POLITECNICO MILANO

DME-FUELLED GARBAGE TRUCKS

Waste to Energy (WTE) Supply Chains

Emma Patuzzo
Federico Silvestri
Mostafa Bahgat
Raihan Rasheed
Stefano Lombardi

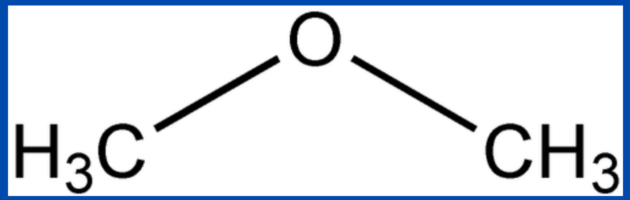
Energy and Emission

Group 16

OVERVIEW

1 - Introduction

DME



Organic compound:
- lack of odour and toxicity
- ability to be absorbed into the troposphere
- CO2 absorber in its production

DME combustion:
- low NOx and CO emissions
- low well-to-wheel greenhouse gas emissions

What is a circular economy?

It is a model of production and consumption, which is based on reusing, repairing, and recycling existing materials and products with the aim of reducing climate changes, biodiversity loss, waste, and pollution

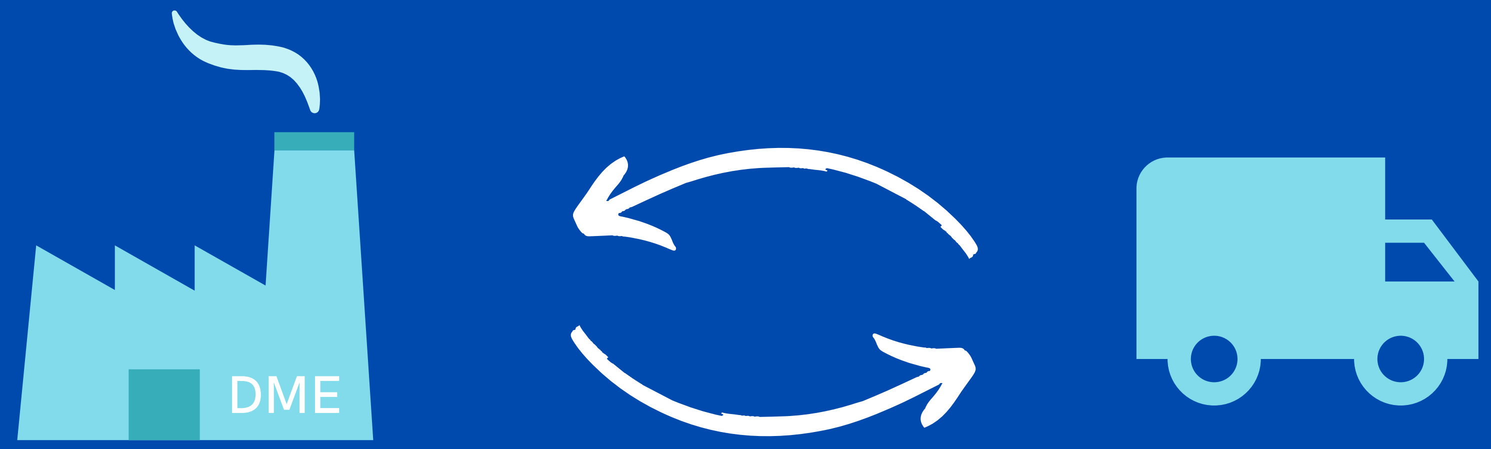
-Waste to Energy (WTE) Supply Chains

Convertion of bio-waste in to some form of bio-based fuel of energy

Objectives and guidelines for WTE DME Supply chain

Keep all phases of the supply chain close to each other to reduce transportation costs and emissions

Constant and sufficient fuel supply in order to cope with mobility demands of the sector that will utilize DME as a propellent.



Waste recycling current situation in Milan

2011

2014

Recycling rate low and mainly of dry recyclables like paper and plastic

Improving up to 90 kg of waste collected per resident each year

Citizens collect their food waste in compostable bags that are transferred to an anaerobic digestion and compositing facility

Anaerobic digestion is a low energy and simple process but the biogas produced contains a big fraction of CO_2.

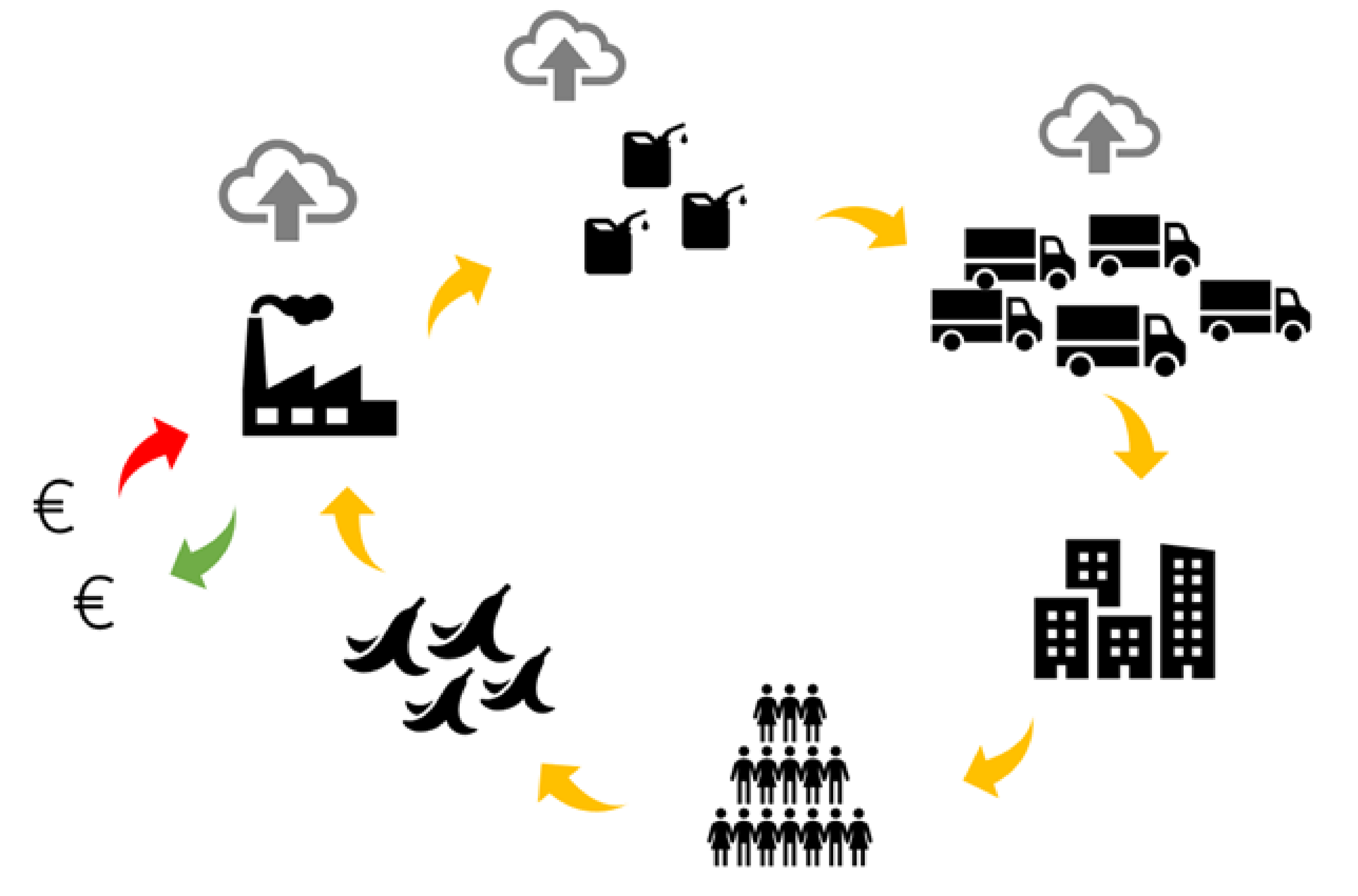
A possible alternative is Gasification of Biomass

2 - Case Study Desctiption

Construction of a conventional plant that produce DME starting from Municipal Solid Waste

MSW is collected by trucks that are fuelled by DME produced by the plant itself

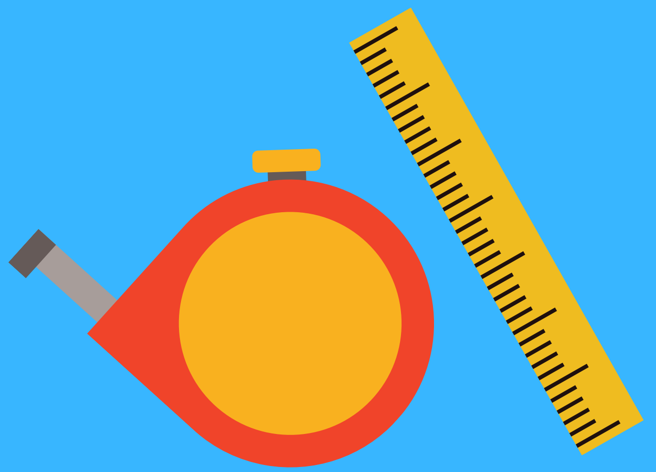
The remaining DME produced and not used is sold



3-Technical evaluation

This chapter is divded in 3 sub chapters:

3.1 - Plant sizing

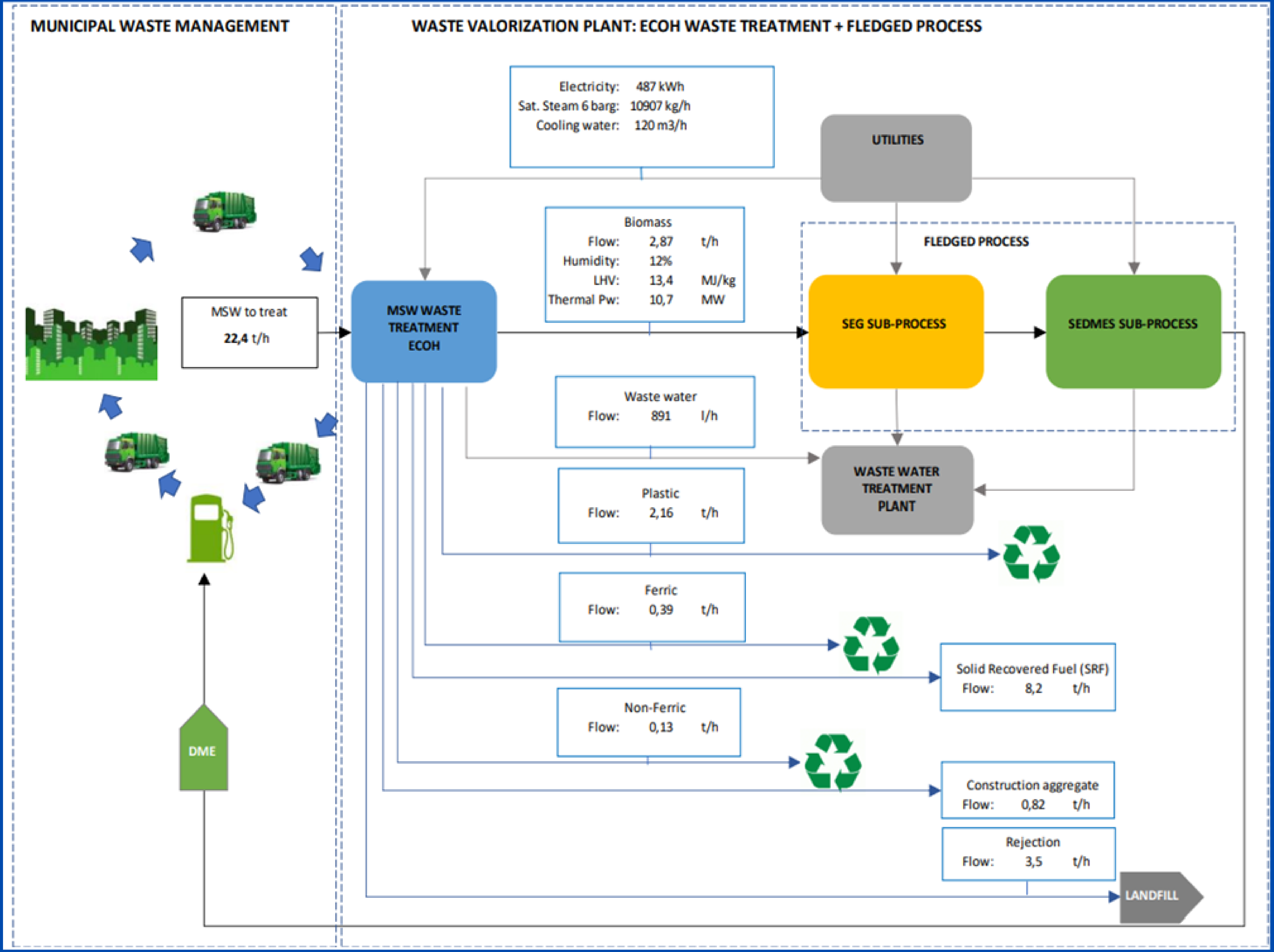


3.2 - Collection process

3.3 - Well to Wheel Emission Analysis

3.1 - Plant Sizing

As a model for our project we have used the scheme developed by Econward in 2020



We calculated the equivalent amount of DME needed to provide the same energy provided by 1L of Diesel
We proceed to compute the litres of DME produced per ton of biomass

