MCEDD

DEEPWATER DEVELOPMENT

28 - 30 March 2023 | Millennium Gloucester Hotel | London, UK

ORGANIZED BY

GULF QUEST

Quest Offshore

World Oil®

Evaluation of Greenhouse Gas Emissions from Design Stages to Achieve Carbon Footprint Reduction of Oil & Gas Process Facilities along their Life Cycle.

Laura Quentin

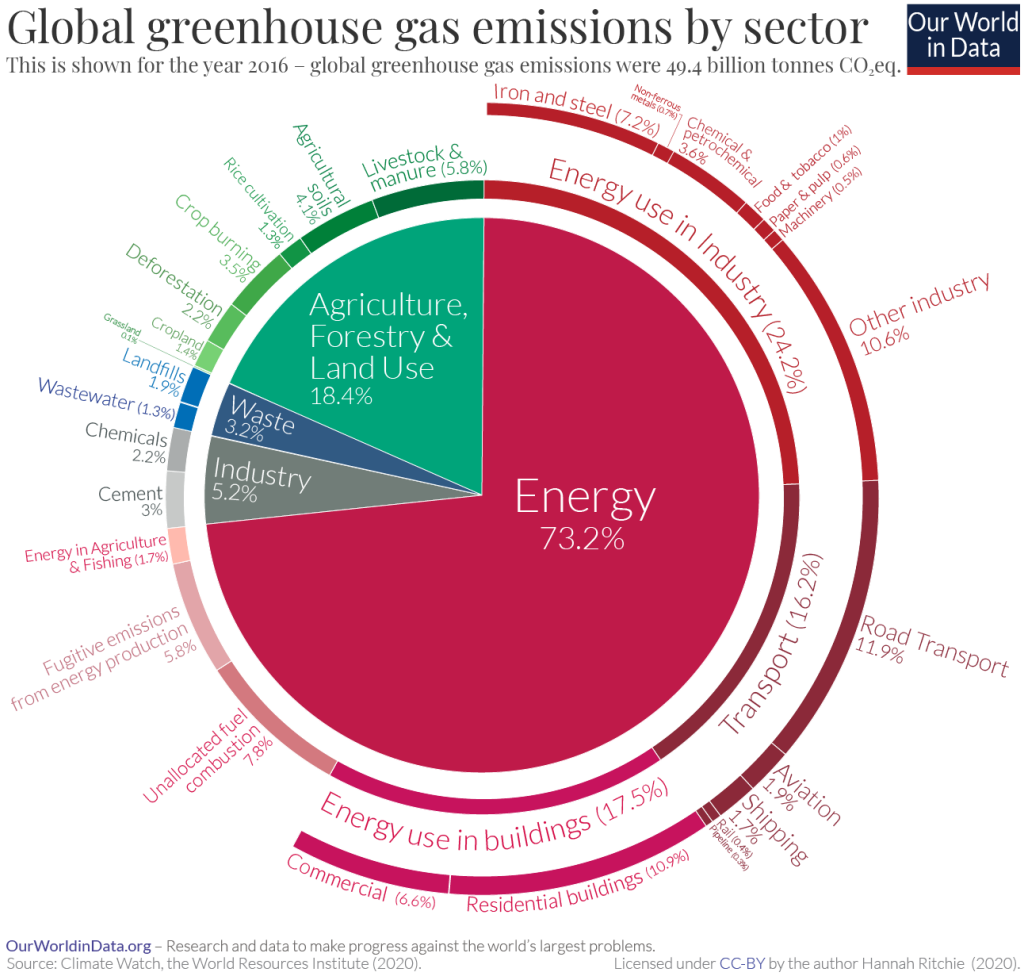
DORIS

Outline

- Introduction
- Presentation of the GHG Assessment Tool
- Case Study
- Conclusion

Introduction

The Greenhouse Gas Challenge



Main contributors in GHG emissions by sectors:

- **73,2%** in Energy Sector
- **18,4%** in Agriculture, forestry & land use
- **5,2%** in Cement & Chemical industries
- **3,2%** in Waste

Main contributors in GHG emissions in Energy Sector:

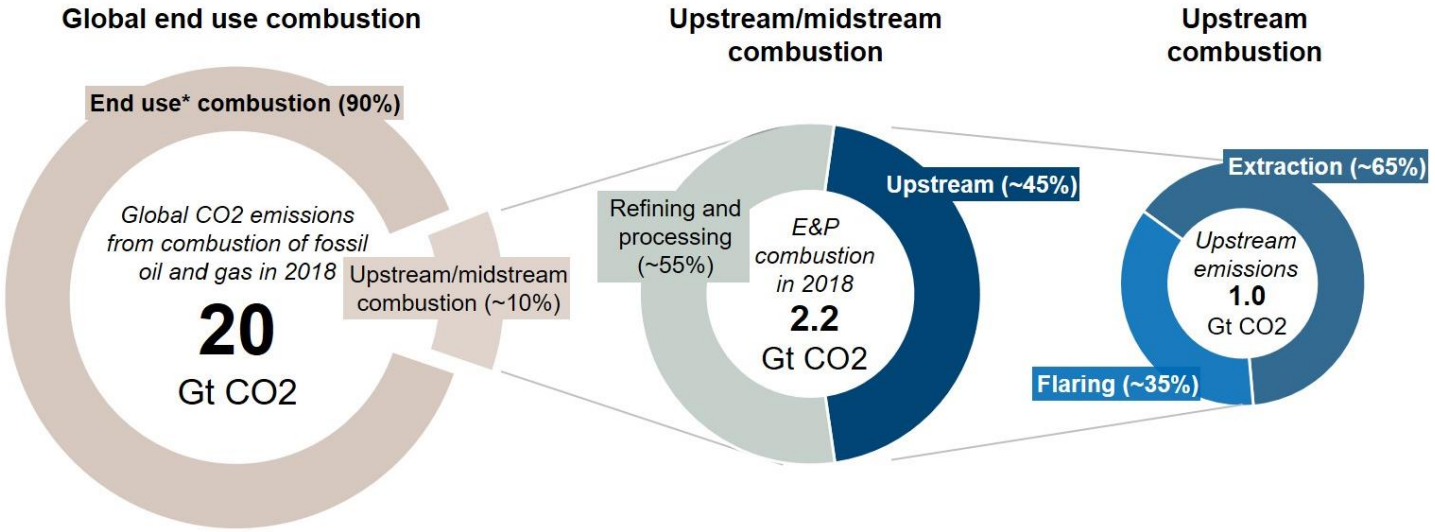
- **33%** from energy used for Industries *(iron, steel, others…)*
- **24%** from energy used in building *(residential, commercial)*
- **22%** from energy used for transports *(road, aviation…)*
- **10%** from unallocated fuel combustion
- **8%** from fugitive emissions from energy production
- **3%** from energy used for agriculture & fishing

