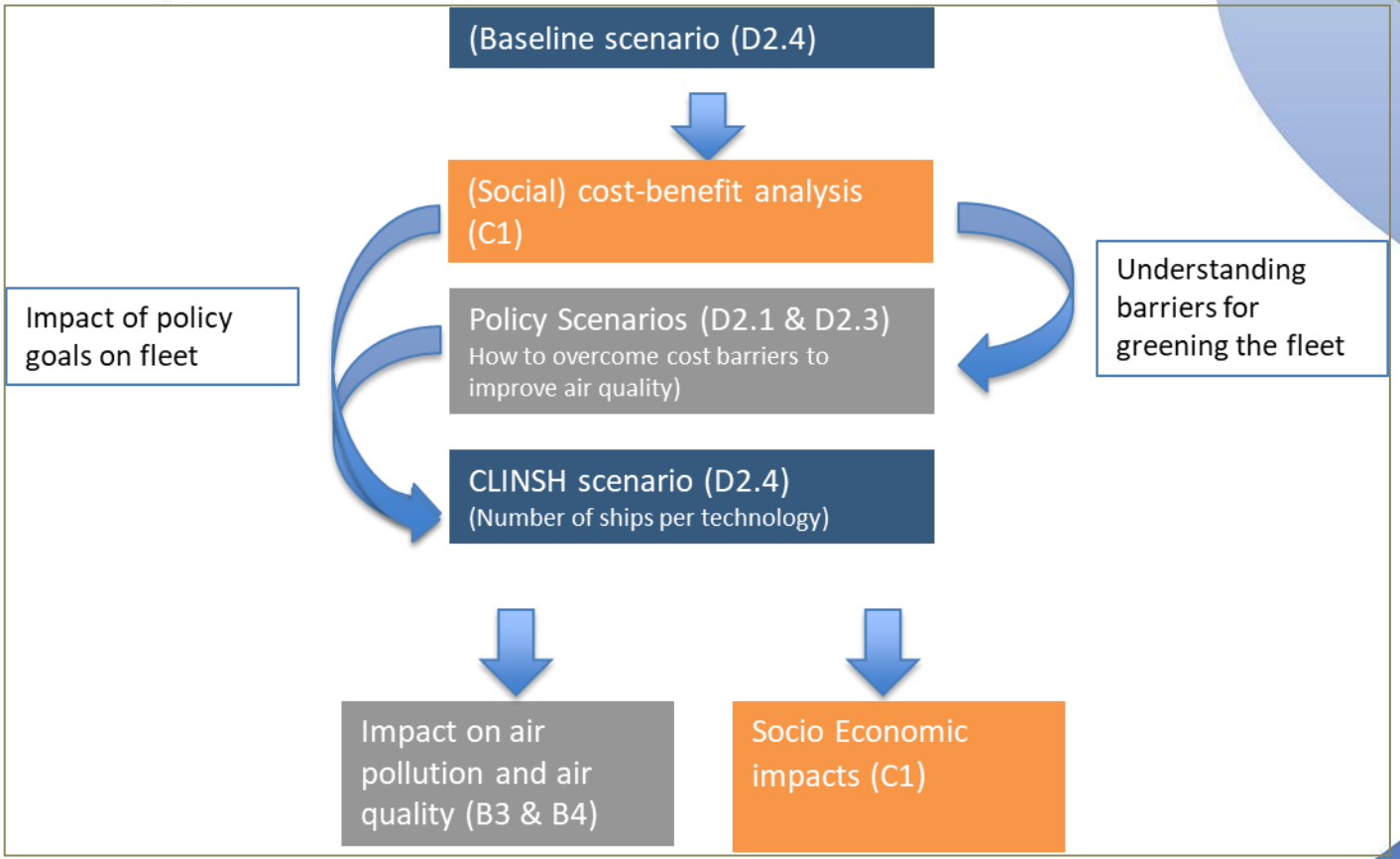
SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Fleet scenarios (D2.4) and Socio-economic study (C1)

