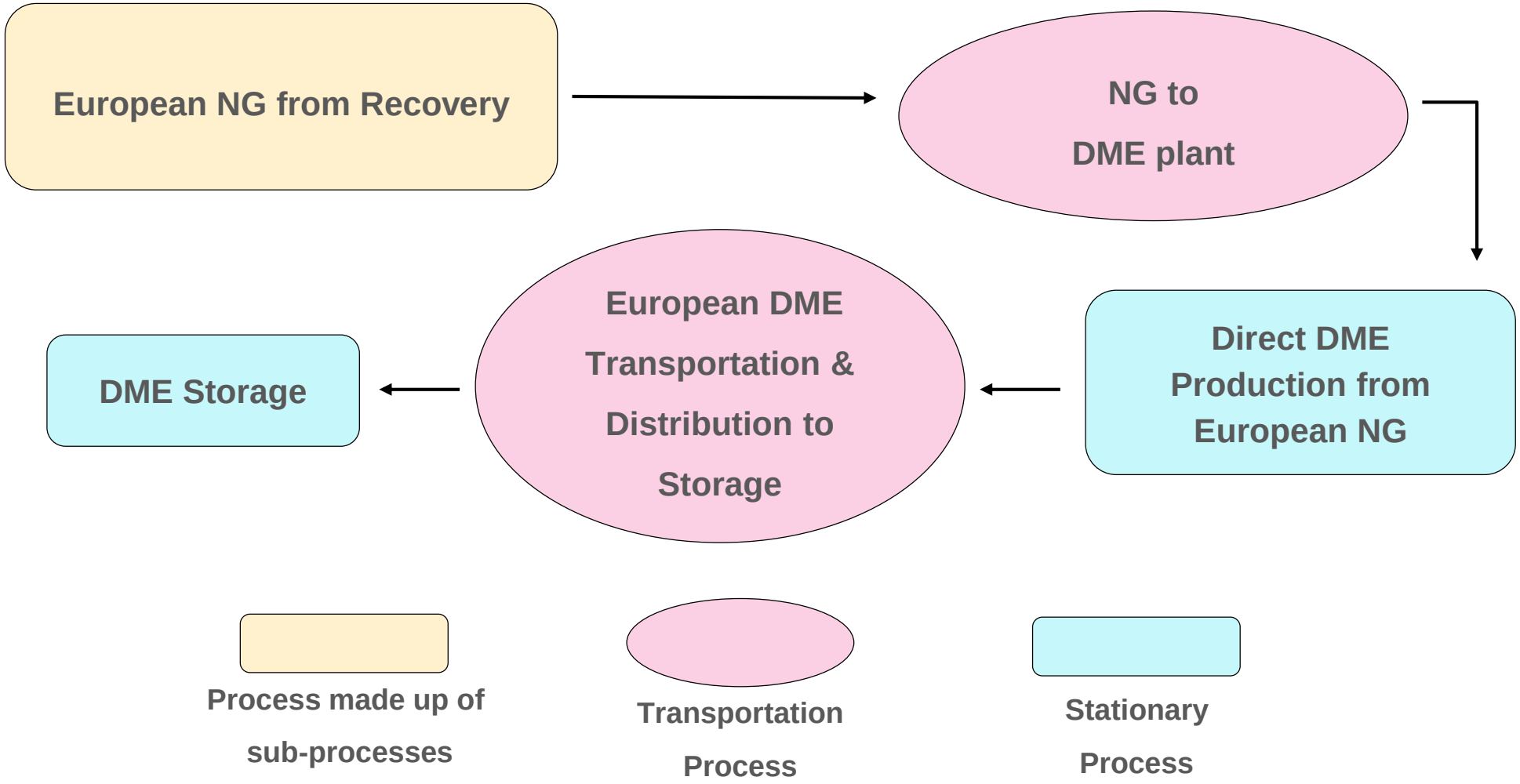


← Electric Transmission and Distribution ← European Average Electricity Mix Generation