Estimated CO_2 emissions from O&G combustion (2018)

Share of emissions in Oil & Gas industry

10% from upstream/midstream
(Scope 1 & 2)

90% from end use combustion
(Scope 2 & 3)



* End use combustion includes industry, power plants, transportation, etc.
Source: Rystad Energy research and analysis

DORIS GHG Assessment and Optimization Programme

1 Understand company or project emissions

- Collect & Assess available data
- Set up emission baseline

2 Forecast GHG emissions

- Elaboration of GHG reduction strategy
- Define appropriate monitoring plan
- Model & Analyze GHG emissions
- Forecast GHG emissions

3 Identify GHG reduction solutions

- Screening & Ranking of GHG reduction solutions
- Select and elaborate GHG reduction solutions

4 Implement GHG reduction solutions

- Engineer and Implement GHG reduction solutions
- Supervise execution

5 Assess performance

- Monitor impact of the solution and compare to the baseline to identify further actions

GHG Assessment Tool Presentation

A unique decision making tool

The DORIS Tool Objective

Supporting operators in selecting the design that will produce the least GHG emissions during operation

GHG Emissions Assessment Tool – Principles

Forecast of GHG emissions

- Rapid estimation of carbon footprint
- Assessment, comparison and validation of GHG emissions reduction opportunities
- Focused on the O&G industry

Rapid Estimation & User Friendly

GHG Emission Sources

Number of fluids and equipments	
Number of cases to study	4
Number of turbo generator types	0
Number of turbo compressor types	0
Number of turbo pump types	0
Number of boiler types	1
Number of other combustion equipment types	0
Number of marine vessel types (bulk)	0
Number of marine vessel types (passenger)	0
Number of other lost energy types	4
Type of electricity sources	1
Type of imported heat/steam and/or cooling	0

Update numbers based on input data table

Types of imported liquid fuels	0
Types of imported gaseous fuels	0
Types of produced oil	1
Types of produced gas	1
Types of reinjected gas	0
Types of gases for gas lift	0
Types of exported crude oil	1
Types of exported gas	1
Types of auto consumed crude	0
Types of auto consumed gas	1

Launch table sizing / Update fluids list

Click to update results

Last modification of the inputs (Composition and input data)
14/02/2023 19:01:51
Last modification of the calculations
14/02/2023 19:01:51

GHG Considered

Global Warming Power CO2	1
Global Warming Power (*) CH4	25
Global Warming Power (*) N2O	298

(*) GWP issued from IPCC Assessment Report AR IV.
As per Climate Dept, the new figures from AR V will be used for reporting from year 2024 (CH4: 28; N2O: 265).

GHG Emissions Assessment Tool – Inputs

Used at conceptual, feed or detailed engineering stage

- **Process data and Emission Factors**

Stationary combustion	Category	Name of the equipment	Parameters	Case 1
	Boilers	Steam Boiler	Composition	Fuel Gas 1
			Mass flow (t/h)	0.37
			Operating time (d/yr)	343
			Combustion efficiency	99.97%
			Emission factor CO2 (kg CO2/kg fuel)	
			Emission factor CH4 (kg CH4/kg fuel)	
			Emission factor N2O (kg N2O/kg fuel)	
			Emission factor CO2eq (kg CO2/kg fuel)	
Mobile combustion				
	Air transportation	Air transportation	Total annual duration of flights (hr)	0.00
			Fuel consumption (t/hr)	
			Emission factor CO2 (kg CO2/kg fuel)	
			Emission factor CH4 (kg CH4/kg fuel)	
			Emission factor N2O (kg N2O/kg fuel)	
			Emission factor CO2eq (kg CO2/kg fuel)	
Lost energy				
	Cold vents	Blanketing	Composition	Fuel Gas 1
			Mass (t/yr)	0.72
			Emission factor CO2 (kg CO2/kg fuel)	
			Emission factor CH4 (kg CH4/kg fuel)	
			Emission factor CO2eq (kg CO2/kg fuel)	
Utility				
	Imported electricity	Imported electricity	Electricity source	
			Quantity imported (MWh/yr)	33257.6
			Emission factor CO2 (kg CO2/MWh utility)	
			Emission factor CH4 (kg CH4/MWh utility)	
			Emission factor N2O (kg N2O/MWh utility)	
			Emission factor CO2eq (kg CO2/MWh utility)	685.40