Quantity	Value	Unit
l_{DME}	1.86	l
E_{syngas}	42.9	MJ
$E_{biomass}$	71.5	MJ
$M_{biomass}$	5.34	kg
y_{DME}	347.82	l/tbiomass

Defined the dimension of the plant, we have computed the DME produced per day.

Assuming for Northern Italy an average production of 90 kg of MSW per citizen per year, we have obtained the number of citizens needed to produce enough MSW to fuel the plant

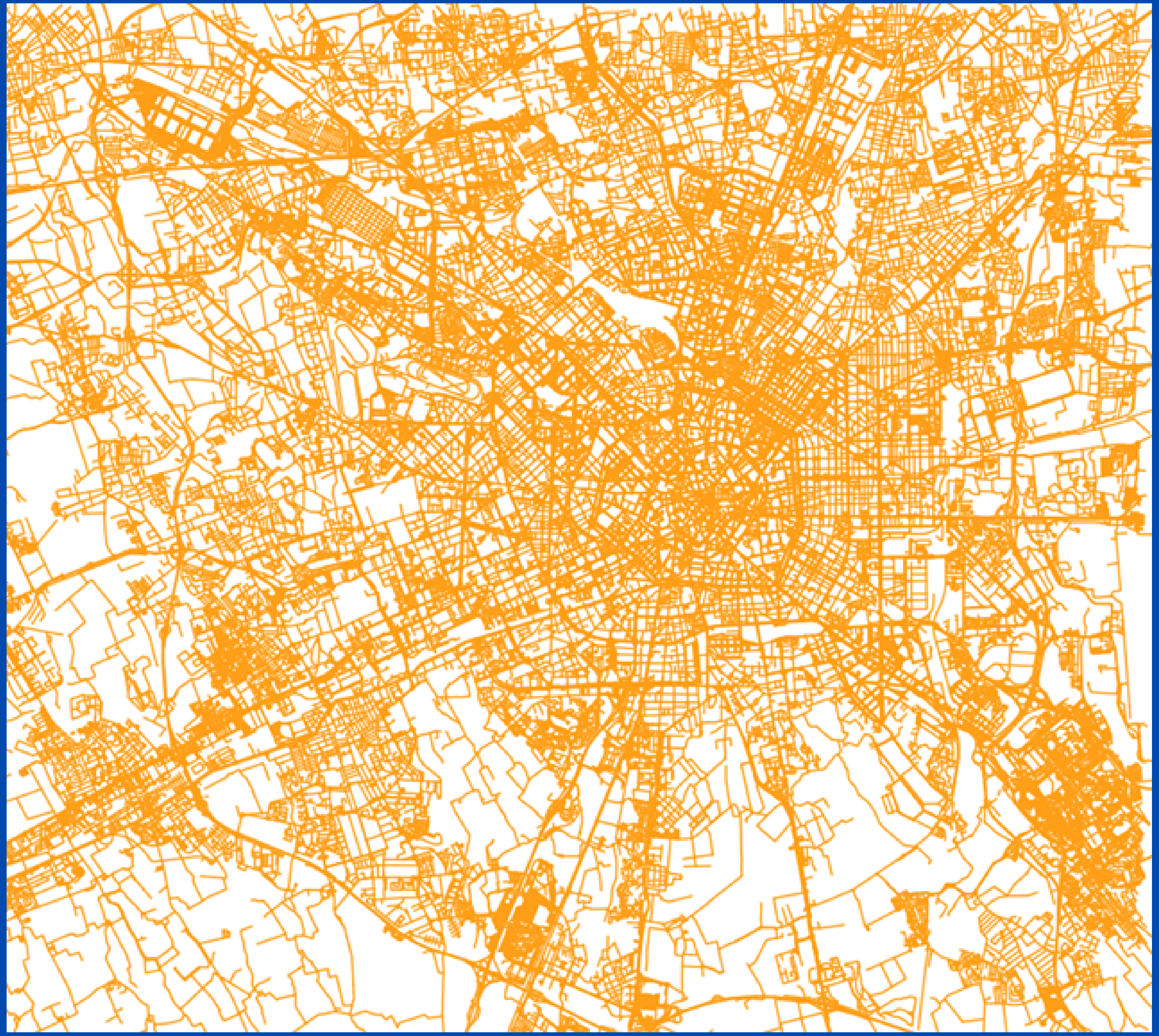
Quantity	Value	Unit
DME_{day}	23’958	l/day
$n_{citizens}$	2.18	Mpeople

We have obtained two different solutions:

Quantity	Value	Unit
E_{equiv}	34.34	MJ
E_{needed}	4’120.32	MJ
$C_{tank,new}$	222.82	l
$tank_{ratio}$	1.86	
$autonomy_1$	778.8	Km
$autonomy_2$	419.4	Km
$n_{trucks,new\ tank}$	107	Trucks/day
$n_{trucks,old\ tank}$	199	Trucks/day