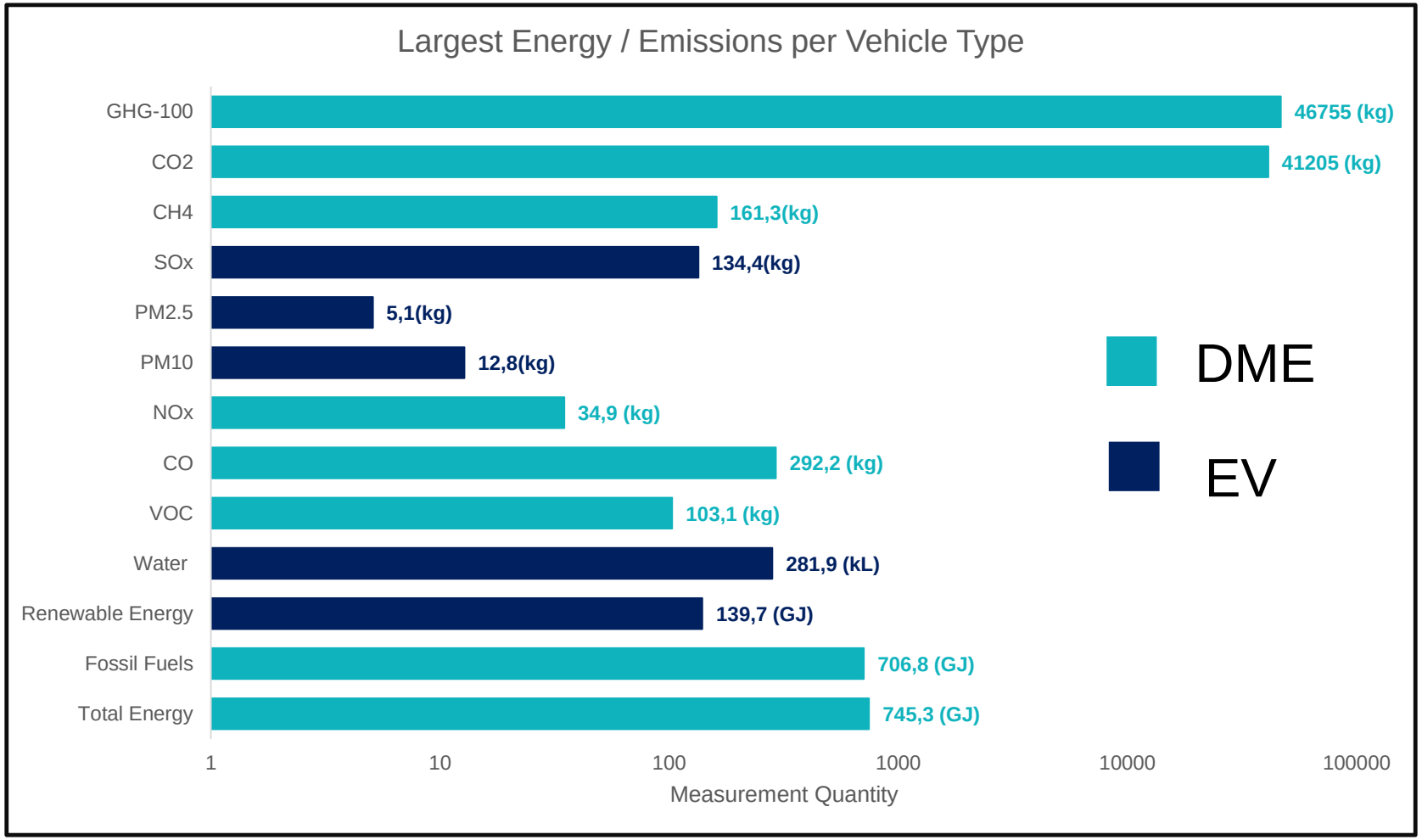
BS3 – NA DME



BS3 – EU DME



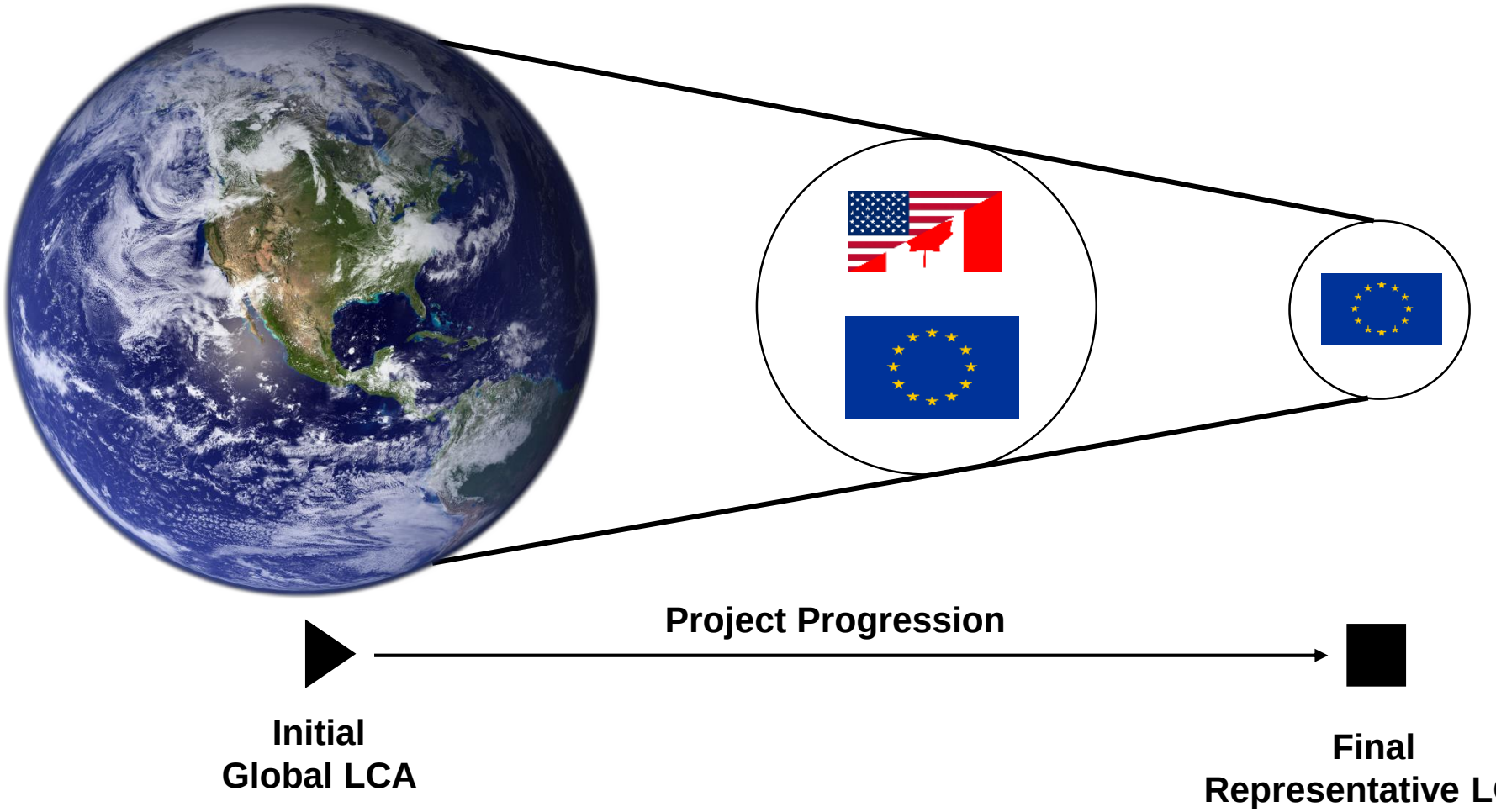
BS Results



North American (BS1 & BS3)			
Measurement	**EV**	**DME**	**DME Relative to EV**
Total Energy (GJ)	494.4	745.3	+50.75%
Fossil Fuels (GJ)	396.2	706.8	+78.39%
Renewable Energy (GJ)	98.2	38.45	-60.85%
Water (kL)	281.9	54.57	-80.64%
VOC (kg)	98.9	103.0	+4.15%