- **Fluids Data**

Total compositions	26

MW (g/mol)	Carbon number of closest alkane
228	16

Size the table

				Fuel Gas 1		Crude production	
Compounds	Carbon Number	MW		%mol	Specific Emission	%mol	Specific Emission
/	/	g/mol		mol$_i$/mol$_{gas}$	TCO2 / Ti	mol$_i$/mol$_{gas}$	TCO2 / Ti
CO2	1	44.0		2.43%	0.043	2.63%	0.061
C1	1	16.0		72.85%	1.288	88.28%	2.062
N2	0	28.0		0.13%	0.000	0.17%	0.000
H2S	0	34.1		0.00%	0.000	0.00%	0.000
C2	2			5.88%	0.208	5.01%	0.234
		(g/mol)		24.89		18.84	
		HHV (MJ/kg)					
		LHV (MJ/kg)		45.03		43.21	

Table of typical emission factors: IOGP Report N° 2.59/197

Equipment	EF CO2 (t CO2/t fuel)	EF CH4 (t CH4/t fuel)	EF N2O (t N2O/t fuel)
Conventional / Low-NOx gas turbines	2.75	0.0004	0.0002
Diesel turbines	3.2	0.00008	0.0002

- **Inputs for energy efficiency calculations**

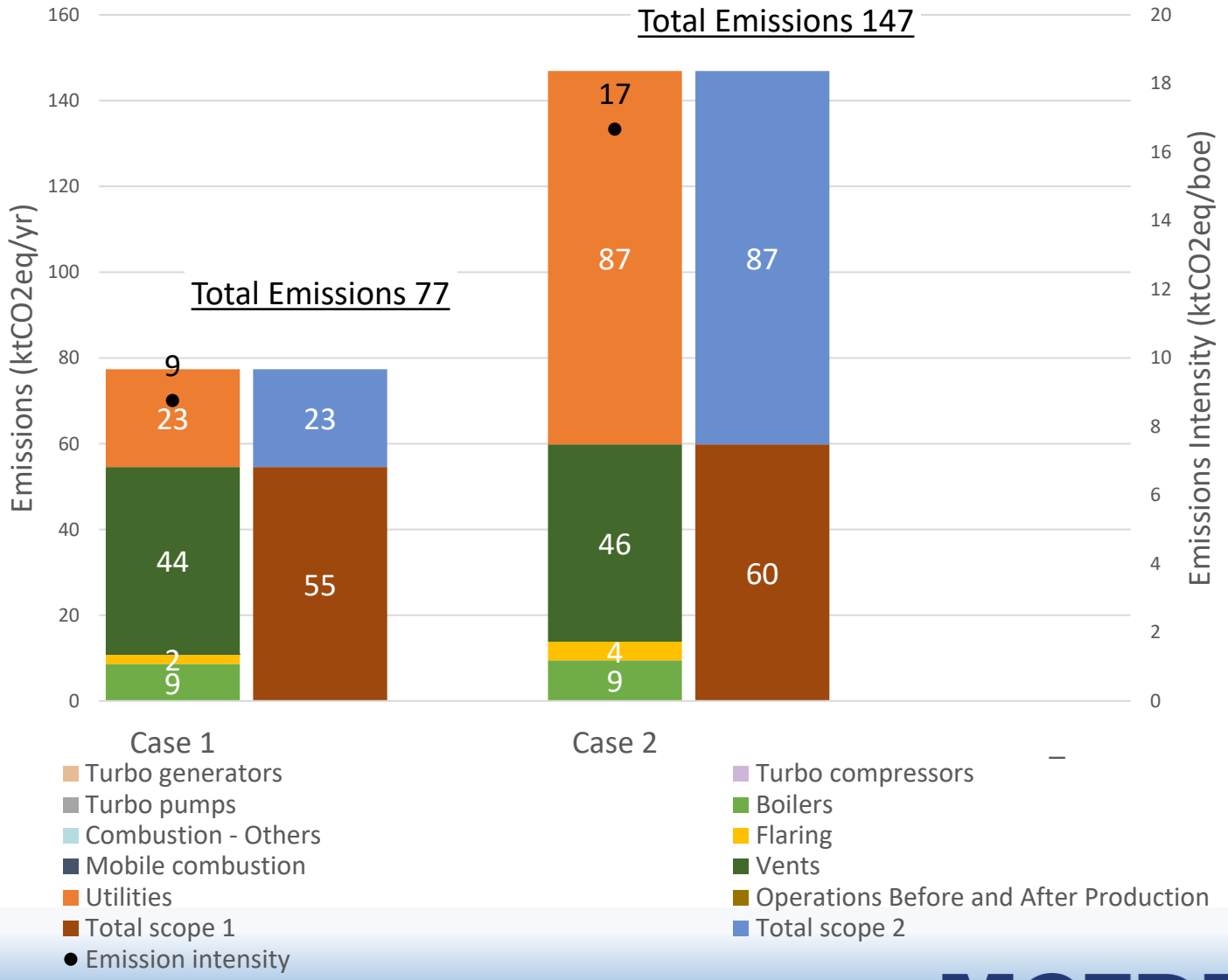
Production				
	Oil production	Oil production 1	Composition Mass (t/yr)	Crude production 159126
	Gas production	Gas production 1	Composition Mass (t/yr)	Slugcatcher Gas 1065318
Gas re-used for extraction				
	Reinjected gas	Reinjected gas 1	Composition Mass (t/yr)	None
	Gas lift	Gas lift 1	Composition Mass (t/yr)	None
Auto consumed energy				
	Auto consumed gas	Auto consumed gas 1	Composition	Fuel Gas 1
Exported products				
	Exported crude oil	Exported crude oil 1	Composition Mass (t/yr)	Crude export 159979
	Exported gas	Exported gas 1	Composition Mass (t/yr)	Slugcatcher Gas 1018336
Exported utilities				
	Exported electricity	Exported electricity 1	Quantity exported (MWh/yr)	0.0
	Exported steam/heat	Exported steam/heat 1	Quantity exported (MWh/yr)	0.0