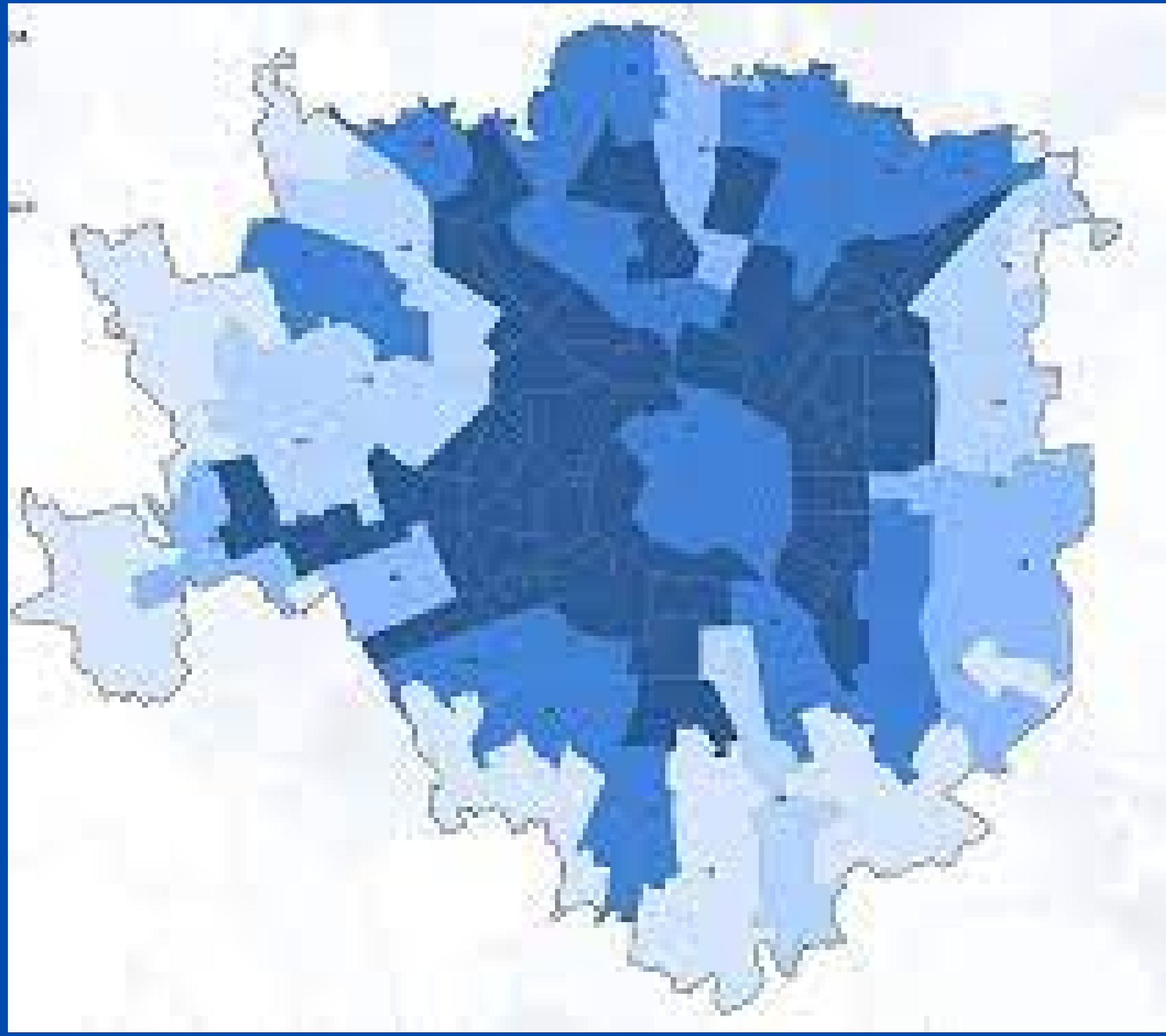
3.2 - Collection process

Geoportale Sit Comune di Milano



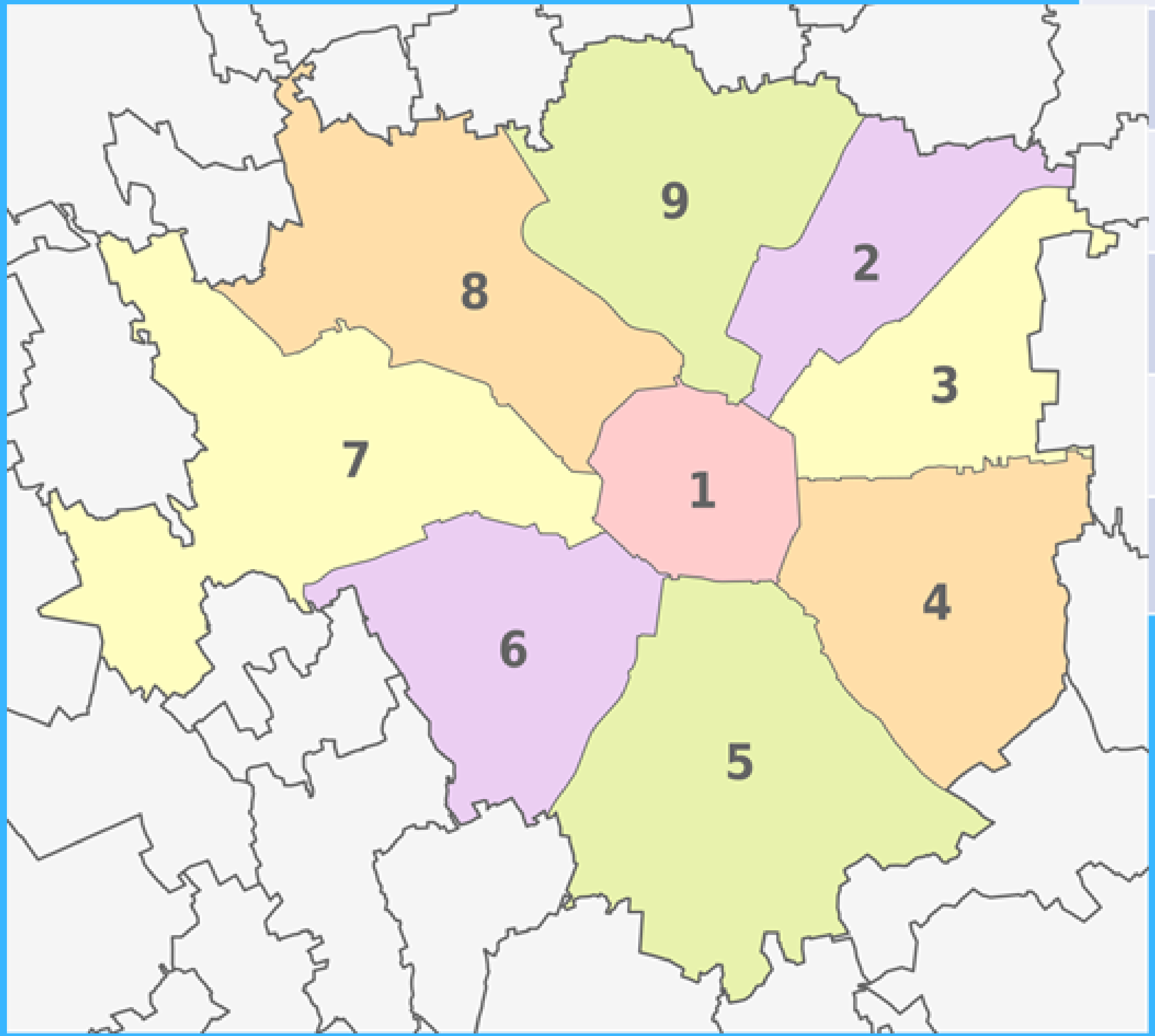
Computation of kms of roads

ISTAT population density



Computation of kg of waste produced

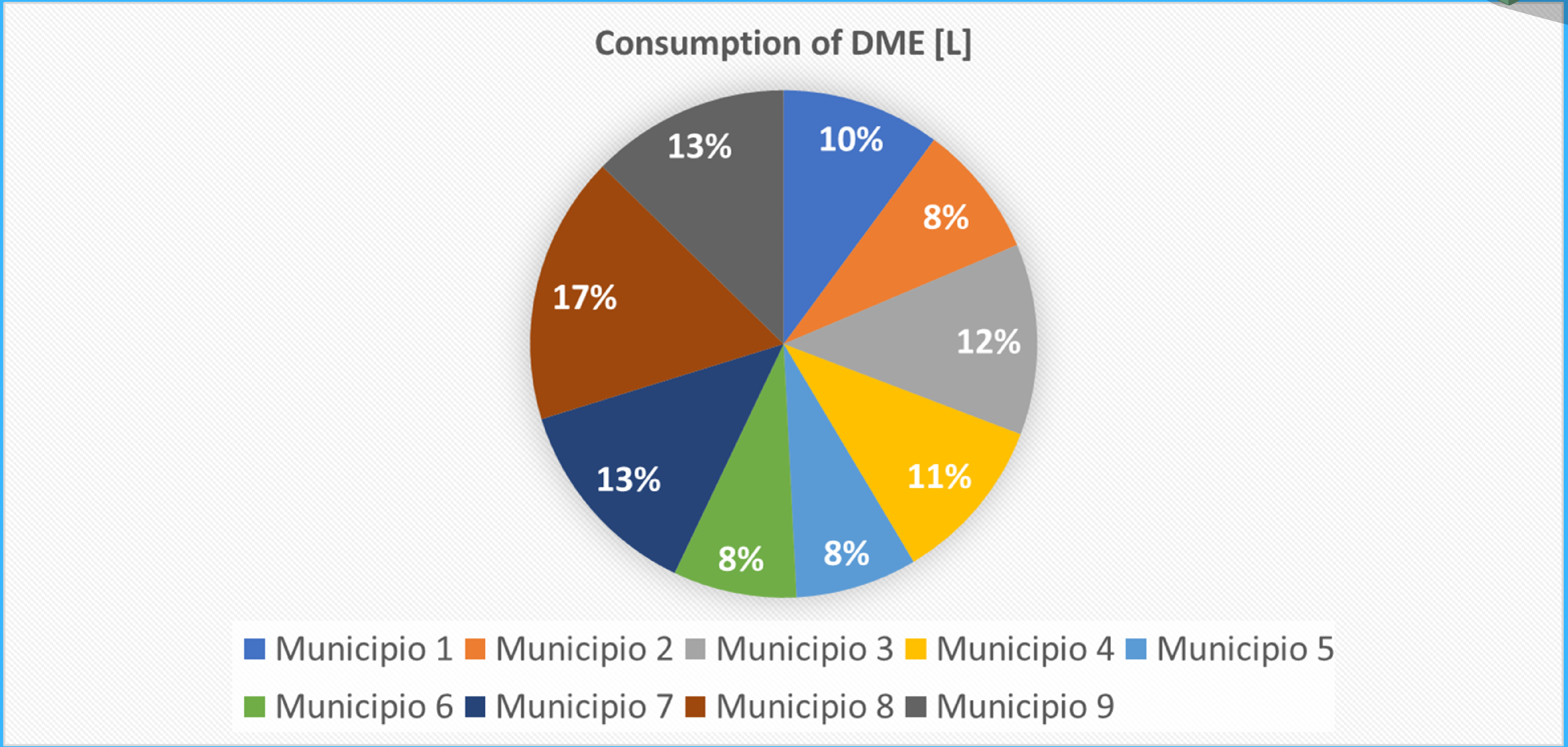
Municipality	Weight km basis	Weight mass basis	Real km for computation [km]	Ideal mass collected [kg]	Allocated trucks on Km basis	Allocated trucks on Mass basis
1	0.109	0.070	797	24295	12	8
2	0.073	0.116	535	39967	8	12
3	0.094	0.103	687	35533	10	11
4	0.120	0.115	876	39834	13	12
5	0.089	0.090	655	3109	10	10
6	0.088	0.108	643	37304	9	12
7	0.116	0.125	847	43265	12	13
8	0.164	0.135	1203	46446	18	15
9	0.143	0.134	1048	46300	15	14



Municipality	N. of trucks for mass collection	N. of trucks for reasonable work shifts	Final number of trucks	AVG of km run by each truck [km]	Consumption of DME in one day [liters]
1	10	16	16	86.255	394.848
2	16	11	16	105.521	332.089
3	15	14	15	118.680	475.364
4	16	18	18	80.683	415.505
5	13	14	14	75.627	302.919
6	15	13	15	82.731	307.705
7	18	17	18	105.470	512.979
8	19	24	24	97.327	668.294
9	19	21	21	82.328	494.643

2 work shifts of 8 hours

Total consumption 2615,9 kg of DME each day



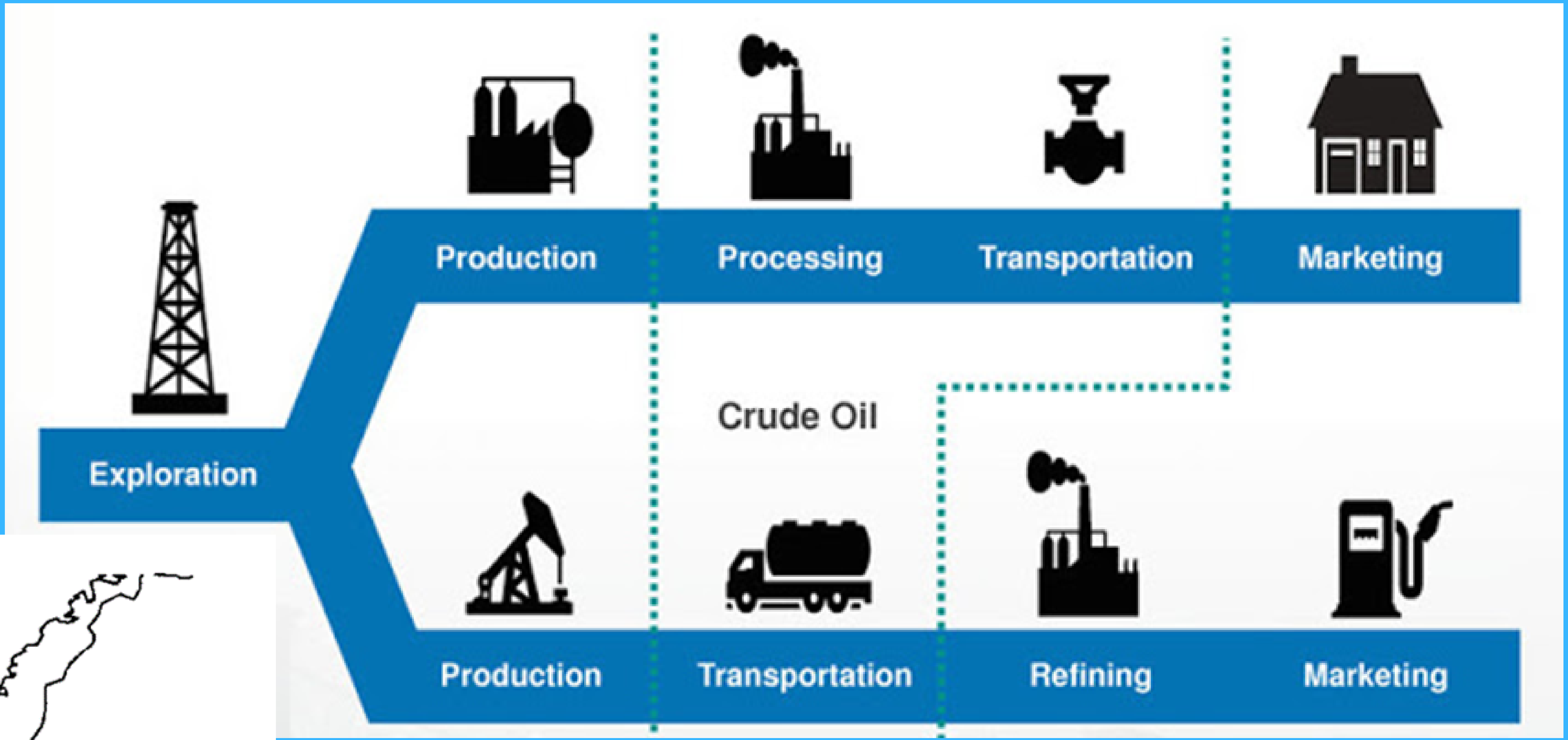
13436 kg/day of DME from production can be sold!