CO (kg)	32.7	292.2	+793.58%
NOx (kg)	30.8	34.9	+13.31%
PM10 (kg)	9.9	4.3	-56.57%
PM2.5 (kg)	4.3	2.1	-51.16%
SOx (kg)	134.4	48.3	-64.06%
CH_4 (kg)	75.8	161.2	+112.66%
CO_2 (kg)	29670	41205	+38.88%
GHG-100 (kg)	31650	46755	+47.73%

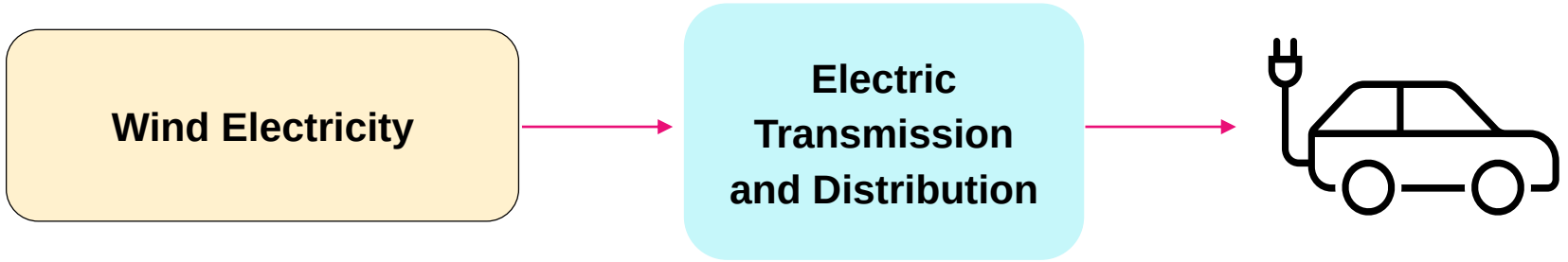
Europe (BS2 & BS4)			
Measurement	**EV**	**DME**	**DME Relative to EV**
Total Energy (GJ)	489.3	739.0	+51.03%
Fossil Fuels (GJ)	349.6	694.05	+98.53%
Renewable Energy (GJ)	139.7	44.95	-67.82%
Water (kL)	262.6	49.32	-81.22%
VOC (kg)	98.4	103.1	+4.78%
CO (kg)	36.5	291.0	+697.26%
NOx (kg)	28.2	34.5	+22.34%
PM10 (kg)	12.8	4.7	-63.28%
PM2.5 (kg)	5.1	2.2	-56.86%
SOx (kg)	130.3	45.9	-64.77%
CH_4 (kg)	67.8	161.3	+137.91%
CO_2 (kg)	28800	40650	+41.15%
GHG-100 (kg)	28365	45765	+61.34%

Variance Scenario (VS)