Emissions Factors can be:

- Calculated based on fuel composition and combustion efficiency
- Values specific to an equipment (e.g., provided by vendor)
- Typical tabulated values

GHG Emissions Assessment Tool – Results

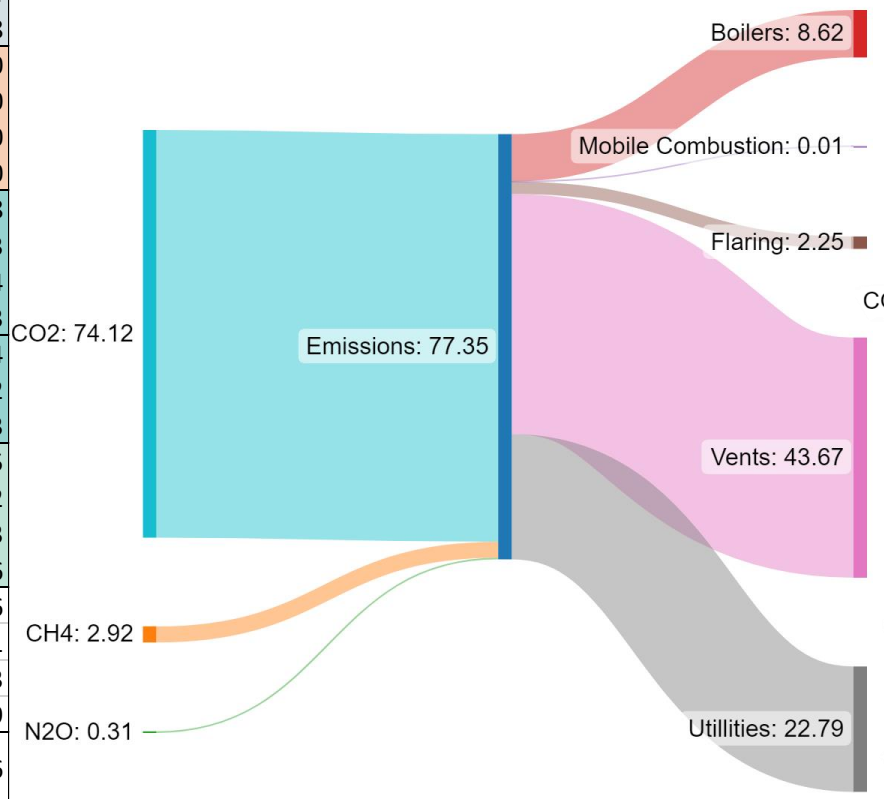
Equipments	Parameters	Case 1	Case 2
Boilers	CO2 emission (ktCO2/yr)	8.43	9.29
	CH4 emission (ktCH4/yr)	4.30E-04	6.08E-05
	N2O emission (ktN2O/yr)	6.11E-04	6.33E-04
	CO2eq emission (ktCO2eq/yr)	8.62	9.48
Mobile combustion	CO2 emission (ktCO2/yr)	0.01	0.00
	CH4 emission (ktCH4/yr)	1.10E-05	0.00E+00
	N2O emission (ktN2O/yr)	1.15E-06	0.00E+00
	CO2eq emission (ktCO2eq/yr)	0.01	0.00
Flaring	CO2 emission (ktCO2/yr)	1.95	4.18
	CH4 emission (ktCH4/yr)	1.12E-02	4.60E-03
	N2O emission (ktN2O/yr)	6.03E-05	1.19E-04
	CO2eq emission (ktCO2eq/yr)	2.25	4.33
Vents	CO2 emission (ktCO2/yr)	41.62	43.94
	CH4 emission (ktCH4/yr)	8.23E-02	8.35E-02
	CO2eq emission (ktCO2eq/yr)	43.67	46.03
Utilities	CO2 emission (ktCO2/yr)	22.11	84.45
	CH4 emission (ktCH4/yr)	2.28E-02	8.71E-02
	N2O emission (ktN2O/yr)	3.82E-04	1.46E-03
	CO2eq emission (ktCO2eq/yr)	22.79	87.06
Total with every category	CO2 emission (ktCO2/yr)	74.12	141.86
	CH4 emission (ktCH4/yr)	1.17E-01	1.75E-01
	N2O emission (ktN2O/yr)	1.05E-03	2.21E-03
	CO2eq emission (ktCO2eq/yr)	77.34	146.89
Emission intensity	Produced CO2eq/Produced energy (ktCO2eq/boe)	8.75	16.66
Total scope 1	CO2 emission (ktCO2/yr)	52.01	57.41
	CH4 emission (ktCH4/yr)	9.39E-02	8.82E-02
	N2O emission (ktN2O/yr)	6.72E-04	7.52E-04
	CO2eq emission (ktCO2eq/yr)	54.55	59.83
Total scope 2	CO2 emission (ktCO2/yr)	22.11	84.45
	CH4 emission (ktCH4/yr)	2.28E-02	8.71E-02
	N2O emission (ktN2O/yr)	3.82E-04	1.46E-03
	CO2eq emission (ktCO2eq/yr)	22.79	87.06