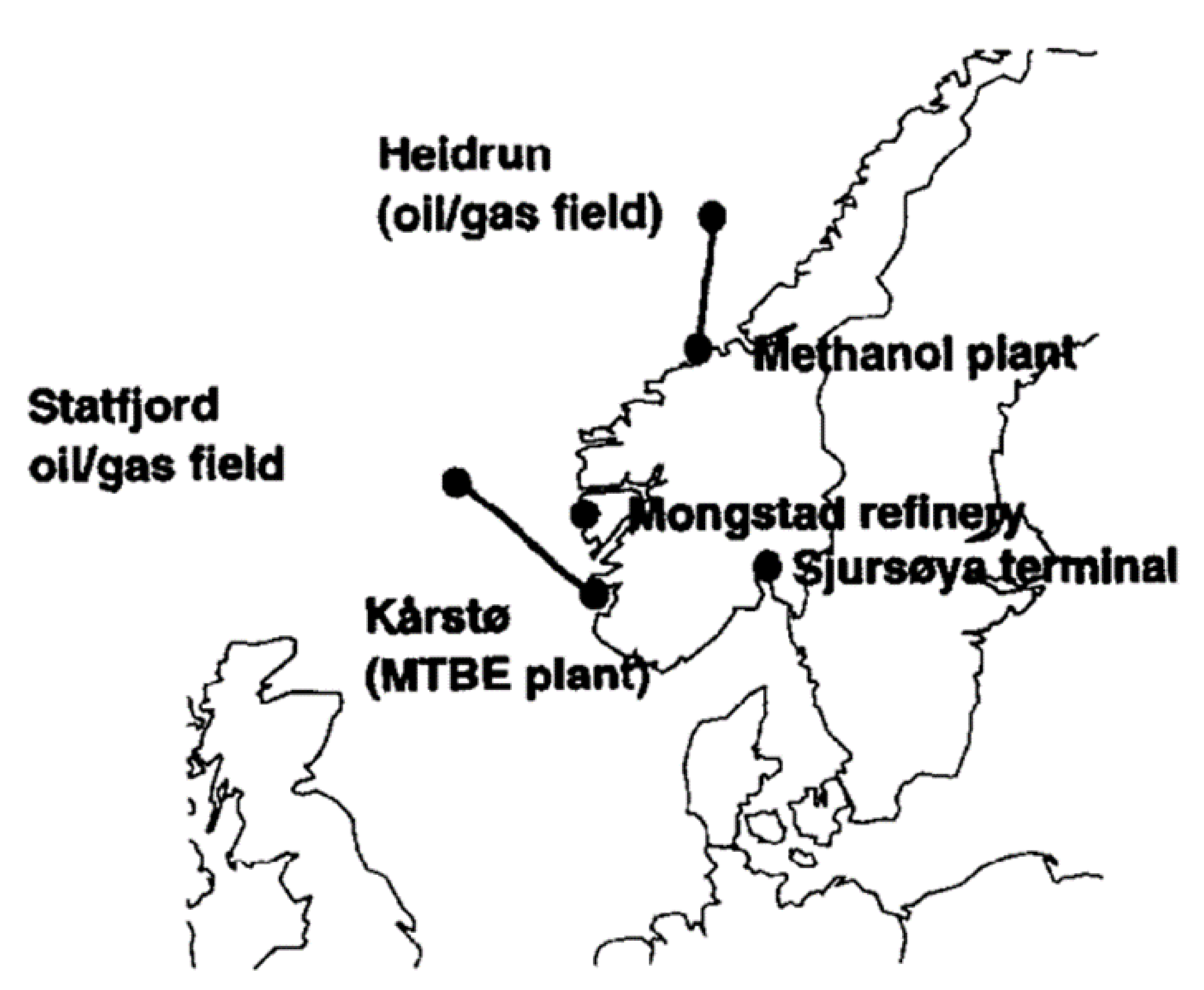
3.3 - Well to Wheel Emission Analysis

Choice of Vehicle – IVECO EUROCARGO E6

Vehicle Characteristics	
Power [kW]	137
Brake Horsepower [HP]	183,58
Torque [Nm]	680
Tank Capacity [l]	120
Average Fuel Consumption (Diesel) l/100km	15,39
Average Fuel Consumption (Diesel) km/l	6,498
Diesel fuel density ρ [g/l]	830

Diesel Life Cycle Assessment

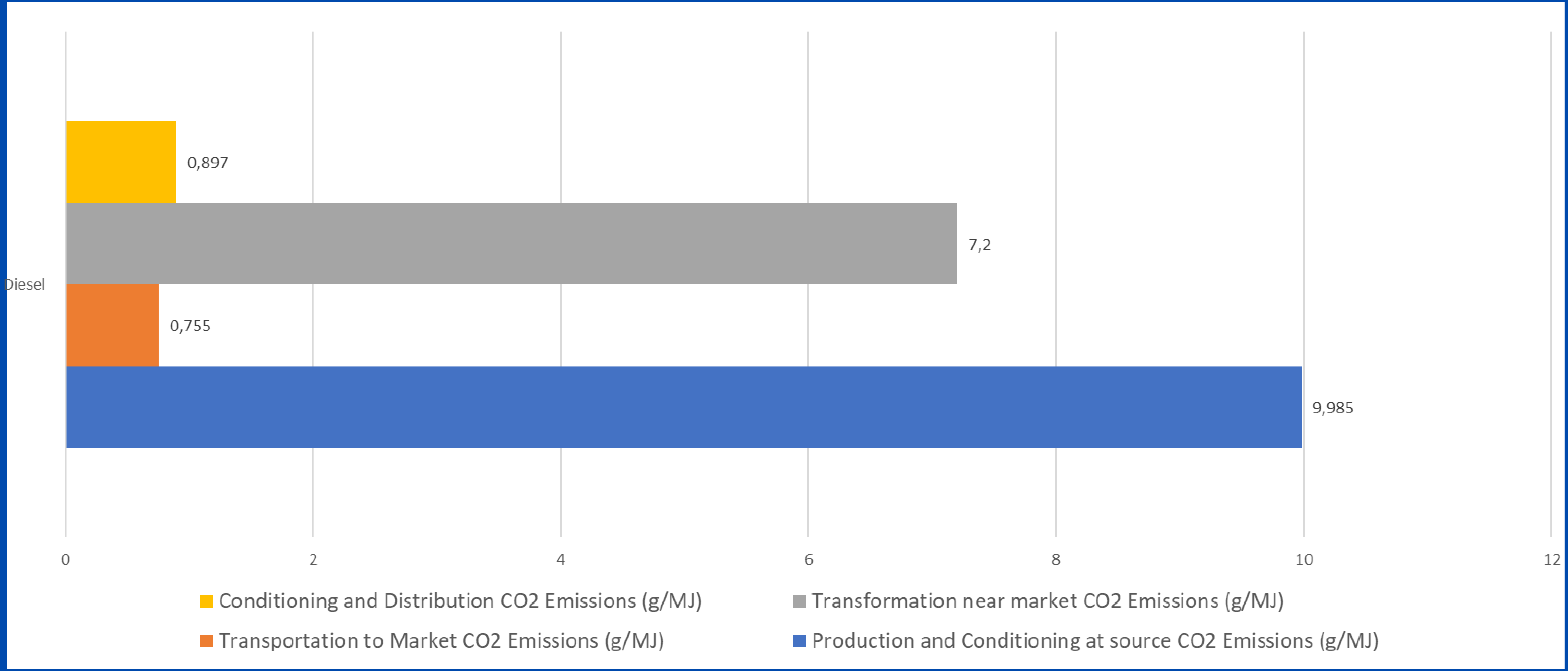




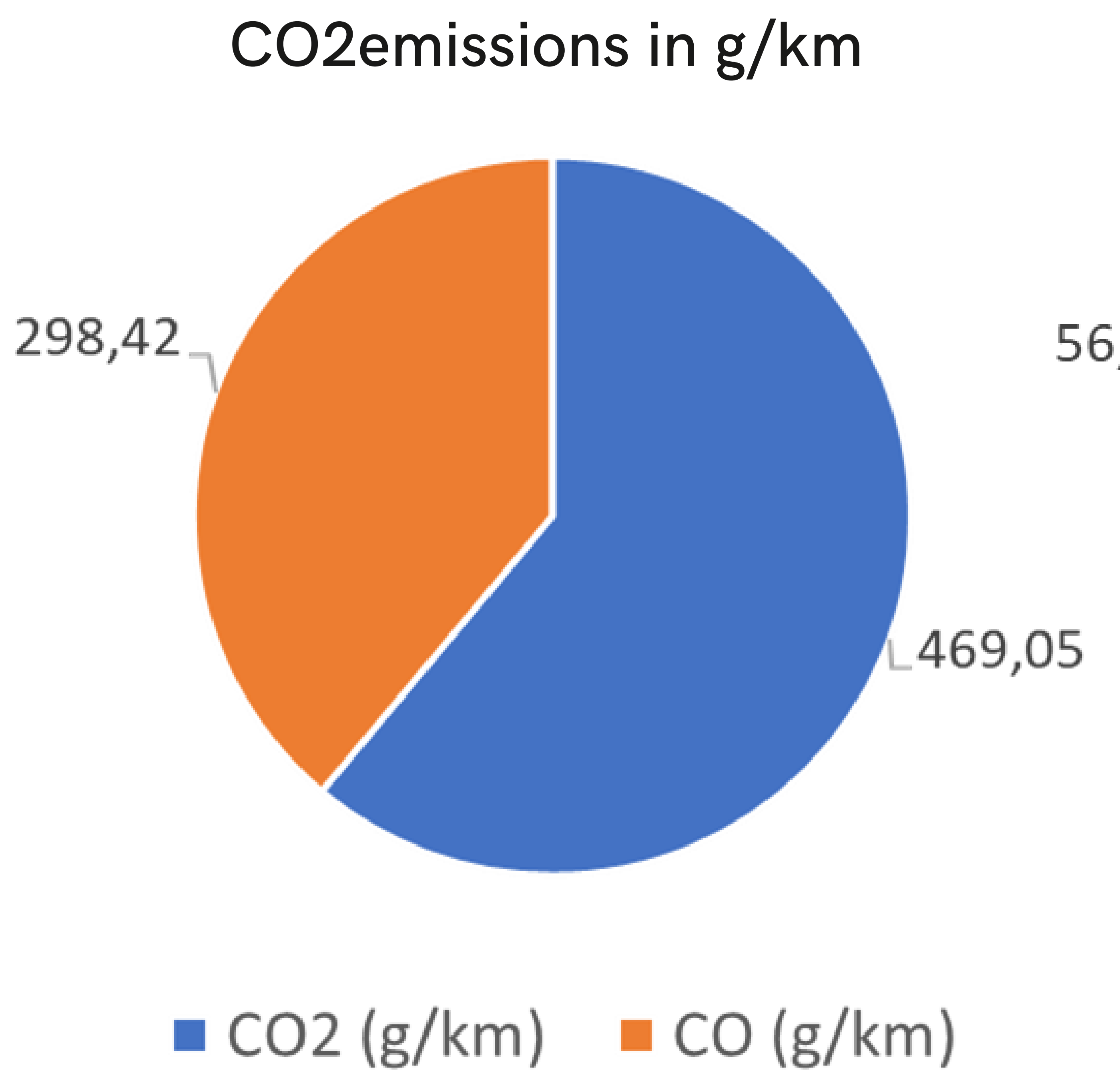
Production chain of fuel products of which diesel is extracted during the refining stage