CLINSH 25 November 2021 Rotterdam, Matthijs Otten

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR



SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

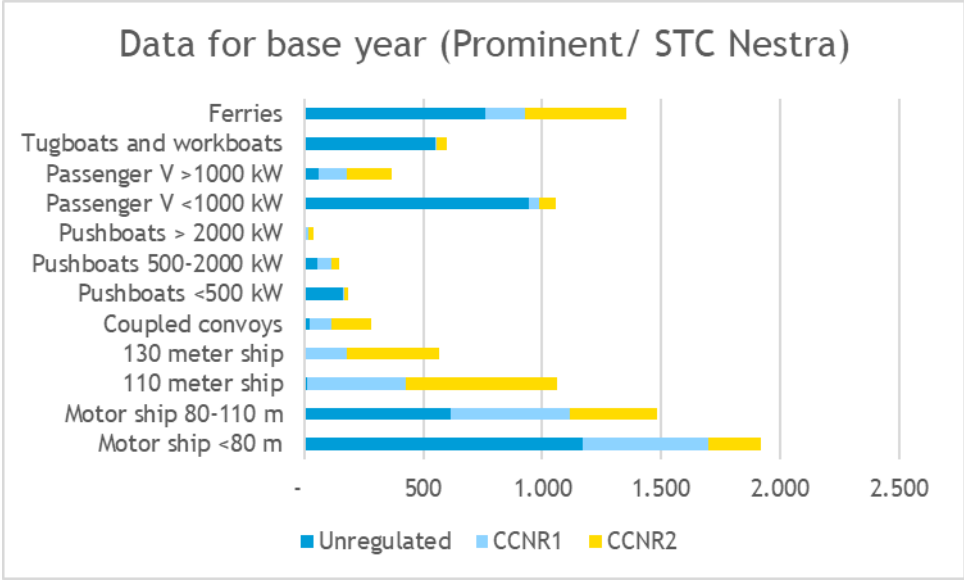
Content

- *Baseline scenario of fleet development (D2.4)*
- *Analysis of socio-economic impact of abatement techniques (C1).*
- *CLINSH scenario: based on most optimal socioeconomic choices (D2.4).*
- *Socio-economic impacts of CLINSH scenario*