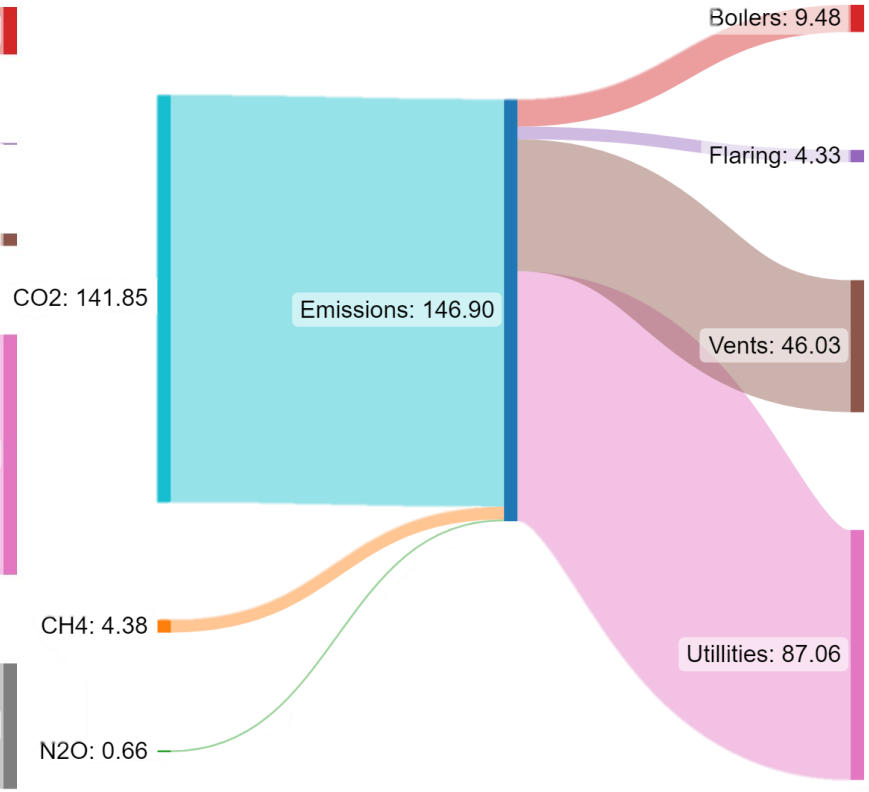
GHG Emissions Assessment Tool – Results

Equipments	Parameters	Case 1	Case 2
Boilers	CO2 emission (ktCO2/yr)	8.43	9.29
	CH4 emission (ktCH4/yr)	4.30E-04	6.08E-05
	N2O emission (ktN2O/yr)	6.11E-04	6.33E-04
	CO2eq emission (ktCO2eq/yr)	8.62	9.48
Mobile combustion	CO2 emission (ktCO2/yr)	0.01	0.00
	CH4 emission (ktCH4/yr)	1.10E-05	0.00E+00
	N2O emission (ktN2O/yr)	1.15E-06	0.00E+00
	CO2eq emission (ktCO2eq/yr)	0.01	0.00
Flaring	CO2 emission (ktCO2/yr)	1.95	4.18
	CH4 emission (ktCH4/yr)	1.12E-02	4.60E-03
	N2O emission (ktN2O/yr)	6.03E-05	1.19E-04
	CO2eq emission (ktCO2eq/yr)	2.25	4.33
Vents	CO2 emission (ktCO2/yr)	41.62	43.94
	CH4 emission (ktCH4/yr)	8.23E-02	8.35E-02
	CO2eq emission (ktCO2eq/yr)	43.67	46.03
Utilities	CO2 emission (ktCO2/yr)	22.11	84.45
	CH4 emission (ktCH4/yr)	2.28E-02	8.71E-02
	N2O emission (ktN2O/yr)	3.82E-04	1.46E-03
	CO2eq emission (ktCO2eq/yr)	22.79	87.06
Total with every category	CO2 emission (ktCO2/yr)	74.12	141.86
	CH4 emission (ktCH4/yr)	1.17E-01	1.75E-01
	N2O emission (ktN2O/yr)	1.05E-03	2.21E-03
	CO2eq emission (ktCO2eq/yr)	77.34	146.89
Emission intensity	Produced CO2eq/Produced energy (ktCO2eq/boe)	8.75	16.66
Total scope 1	CO2 emission (ktCO2/yr)	52.01	57.41
	CH4 emission (ktCH4/yr)	9.39E-02	8.82E-02
	N2O emission (ktN2O/yr)	6.72E-04	7.52E-04
	CO2eq emission (ktCO2eq/yr)	54.55	59.83
Total scope 2	CO2 emission (ktCO2/yr)	22.11	84.45
	CH4 emission (ktCH4/yr)	2.28E-02	8.71E-02
	N2O emission (ktN2O/yr)	3.82E-04	1.46E-03
	CO2eq emission (ktCO2eq/yr)	22.79	87.06

Sankey Diagrams – GHG Emissions (ktCO2eq/yr)