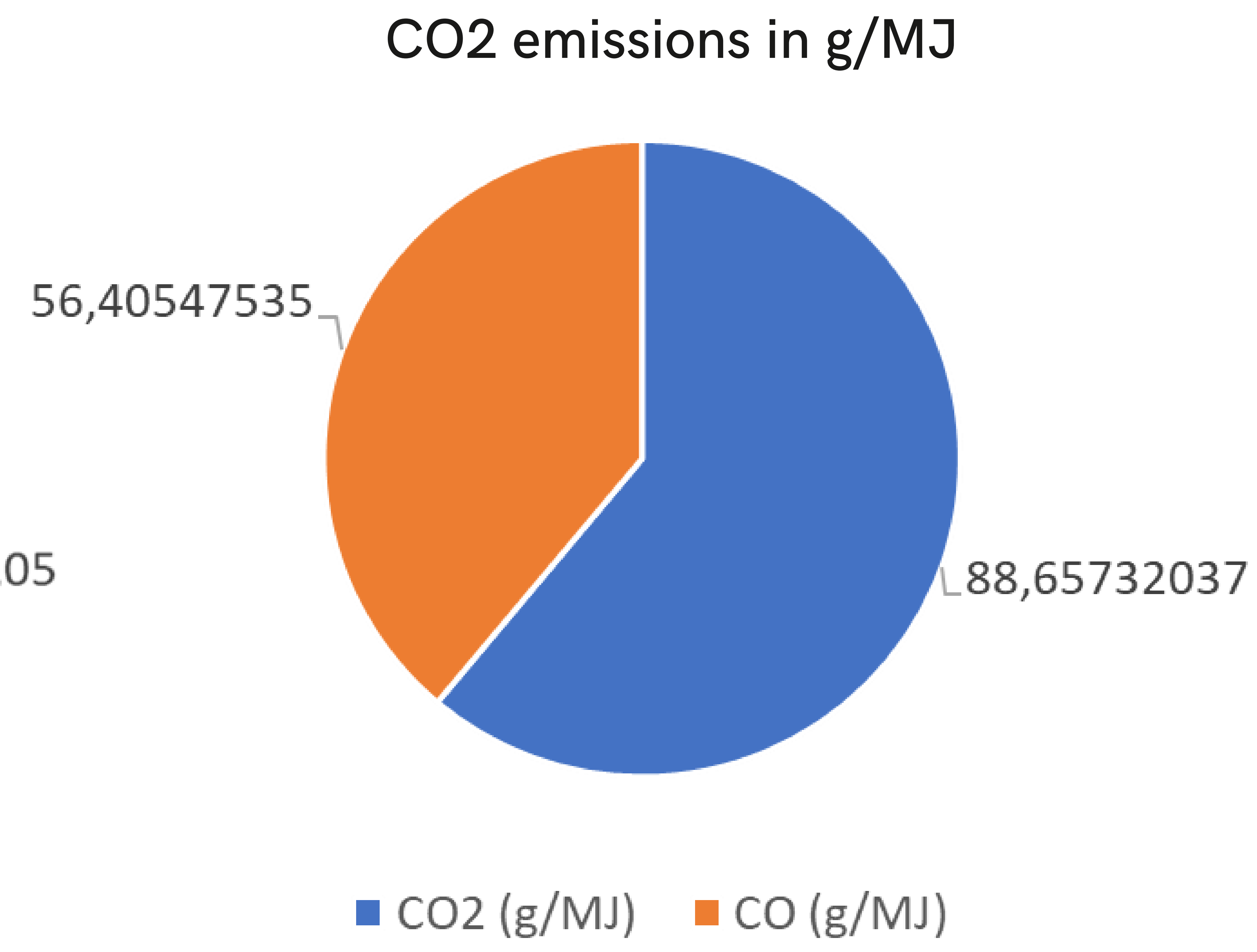
Considering the study to be conducted in strictly European market, we consider the fuel production plants and pipelines to be established in Norway