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

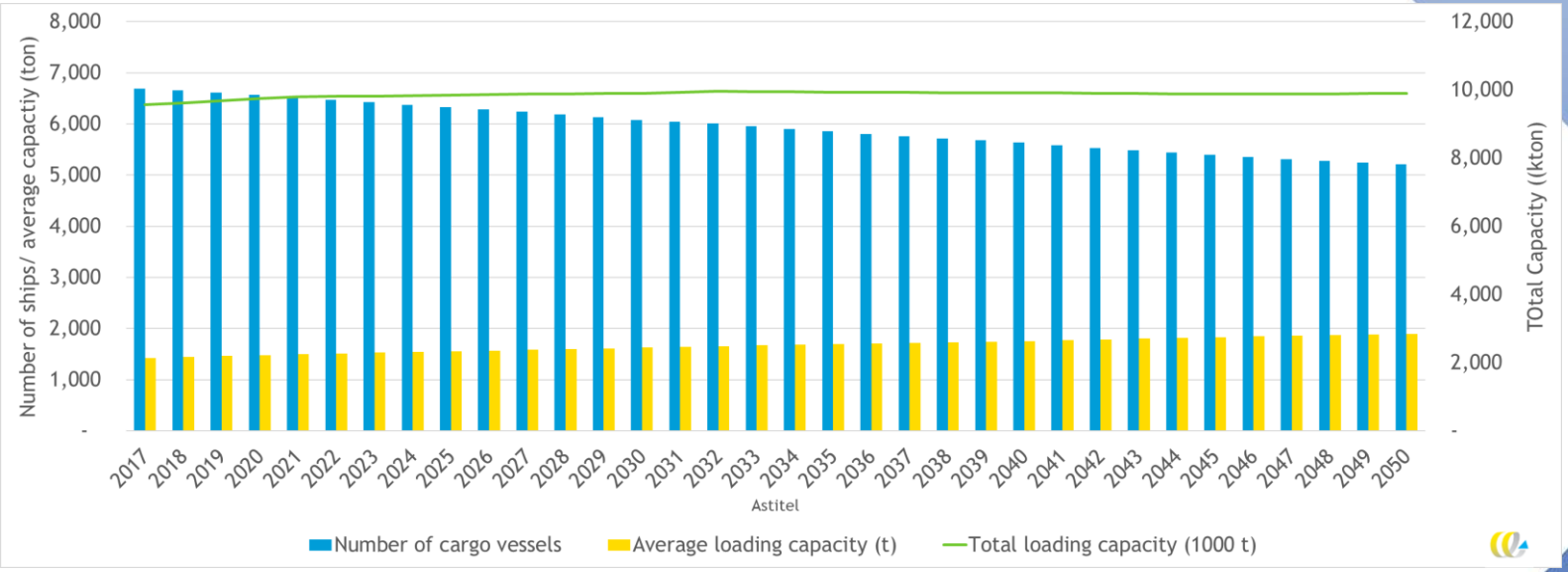
Baseline scenario CLINSH

1. *Engines in fleet based on date from Prominent/ STC Nestra (base year 2015)*
2. *Developments towards 2050 modelled taking into account:*
   - Autonomous engine renewal based on engine age and engine lifetime and restrictions in Rotterdam.
   - Market developments of transport volumes (e.g. oil coal)
   - Developments in vessel size
3. *Result: Number of vessels and engines by age and vessel type from 2015-2035*



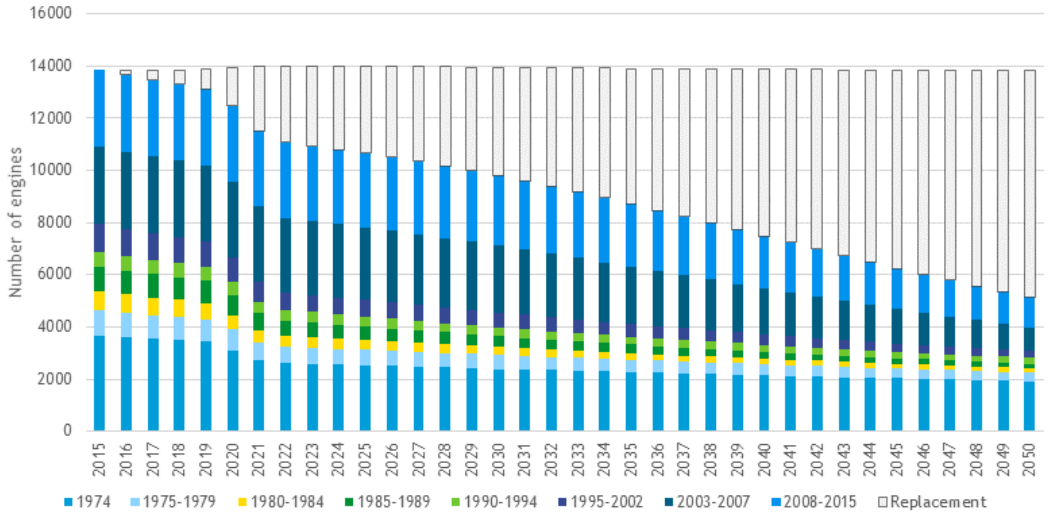
SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Development of vessel size



SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Baseline scenario CLINSH

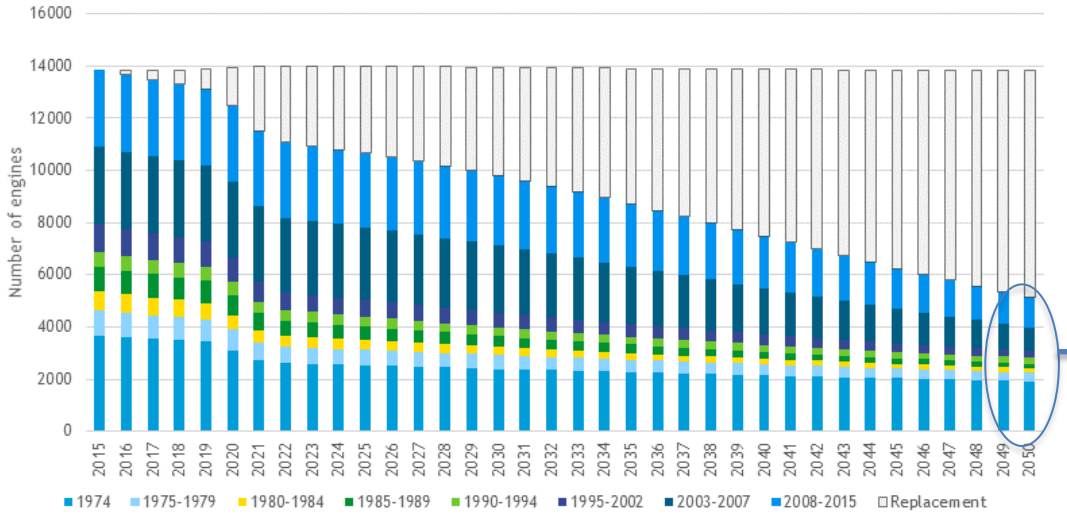


New engines: default Stage V

Remaining old engines (CCR0, 1,2)

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Baseline scenario CLINSH



CLINSH scenario

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Analysis of socio-economic impact of abatement technologies (C1).

Technologies considered in relation to revision of existing engine:

- New stage V engine
- LNG dual fuel refit
- SCR/ DPF
- Battery electric,
- Revision + GTL
- LNG mono-fuel
- SCR
- Diesel- electric
- Revision + FWE,
- Euro VI engine

Social Costs and benefits assessed based with input from

- CLINSH monitoring results on emissions (NOx reduction) complemented with literature (PM and CO_2 reduction)
- Investment and operational costs based on monitoring ships and literature (e.g. Prominent study)