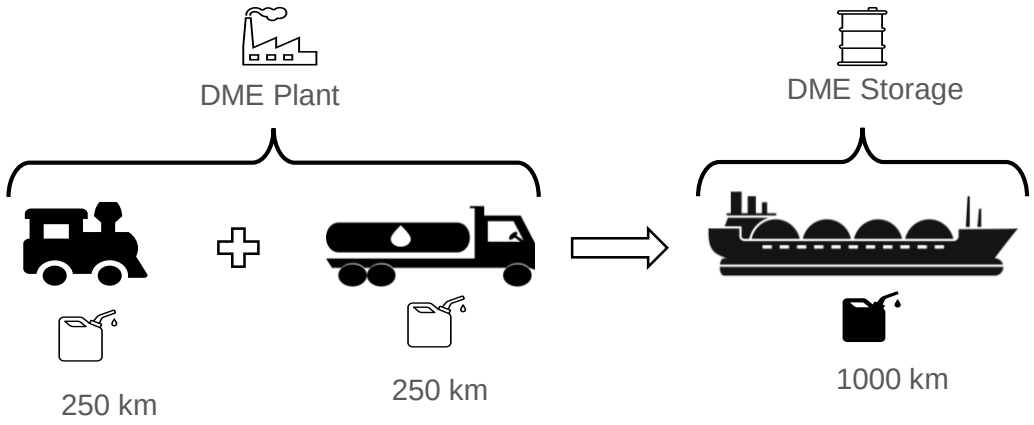


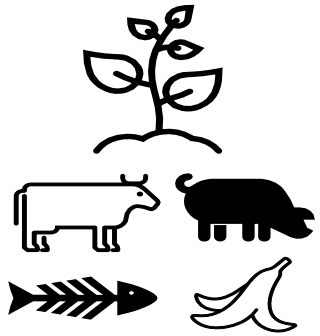
Variance Scenarios

EV



DME





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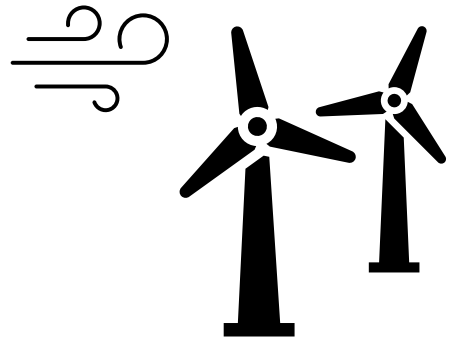
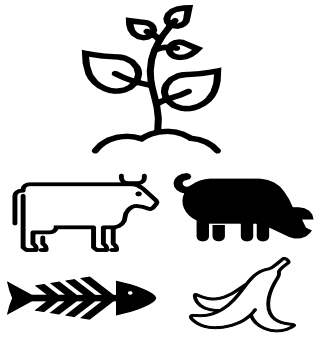
Notable VS Results

Optimal Variance Scenarios (VS2.1 & VS4.1)			
Measurement	**EV**	**DME**	**DME Relative to EV**
Total Energy (GJ)	347.11	830.86	+139.4%
Fossil Fuels (GJ)	174.87	156.31	-10.6%
Renewable Energy (GJ)	172.23	674.55	+291.7%
Water (kL)	28.20	31.99	+13.4%
VOC (kg)	96.58	96.51	-0.1%
CO (kg)	22.09	285.32	+1191.6%
NOx (kg)	16.72	29.17	+74.5%
PM10 (kg)	6.64	4.10	-38.3%
PM2.5 (kg)	3.04	1.97	-35.2%
SOx (kg)	103.80	38.22	-63.2%
CH4 (kg)	36.77	51.25	+39.4%
CO2 (kg)	11808.00	33217.00	+181.3%
GHG-100 (kg)	13594.00	12032.00	-11.5%