Diesel Well to Tank Emisisons

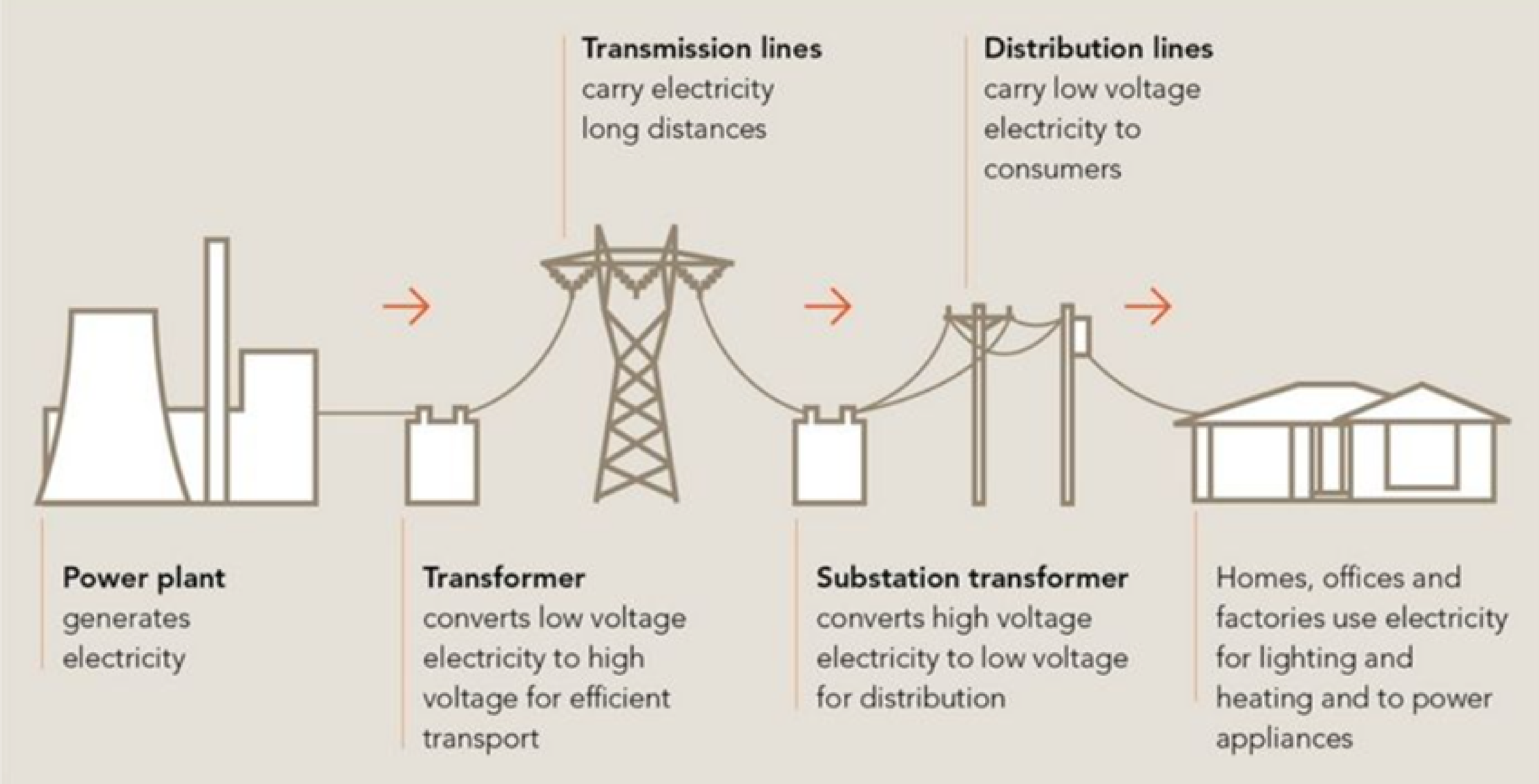


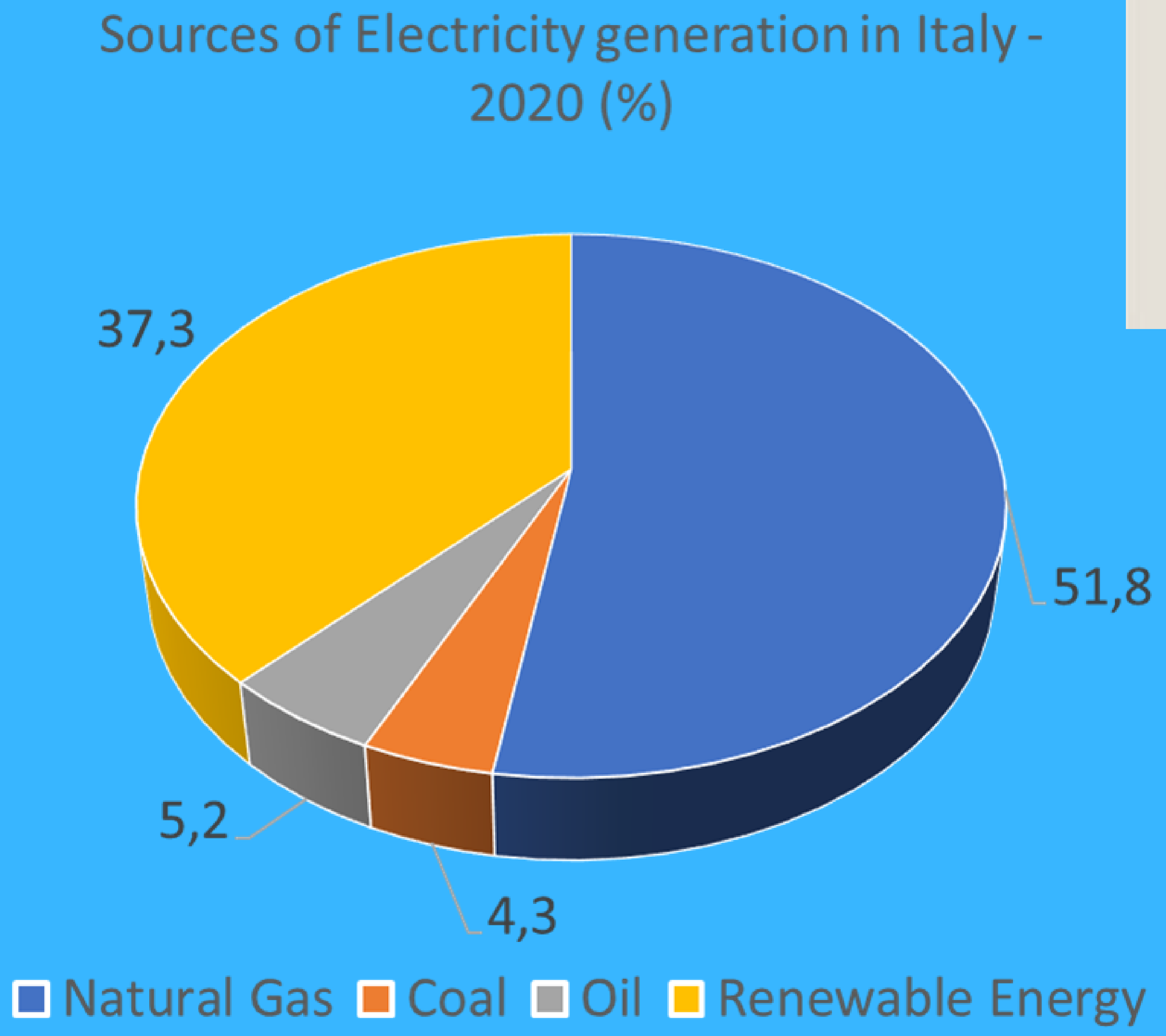
Diesel - Tank to Wheel Emissions





DME Life Cycle Assessment





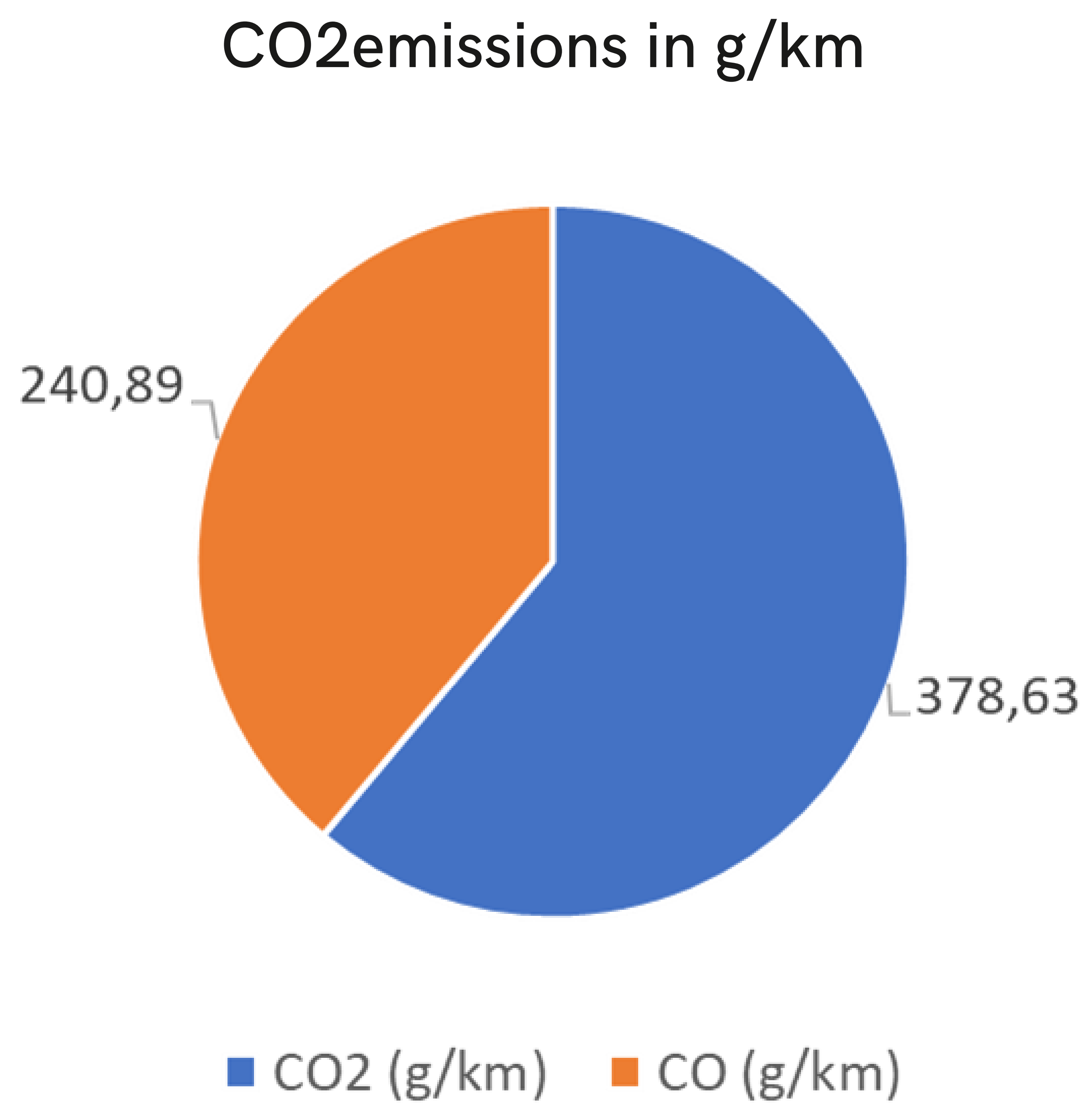
The Carbon emissions produced by the production plant are not considered

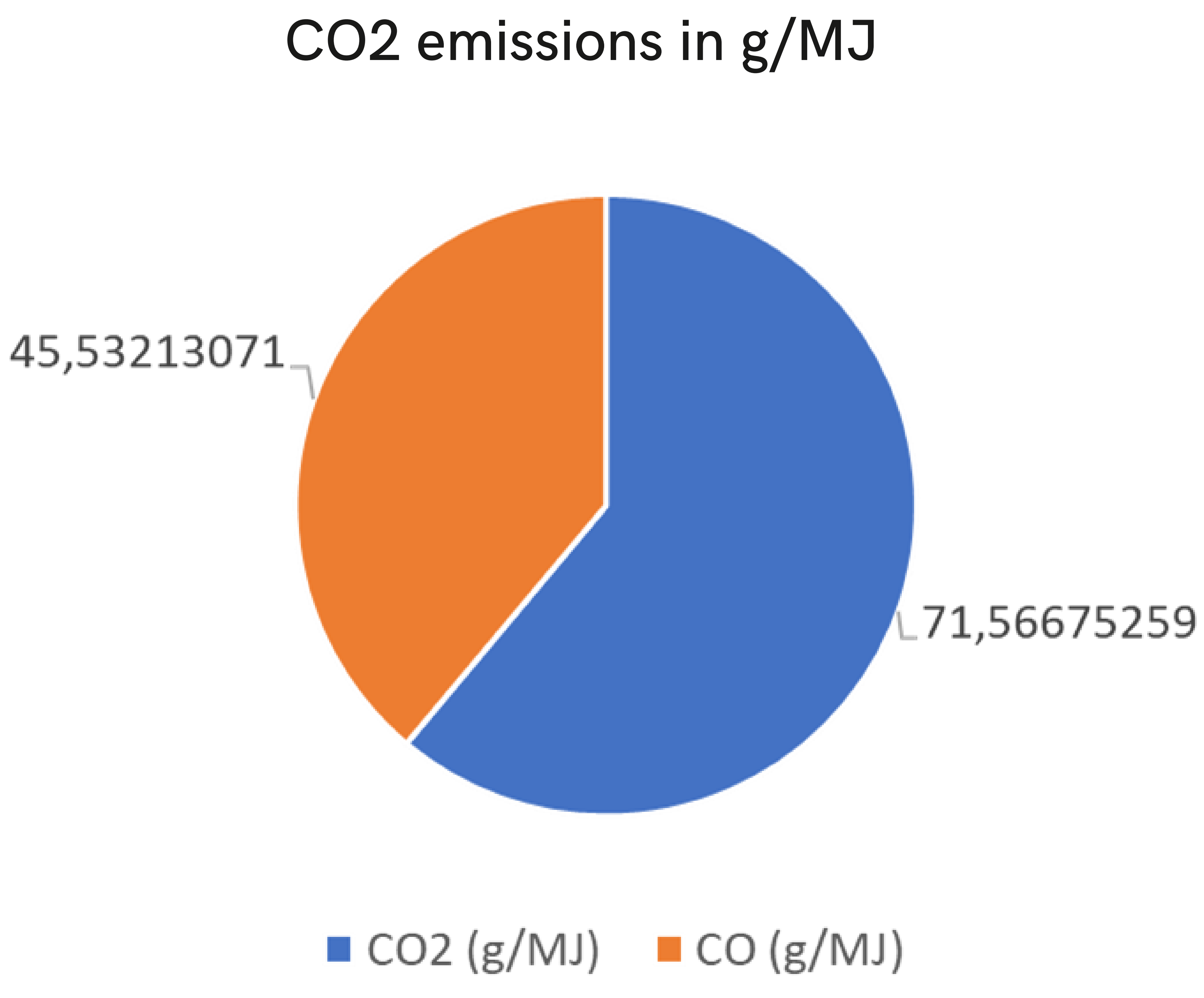
The Well-to-Wheel analysis approach for this synthetic fuel considers only the electricity exploited in the production of the fuel to the plant

DME - Well to Tank Emissions

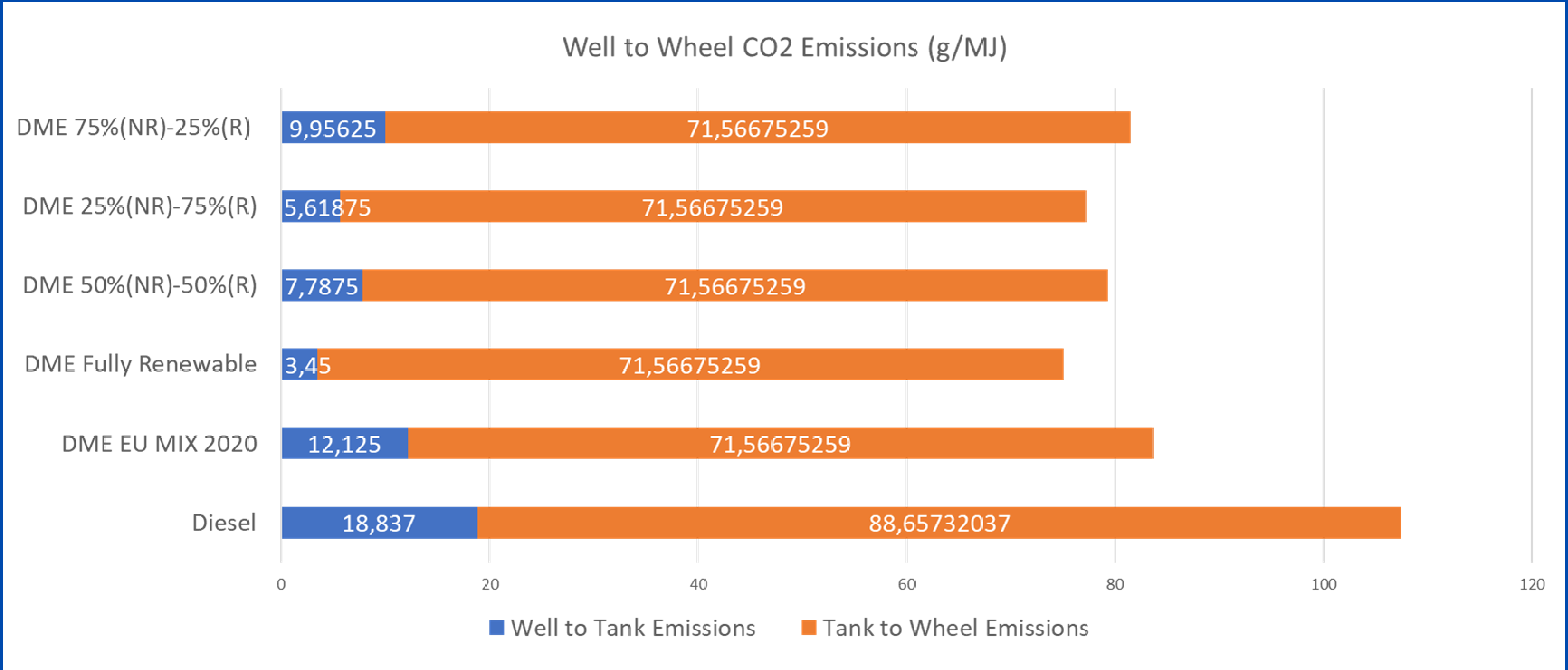
Well to tank Emission – only electricity generation	
Total Well to Tank CO_2 Emissions [g/MJ] – EU MIX 2020	48,50
Complete CO_2 Emissions Per day during DME production [g/s]	62,17
Conversion of CO_2 to [Tons/year]	1960,71
Specific CO_2 Emissions for the production process [g/MJ] DME Produced	12,12