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

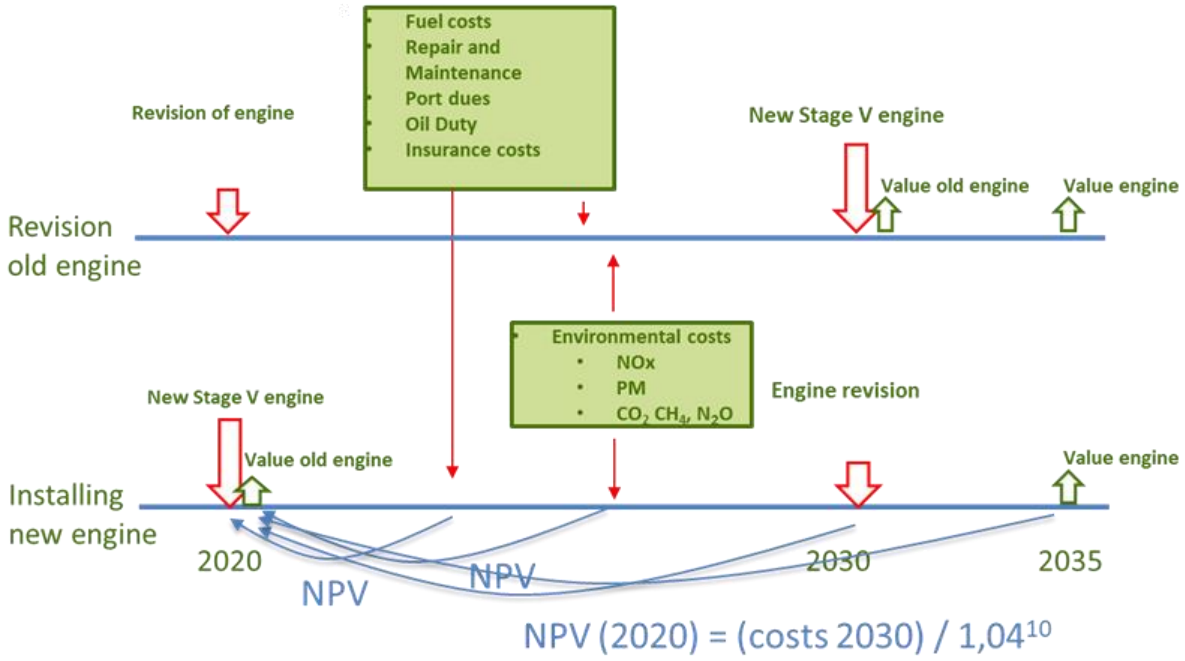
(S)CBA analysis - assumptions

- *Assessment of costs and benefits over **15** years.*
- *Analysis per ship category; Per ship category differentiation between low, medium and high fuel consumption.*
- *Costs included in assessment :*
  - Investments, reinvestments in same technology, upkeep investments, residual values, energy costs, other variable cost, and external costs.
- *Monetisation of emissions*:*
  - WTW CO_2: €167 / tonne average_ € 100 (2020)- € 269 (2050)/ tonne,
  - NO_x: (€20/ kg),
  - $PM_{2.5}$: (€123/ kg)
- *Cost and benefits calculated as Net Present Value over **15** years;*
  - Diesel price € 697 /tonne
  - LNG: 75% of diesel price (per ton fuel)
  - Electricity: € 0.10 / kWh
  - Battery price €500 (2020) – 150 (2040)

*Handbook on the external costs of transport – January 2019

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

SCBA framework



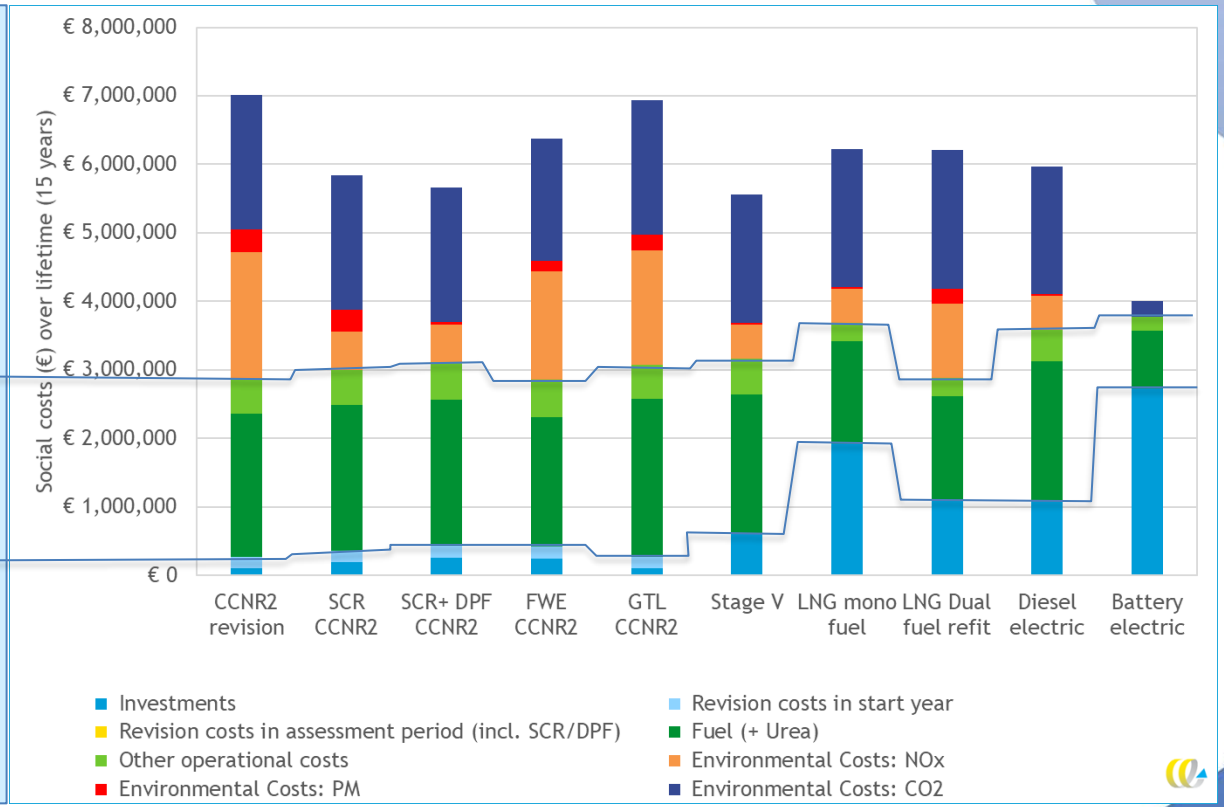
Results engine costs 110 m ship – 15 years