DME or EV

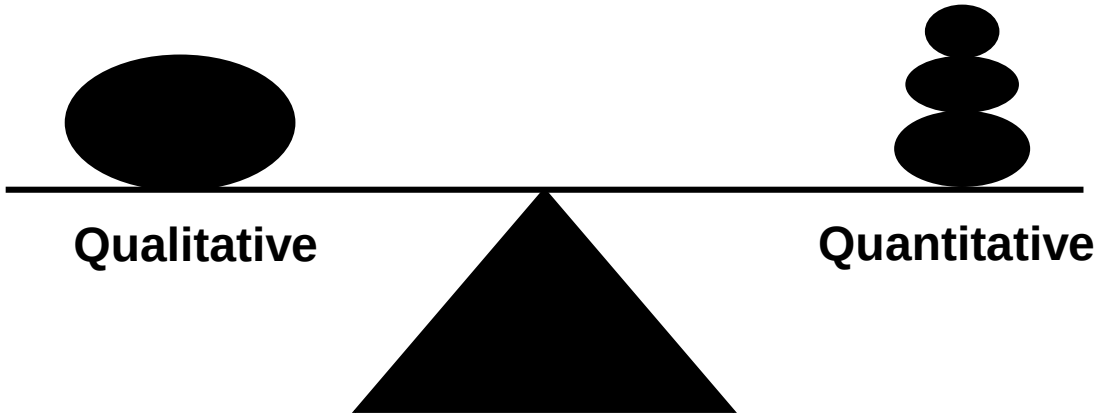
DME			
Measurement	BS	Value	Unit
Total Energy	3	745.3	GJ
Fossil Fuels	3	706.8	GJ
VOC	4	103.1	kg
CO	3	292.2	kg
NOx	3	34.9	kg
CH4	4	161.3	kg
CO2	3	41205	kg
GHG-100	3	46755	kg

EV			
Measurement	BS	Value	Unit
Renewables	2	139.7	GJ
Water	1	281.9	kL
PM10	2	12.8	kg
PM2.5	2	5.1	kg
SOx	1	134.4	kg

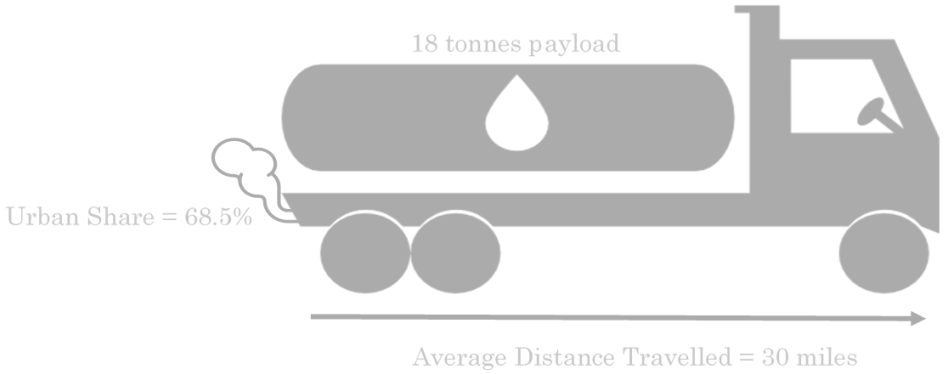
	North America		Europe	
	EV	DME	EV	DME
Total Energy (GJ)	494.4	745.3	489.3	739.0
Total Emissions* (Tonnes)	30.10	41.85	29.18	41.29