DME - Tank to Wheel Emissions





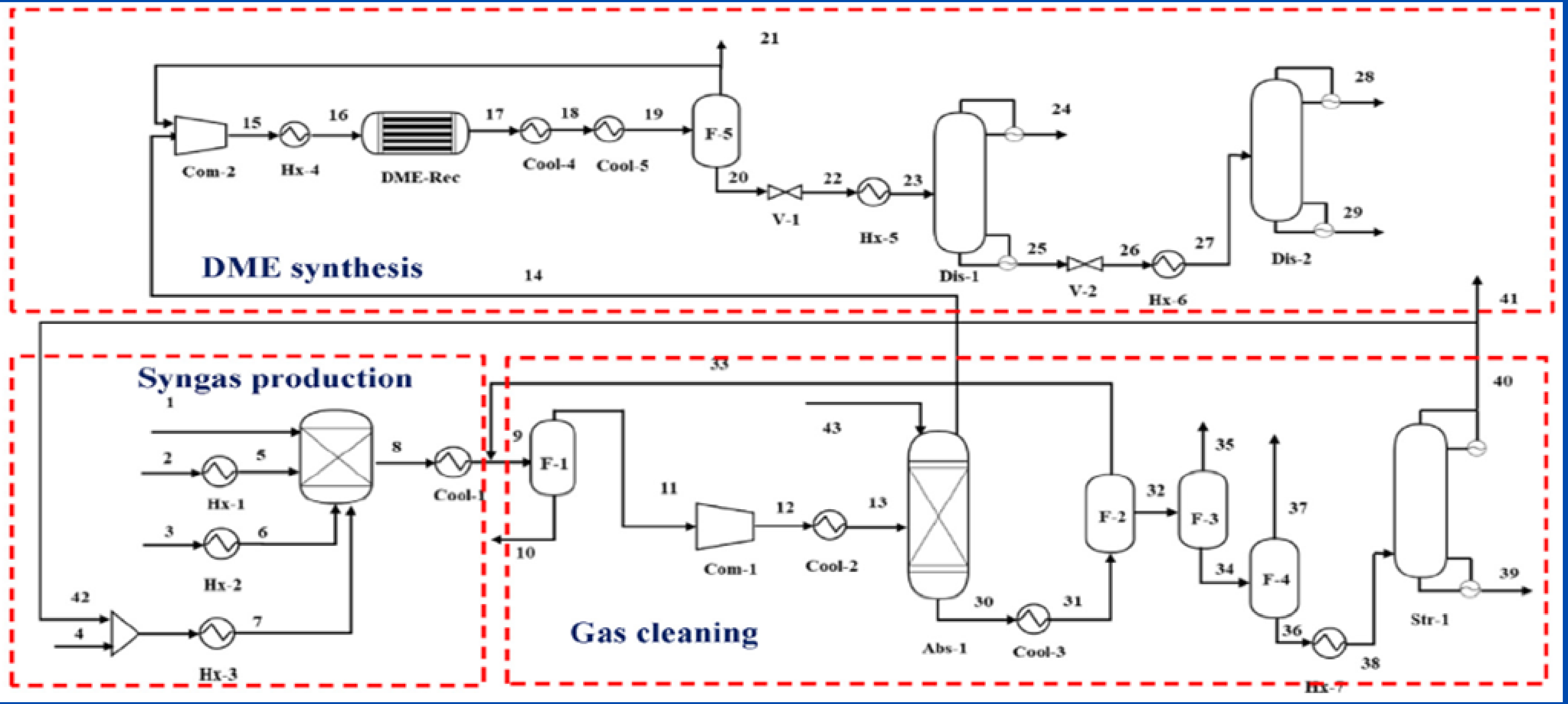
Complete Well-to-Wheel Comparison



4-Economic evaluation

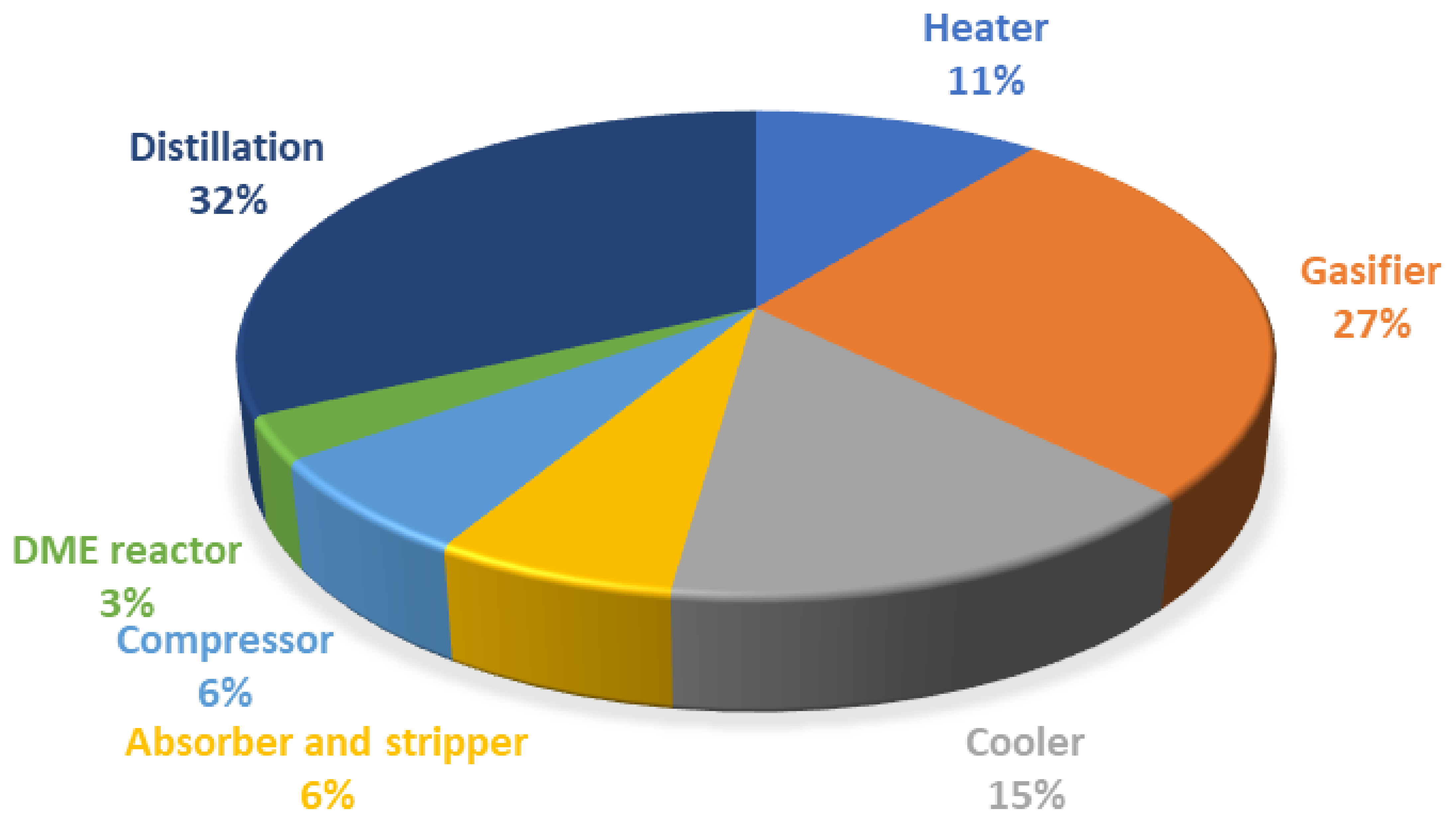
Description of the techno-economic analysis for the process of establishing a closed economy to produce DME from MSW to fuel our garbage collection truck fleet

DME production plant Capital Cost estimate



Component	Capacity for each component in our plant	Units	Capital Cost (M$)
Heater	3.68	Mwe	0.92
Gasifier	10.68	MW LHV biomass	2.29
Cooler	2.93	MWe	1.26
Absorber and stripper	0.17	kg/s co2 removal	0.55
Compressor	0.26	MWe	0.56
DME reactor	0.004	Kmole/sec	0.25
Distillation	0.19	kg/sec	2.75
Total Capex of the production plant	-	--	8.59

PRODUCTION PLANT CAPITAL COST



Operating and feed costs

Operating Costs	Amount	Operating Cost (M$/year)
Operation and Maintenance	15% of capex/year	1.28
Electricity	0.21 $/kwh	2.33
Total OPEX	-	3.62

Feed	Unitary Cost	Unit	Cost of feed (M$/year)
Biomass (MSW and Bio-Mass Separation)	126.66	$/ton	3.18
Water	4.59	$/ton	0.04
Total Feed Cost	-	-	2.90

Landfill costs saving

The Biomass separated from solid waste will reduce the amount of waste that has to be dumped into landfills eventually which in return will reduce the cost being paid to rent landfills

Savings	Unitary Cost	Savings (M$/Year)
Land Fill Cost	53.72 $/ton	1.35

Collection Process Cash Flows

Collection Process Cash Flows	Unitary Cost	Unit	Cash flows per year (M$/year)
Collection Fees paid by citizens	5	$/citizen/month	130.816
Collection and transportation costs	600	$/ton	-118.127
Wages	800	$/employee/month	-4.129
number of employees	4	employees/truck	-
Total Revenues	-	-	8.560

Levelized cost of DME

Now with all the data mentioned above which includes all the cash inflows and our flows involved in the DME production process the levelized cost of DME can be calculated

LCOF DME Production from MSW Collected	0.875	$/kg DME
	0.587	$/l DME
	31.728	$/GJ DME
	28.555	Euro/GJ DME

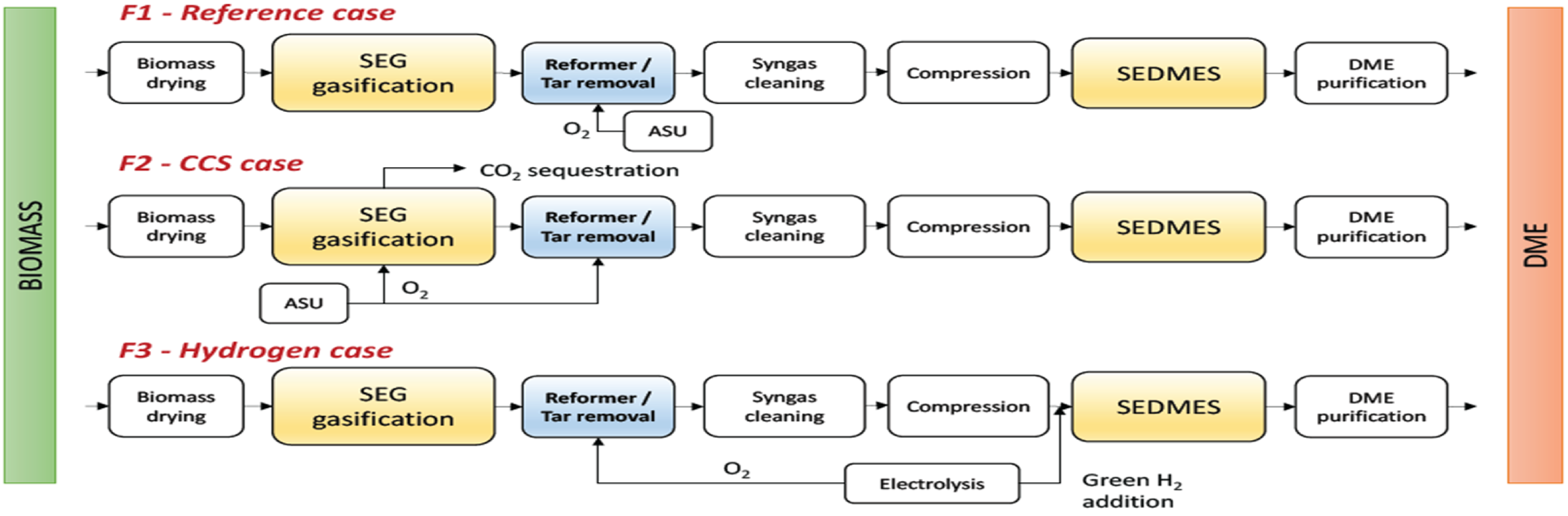
DME 28,55 €/Gj $ DIESEL 20 €/Gj

CIC Bonds Revenues

CO2 BONDS (CIC) (ref: GSE)		
CIC Value	375.00	€
Biofuel emission	5	Gcal
J to cal conversion	0.238846	cal
DME produced	21,344.19	MJ/h
DME produced	186*1e6	MJ/year
DME produced	44’658	Gcal/year
n of CIC due	8,932	CIC/year
Economic Value	3.35	M€/year

DME 12 €/Gj $ DIESEL 20 €/Gj

5-Sensitive analysis



We will compare our design to two assessed FLEDGED process concepts which are the F1-baseline case and the F3-Hydrogen case