External costs

TCO

Variable costs

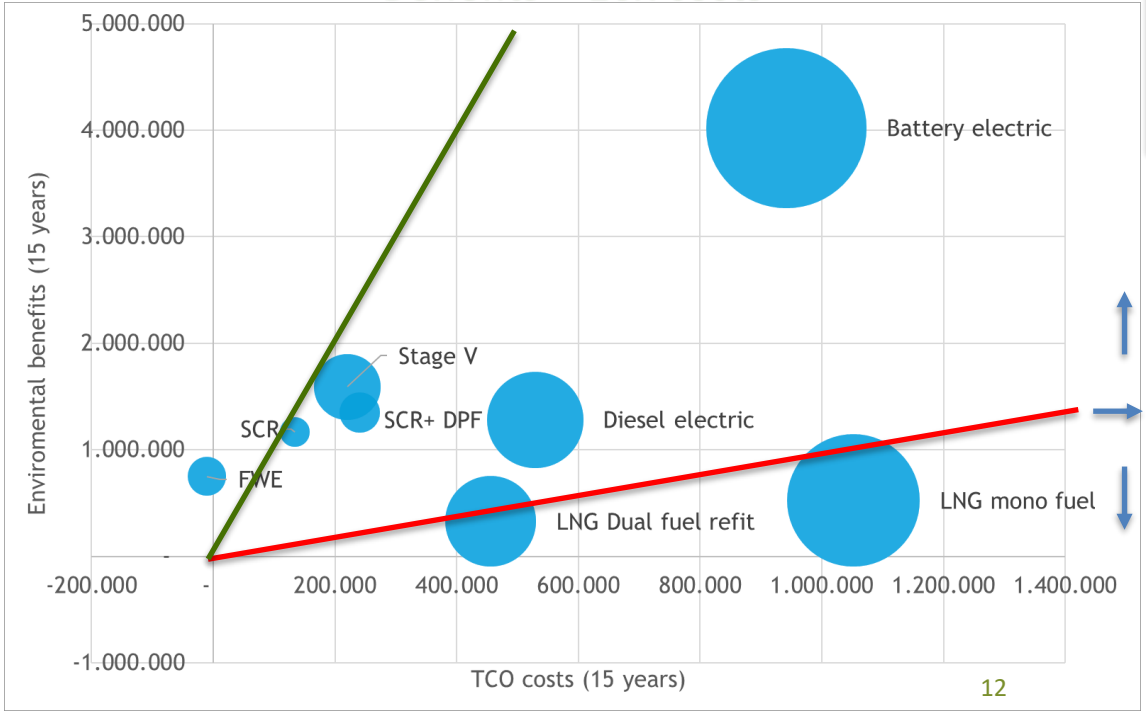
Investments



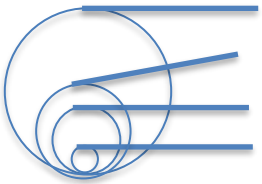
SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Results: Example 110 meter ship