Case 1



Case 2

GHG Emissions Assessment Tool – Results

Equipments	Parameters	Case 1	Case 2
Boilers	CO2 emission (ktCO2/yr)	8.43	9.29
	CH4 emission (ktCH4/yr)	4.30E-04	6.08E-05
	N2O emission (ktN2O/yr)	6.11E-04	6.33E-04
	CO2eq emission (ktCO2eq/yr)	8.62	9.48
Mobile combustion	CO2 emission (ktCO2/yr)	0.01	0.00
	CH4 emission (ktCH4/yr)	1.10E-05	0.00E+00
	N2O emission (ktN2O/yr)	1.15E-06	0.00E+00
	CO2eq emission (ktCO2eq/yr)	0.01	0.00
Flaring	CO2 emission (ktCO2/yr)	1.95	4.18
	CH4 emission (ktCH4/yr)	1.12E-02	4.60E-03
	N2O emission (ktN2O/yr)	6.03E-05	1.19E-04
	CO2eq emission (ktCO2eq/yr)	2.25	4.33
Vents	CO2 emission (ktCO2/yr)	41.62	43.94
	CH4 emission (ktCH4/yr)	8.23E-02	8.35E-02
	CO2eq emission (ktCO2eq/yr)	43.67	46.03
Utilities	CO2 emission (ktCO2/yr)	22.11	84.45
	CH4 emission (ktCH4/yr)	2.28E-02	8.71E-02
	N2O emission (ktN2O/yr)	3.82E-04	1.46E-03
	CO2eq emission (ktCO2eq/yr)	22.79	87.06
Total with every category	CO2 emission (ktCO2/yr)	74.12	141.86
	CH4 emission (ktCH4/yr)	1.17E-01	1.75E-01
	N2O emission (ktN2O/yr)	1.05E-03	2.21E-03
	CO2eq emission (ktCO2eq/yr)	77.34	146.89
Emission intensity	Produced CO2eq/Produced energy (ktCO2eq/boe)	8.75	16.66
Total scope 1	CO2 emission (ktCO2/yr)	52.01	57.41
	CH4 emission (ktCH4/yr)	9.39E-02	8.82E-02
	N2O emission (ktN2O/yr)	6.72E-04	7.52E-04
	CO2eq emission (ktCO2eq/yr)	54.55	59.83
Total scope 2	CO2 emission (ktCO2/yr)	22.11	84.45
	CH4 emission (ktCH4/yr)	2.28E-02	8.71E-02
	N2O emission (ktN2O/yr)	3.82E-04	1.46E-03
	CO2eq emission (ktCO2eq/yr)	22.79	87.06

Category	Case 1	Case 2
Total imported utilities (mm MJ) HHV	119.73	537.95
Total imported utilities (mm MJ) LHV	119.73	537.95
Total production (mm MJ) HHV	Not Relevant	Not Relevant
Total production (mm MJ) LHV	56061.56	56050.16
Total production (mm boe) HHV	Not Relevant	Not Relevant
Total production (mm boe) LHV	9.16	9.16
Total auto-consumed energy (mm MJ) HHV	Not Relevant	Not Relevant
Total auto-consumed energy (mm MJ) LHV	137.62	140.40
Total auto-consumed energy (mm boe) HHV	Not Relevant	Not Relevant
Total auto-consumed energy (mm boe) LHV	0.02	0.02
Total exported products (mm MJ) HHV	Not Relevant	Not Relevant
Total exported products (mm MJ) LHV	53922.86	53800.66
Total exported products (mm boe) HHV	Not Relevant	Not Relevant
Total exported products (mm boe) LHV	8.81	8.79
Total exported utilities (mm MJ)	0.00	0.00
Total exported utilities (mm boe)	0.00	0.00
Total lost energy (mm MJ) HHV	Not Relevant	Not Relevant
Total lost energy (mm MJ) LHV	35.24	9.44
Net utilized production (mm boe) HHV	Not Relevant	Not Relevant
Net utilized production (mm boe) LHV	8.8349	8.8153
Selected basis	LHV only	LHV only
SEI	29.13	76.95
SEE	33.20	78.22
EI	29.20	77.15
η	0.25%	0.26%
EFF	95.98%	95.07%
KPI 1	0.54%	1.28%

Summary of the corresponding energy values.

Estimation of energy indicators to assess the performance of the facility.