Future Work

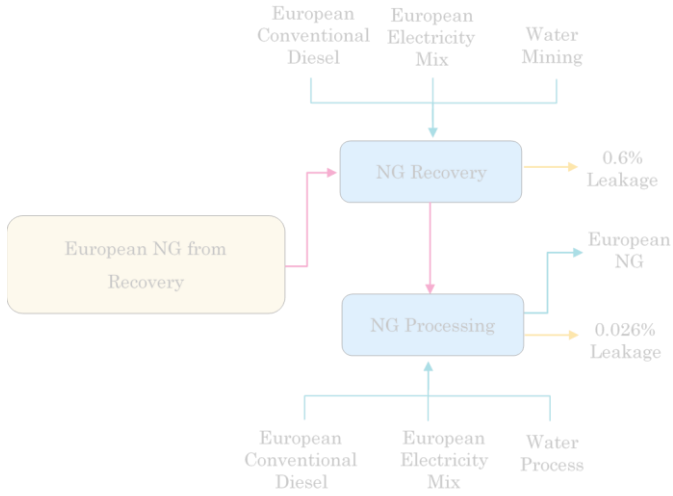
Additional Pathways



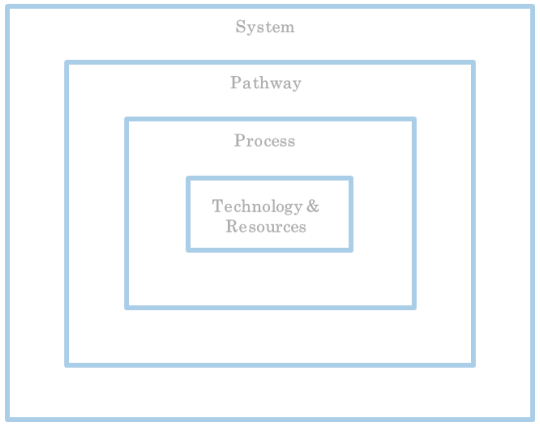
DME vs. EV LCA

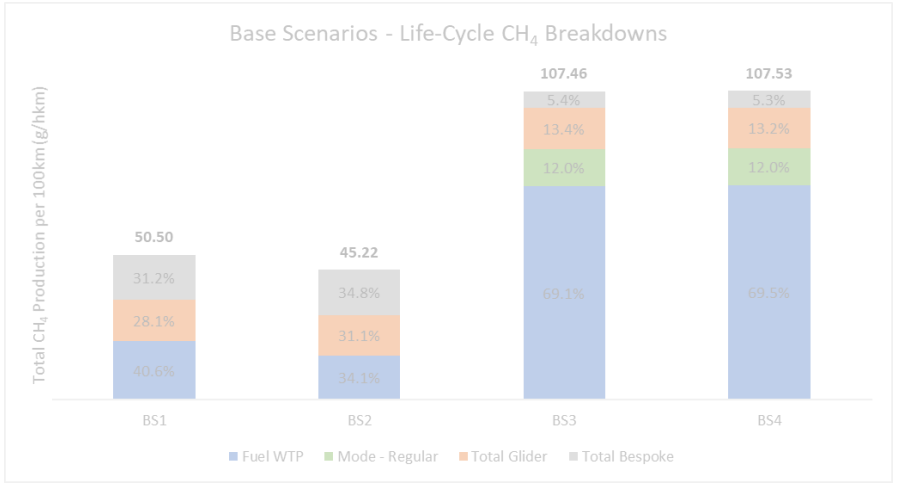


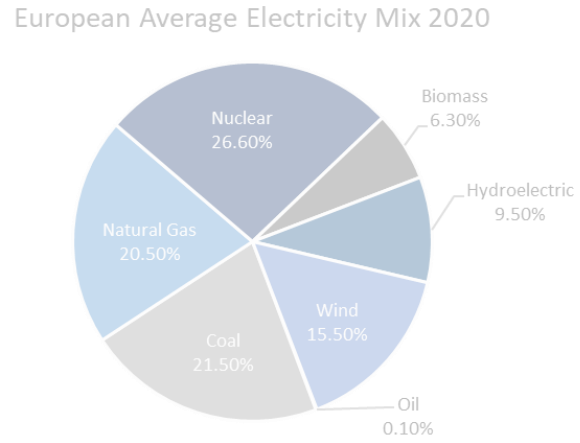
- Operating Fuel = Conventional Diesel from Crude Oil
- Energy Intensity = 0.75 J/kg m
- Fuel Economy = 9.22 miles/gallon



$$WTW = WTP + Mode + \sum_{A=1}^{ADR} A(a) + \sum_{b=1}^{battery} B(b) + \sum_{c=1}^{components} C(c) + \sum_{F=1}^{fluids} F(f)$$







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