F1 - baseline case

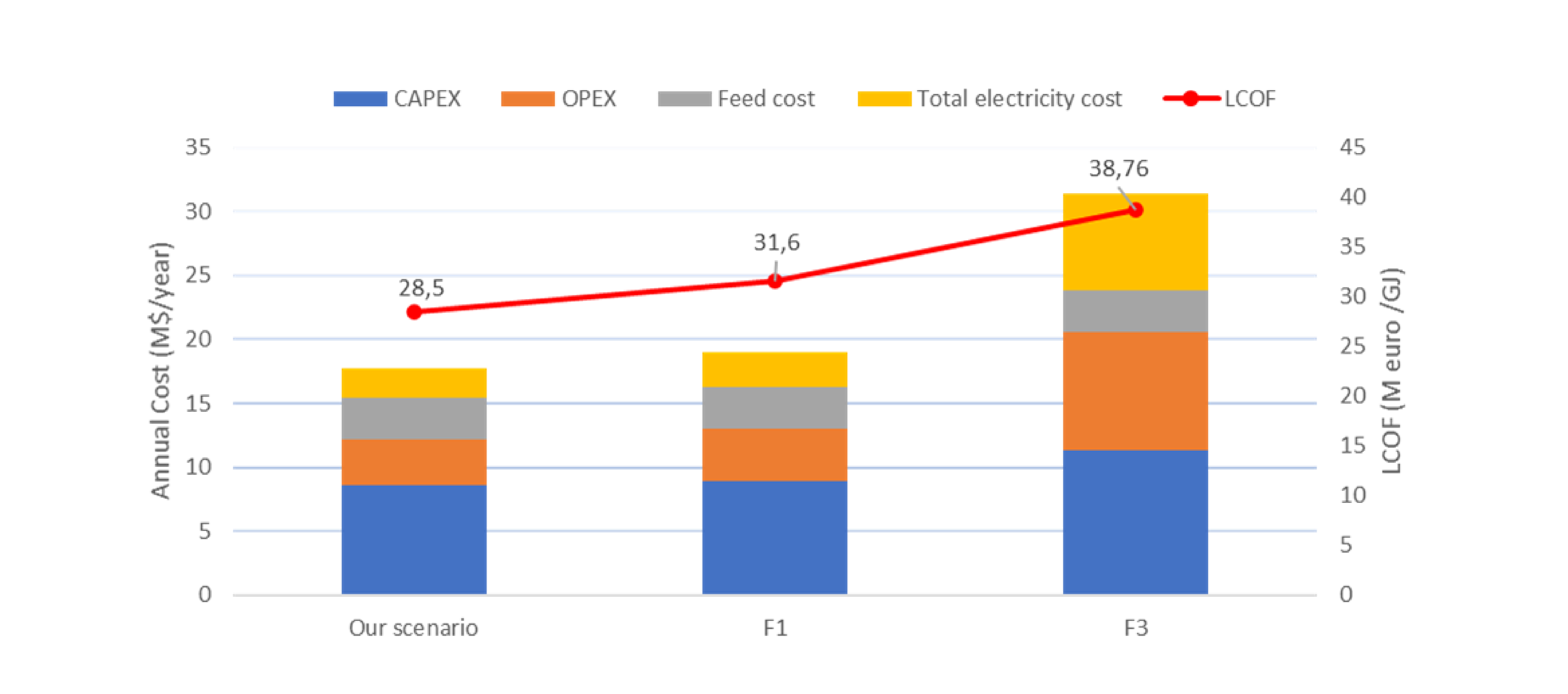
Novel SEG and SEDMES process units are integrated in a biomass to DME plant also including biomass pretreatment, syngas cleaning, syngas compression and DME purification units, based on conventional technologies

F3 - Hydrogen case

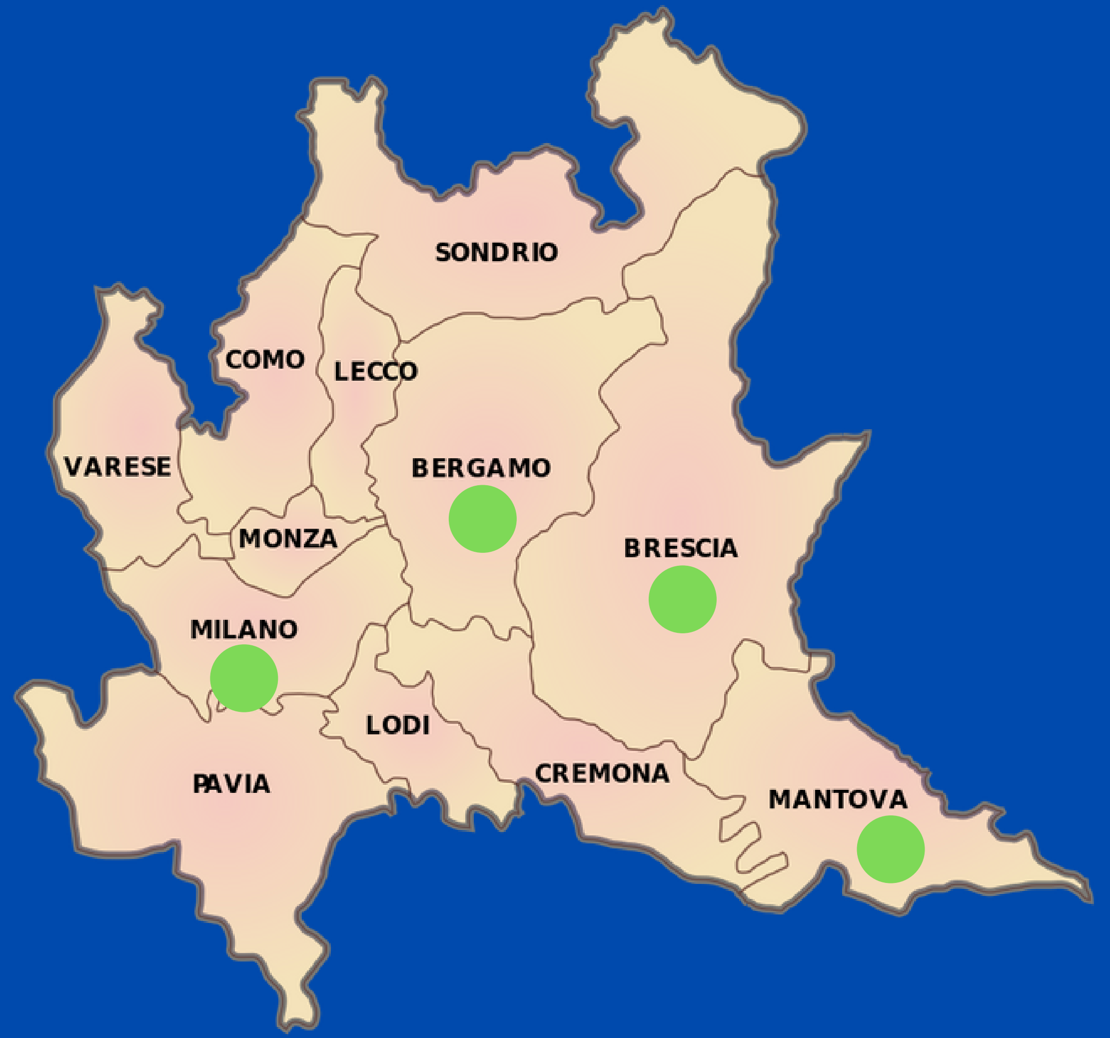
Includes an electrolysis system, can provide hydrogen when the renewable electricity price is sufficiently low. This case involves reducing the amount of CO2 separated in SEG and an increase of the carbon ending up in the final fuel, enhancing the overall DME yield

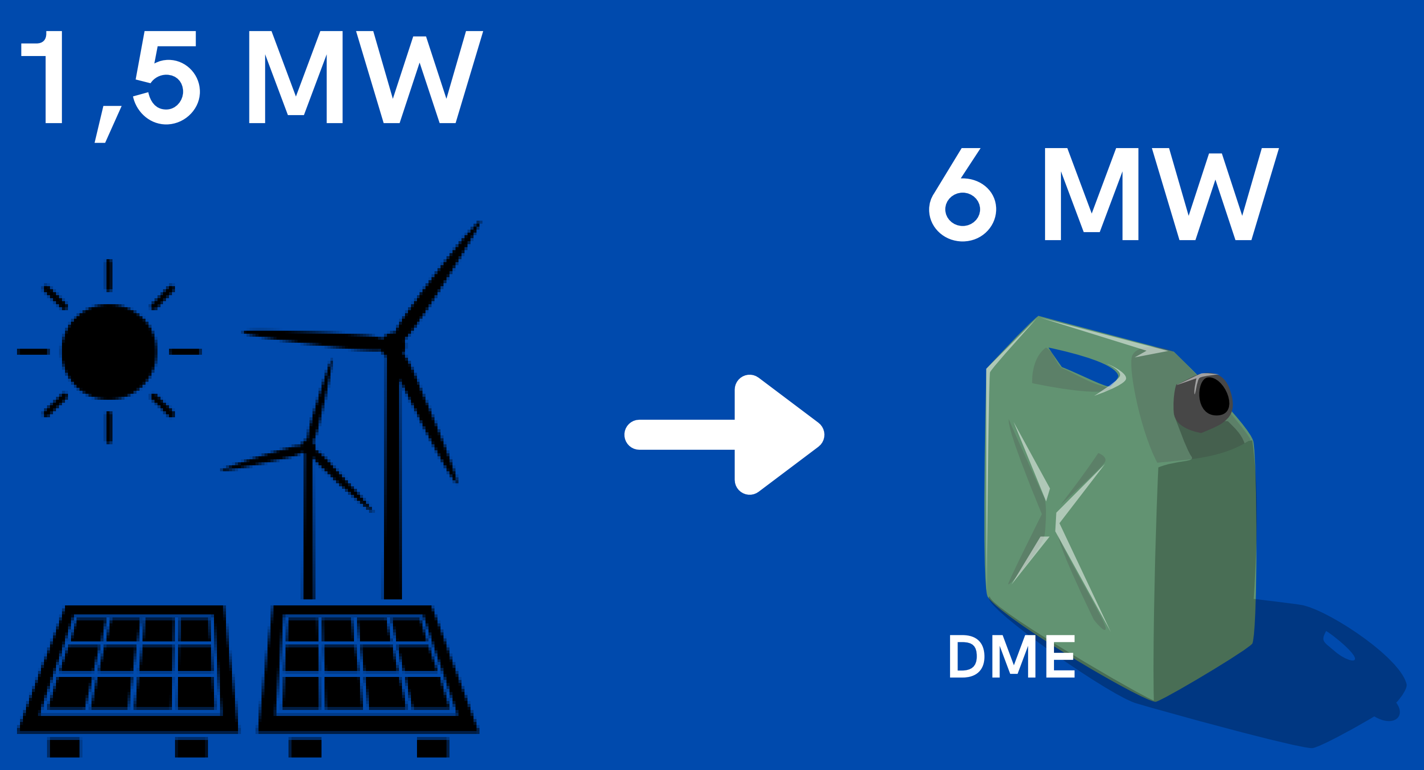
Electrolyzer Specifications		
CAPEX	0.44	M$/MW
Capacity	47	Kwh elec/ kg H2
Size	1.7	MW
Electricity Price	0.21	$/kwh

Performance Index	Our scenario	F1-base case	F3-Hydrogen case	Unit
η_{fuel}	48	55.7	93.3	%
CAPEX	8.6	8.95	11.3	M$
OPEX	3.6	4.1	9.3	M$/year
Feed cost	3.2	3.2	3.2	M$/year
Total electricity cost	2.3	2.71	7.6	M$/year
Dme yield	0.186	0.215	0.361	Kg/sec
LCOF	28.5	31.6	38.76	$/GJ



6-Conclusion





Thanks for the attention

POLITECNICO MILANO