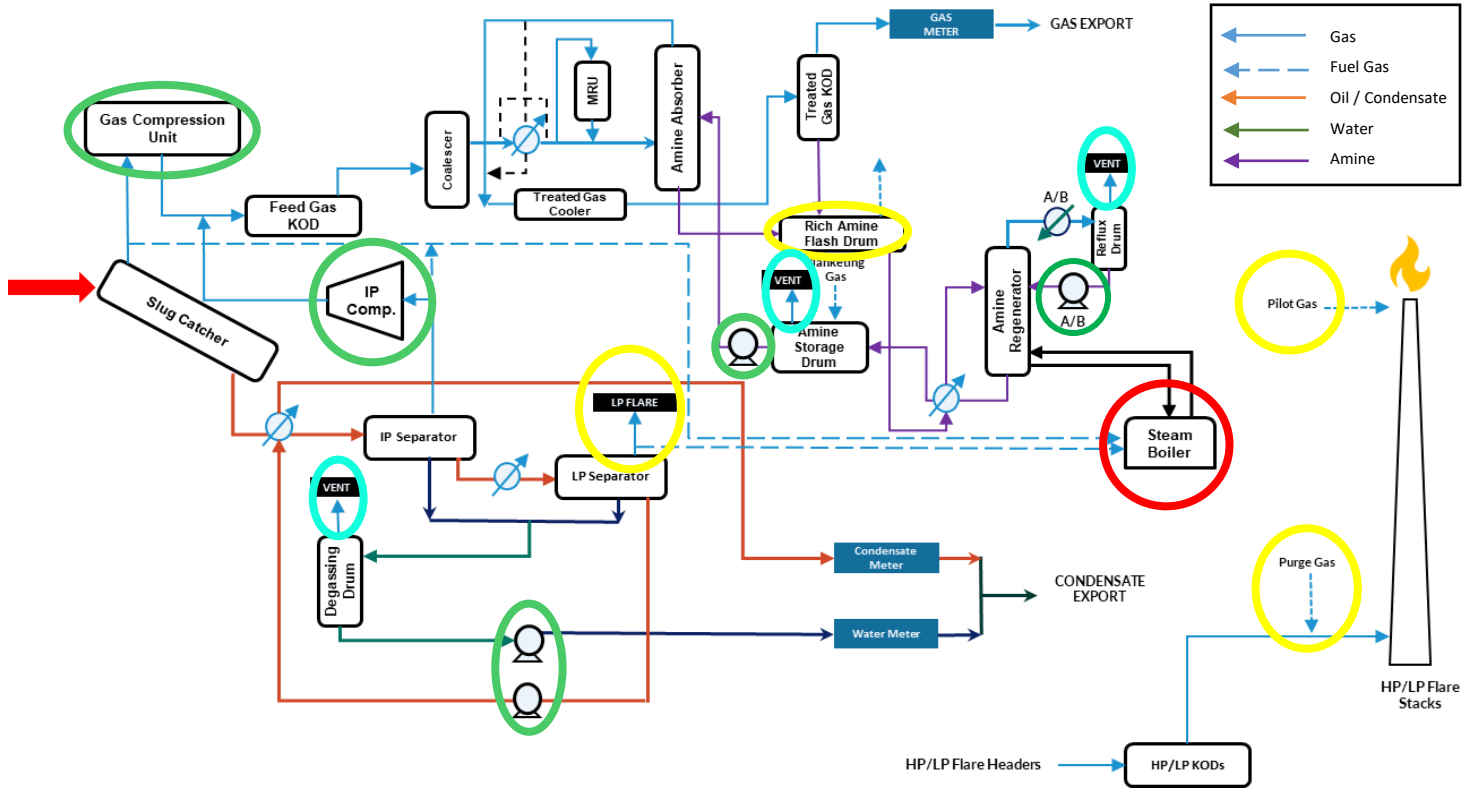
Case Study

Existing Configuration

3.5 MSm³/d

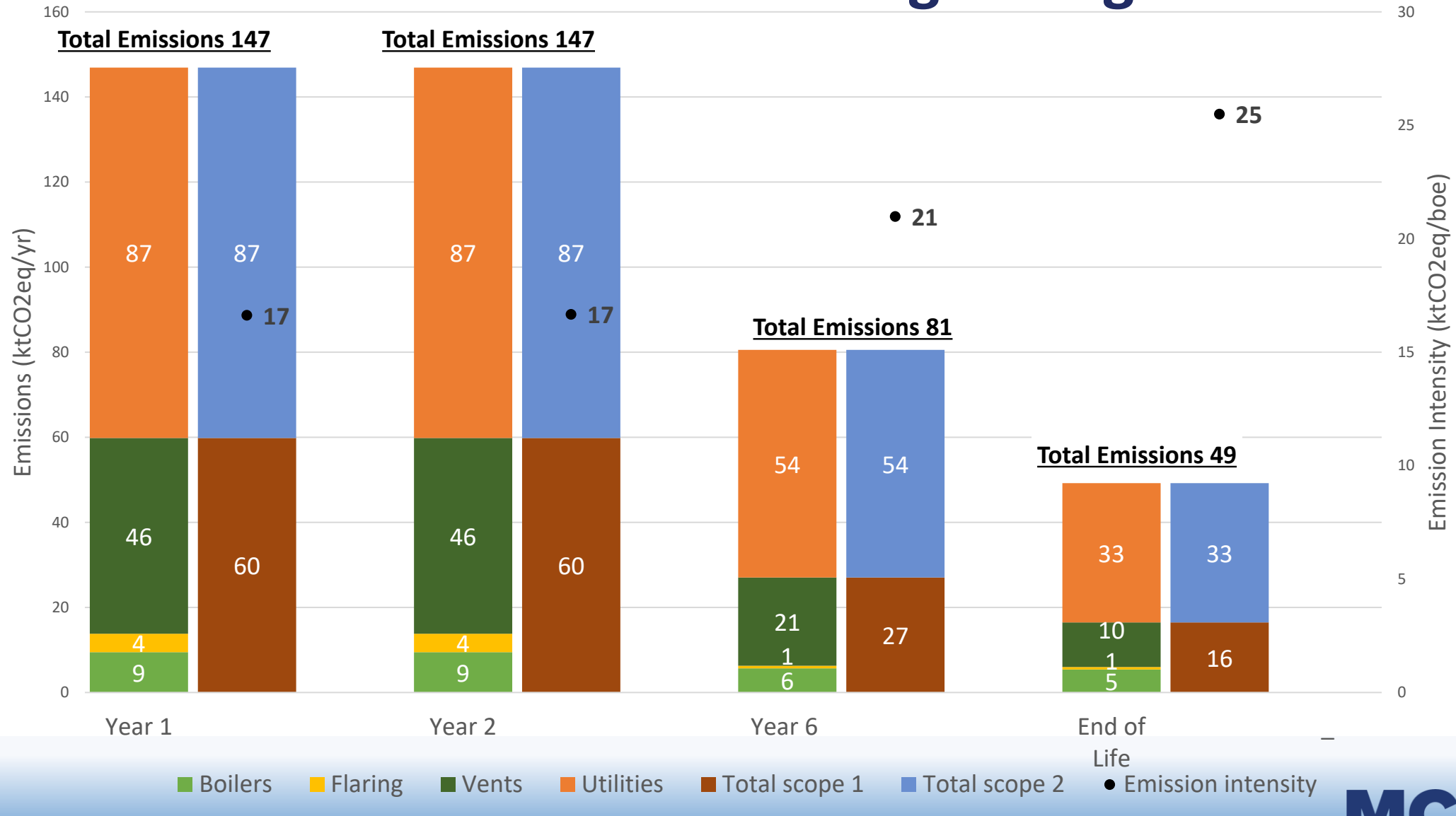
Identification of GHG emission sources for normal continuous operation

