Chapter 2: Parameters

2.1 Economic Parameters

Parameter	Value	Unit	Source
Discount Rate	**0.0**	-	base.yaml
Annualization Interest Rate	**0.07**	-	base.yaml
Fuel Price	600.0	USD/ton	base.yaml
Electricity Price	0.0769	USD/kWh	base.yaml

Note: With discount_rate = 0.0, all years are weighted equally (no time value of money).

2.2 Time Period

Parameter	Value	Unit	Source
Start Year	2030	year	base.yaml
End Year	2050	year	base.yaml
Analysis Period	**21**	years	Calculated

2.3 Shipping Parameters

Parameter	Value	Unit	Source
Fuel per Voyage	2,158,995	kg	base.yaml
Voyages per Year	12	voyages/vessel/year	base.yaml
Start Vessels (2030)	50	vessels	base.yaml
End Vessels (2050)	500	vessels	base.yaml

Vessel Growth Calculation

```
Vessels(year) = 50 + (500 - 50) × (year - 2030) / (2050 - 2030)
              = 50 + 22.5 × (year - 2030)
```

Year	Vessels
2030	50
2035	163
2040	275
2045	388

Year	Vessels
2050	500

2.4 Ammonia Properties

Parameter	Value	Unit	Source
Density (Storage)	0.680	ton/m3	base.yaml
Density (Bunkering)	0.681	ton/m3	base.yaml

2.5 Operational Parameters

Parameter	Value	Unit	Source
Max Annual Hours	**8000**	hours/vessel/year	base.yaml
Setup Time (Hose)	0.5	hours	base.yaml
Tank Safety Factor	2.0	-	base.yaml
Daily Peak Factor	1.5	-	base.yaml

2.6 Pump Parameters

Parameter	Value	Unit	Source
Main Analysis Rate	**1000**	m3/h	base.yaml (available_flow_rates)
Shore Pump Rate	**1500**	m3/h	base.yaml (shore_supply.pump_rate_m3ph)
Pump Pressure Drop	4.0	bar	base.yaml
Pump Efficiency	0.7	-	base.yaml
Pump Power Cost	2000	USD/kW	base.yaml

Sensitivity Analysis Range

Rate (m3/h)	Analysis Type
400	Sensitivity (S7)
600	Sensitivity (S7)

Rate (m3/h)	Analysis Type
800	Sensitivity (S7)
1000	**Main Analysis**
1200	Sensitivity (S7)
1400	Sensitivity (S7)
1600	Sensitivity (S7)
1800	Sensitivity (S7)
2000	Sensitivity (S7)

2.7 Shuttle CAPEX Parameters

Parameter	Value	Unit	Source
Reference CAPEX	61,500,000	USD	base.yaml
Reference Size	40,000	m3	base.yaml
Scaling Exponent	0.75	-	base.yaml
Fixed OPEX Ratio	0.05	% of CAPEX	base.yaml
Equipment Ratio	0.03	% of CAPEX	base.yaml

CAPEX Formula

```
Shuttle_CAPEX = 61,500,000 × (Shuttle_Size / 40,000)^0.75
```

Example Calculations

Shuttle Size (m3)	CAPEX (USD)
500	$2,450,715
1,000	$4,121,543
2,500	$7,761,316
5,000	$13,051,896
10,000	$21,951,652
15,000	$29,631,149

2.8 Tank Storage Parameters (Case 1 Only)

Parameter	Value	Unit	Source
Tank Size	35,000	tons	case_1.yaml
Cost per kg	1.215	USD/kg	base.yaml

Parameter	Value	Unit	Source
Cooling Energy	0.0378	kWh/kg	base.yaml
Fixed OPEX Ratio	0.03	% of CAPEX	base.yaml

Tank CAPEX Calculation

```
Tank_CAPEX = 35,000 × 1000 × $1.215 = $42,525,000
```

2.9 Case-Specific Parameters

Case 1: Busan Port with Storage

Parameter	Value	Unit	Source
Travel Time (one-way)	1.0	hours	case_1.yaml
Has Storage at Busan	**true**	-	case_1.yaml
Port Pump Rate	1500	m3/h	case_1.yaml
Bunker Volume per Call	5000	m3	case_1.yaml

Available Shuttle Sizes: 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000, 7500, 10000 m3

Case 2-1: Yeosu to Busan

Parameter	Value	Unit	Source
Distance	86	nautical miles	case_2_yeosu.yaml
Speed	15	knots	case_2_yeosu.yaml
Travel Time (one-way)	**5.73**	hours	Calculated (86/15)
Has Storage at Busan	**false**	-	case_2_yeosu.yaml
Bunker Volume per Call	5000	m3	case_2_yeosu.yaml

Available Shuttle Sizes: 2500, 5000, 10000, 15000, 20000, 25000, 30000, 35000, 40000, 45000, 50000 m3

Case 2-2: Ulsan to Busan

Parameter	Value	Unit	Source
Distance	25	nautical miles	case_2_ulsan.yaml
Speed	15	knots	case_2_ulsan.yaml
Travel Time (one-way)	**1.67**	hours	Calculated (25/15)

Parameter	Value	Unit	Source
Has Storage at Busan	**false**	-	case_2_ulsan.yaml
Bunker Volume per Call	5000	m3	case_2_ulsan.yaml

Available Shuttle Sizes: 2500, 5000, 10000, 15000, 20000, 25000, 30000, 35000, 40000, 45000, 50000 m3

2.10 Annualization Calculation

Annuity Factor Formula

```
AF = [1 - (1 + r)^(-n)] / r
where:
  r = 0.07 (annualization interest rate)
  n = 21 years (2030-2050 inclusive)
```

Verification

```
AF = [1 - (1.07)^(-21)] / 0.07
   = [1 - 0.2415] / 0.07
   = 0.7585 / 0.07
   = 10.8355
```

CSV Verification: All scenario files show `Annuity_Factor = 10.8355` [PASS]

2.11 MCR (Maximum Continuous Rating) Values

Case 1 MCR Map (kW)

Size (m3)	MCR (kW)
500	1296
1000	1341
1500	1385
2000	1429
2500	1473
3000	1517
3500	1562
4000	1606
4500	1650
5000	1694
7500	1927
10000	2159

Case 2 MCR Map (kW)

Size (m3)	MCR (kW)
2500	1473
5000	1694
10000	2159
15000	2485
20000	2751
25000	2981
30000	3185
35000	3372
40000	3546
45000	3710
50000	3867