- Stationary combustion
- Normal operation flaring
- Vents
- Electricity consumption



Assessment of GHG emissions of the existing facility → Definition of GHG emissions reduction solutions → Impact of solutions on GHG emissions

GHG Emission Reduction – Existing Configuration



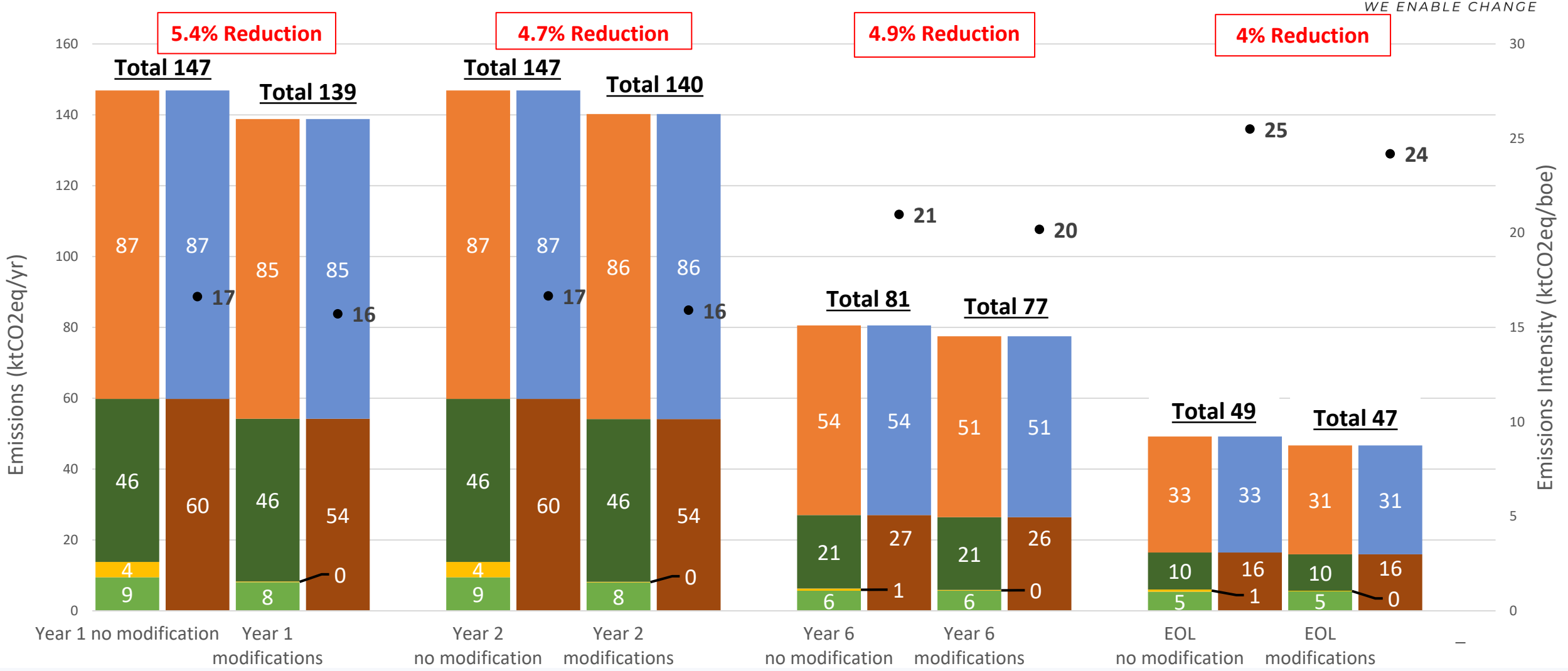
GHG Emission Reduction

- **22 potential GHG emission reduction solutions** (e.g., Nitrogen for purge and blanketing, gas recovery, heat recovery)

	Emission Reduction	Emission Increase	Emission Reduction and Increase	Not assessed	Total
Number of Options	14	1	1	6	22

- **Cost estimations were not included in the scope of the project (only preliminary sizing of equipment and layout).**
- **Selection of 4 representative years to assess GHG emissions reduction.**
- **Maximum individual preliminary GHG emission reduction is ~ 7 $ktCO_{2eq}/yr$ for years with highest emissions (overall GHG reduction of 5%)**

GHG Emission Reduction – Combination of Options



Conclusion

Ways forward for our tool development

- **Implement consideration of emergency and maintenance flaring (could be partially automatized based on pieces of equipment considered)**

- **Implement a way of assessing emissions due to plant construction and dismantling phases to allow a complete life cycle assessment**

MCEDD

DEEPWATER DEVELOPMENT

28 - 30 March 2023 | Millennium Gloucester Hotel | London, UK

ORGANIZED BY

GULF QUEST

Quest Offshore

World Oil®

Thank you!

Laura QUENTIN

Process Engineer

laura.quentin@dorisgroup.com