Benefits = 10x costs



Bell size = Initial extra investment costs



Costs < benefits

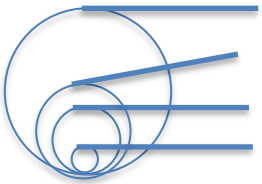
Costs = benefits

Costs > benefits

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

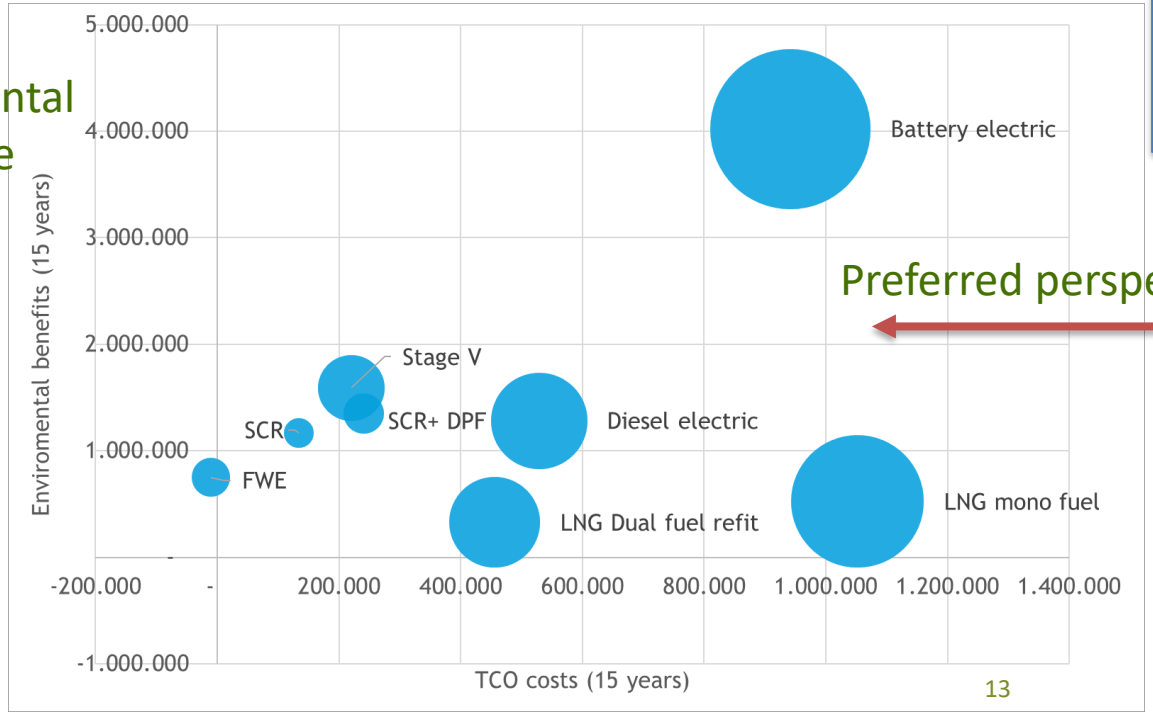
Results: Example 110 meter ship

Bell size = Initial extra investment costs



2.5 mln
1.0 mln
0.5 mln
0.1 mln

Environmental Perspective



Preferred perspective end user

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Results: Example 110 meter ship

	User perspective		Environmental perspective	
	Initial investment costs	TCO extra costs	Enviromental benefits (euro)	Benefits / Costs
Stage V	437.255	220.380	1.591.376	7,2
LNG mono fuel	1.752.035	1.052.378	523.724	0,5
LNG Dual fuel refit	824.270	455.760	327.302	0,7
SCR	87.032	133.777	1.167.514	8,7
SCR+ DPF	161.785	240.787	1.350.749	5,6
Diesel electric	927.721	528.702	1.283.054	2,4
Battery electric	2.561.163	941.805	4.022.564,7	4,3
FWE	148.637	-10.735	751.182	-70,0
GTL	-	208.948	202.697	1,0

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

CLINSH Scenario

- *Projection Year 2035*
- *Focus on Air quality*
  - Biofuels (HVO, bio LNG) are options in combination with assessed technologies but not part of assessment.
  - Battery electric till 2035 still immature: high (re)-investment; limited range.
- *Social optimum scenario*

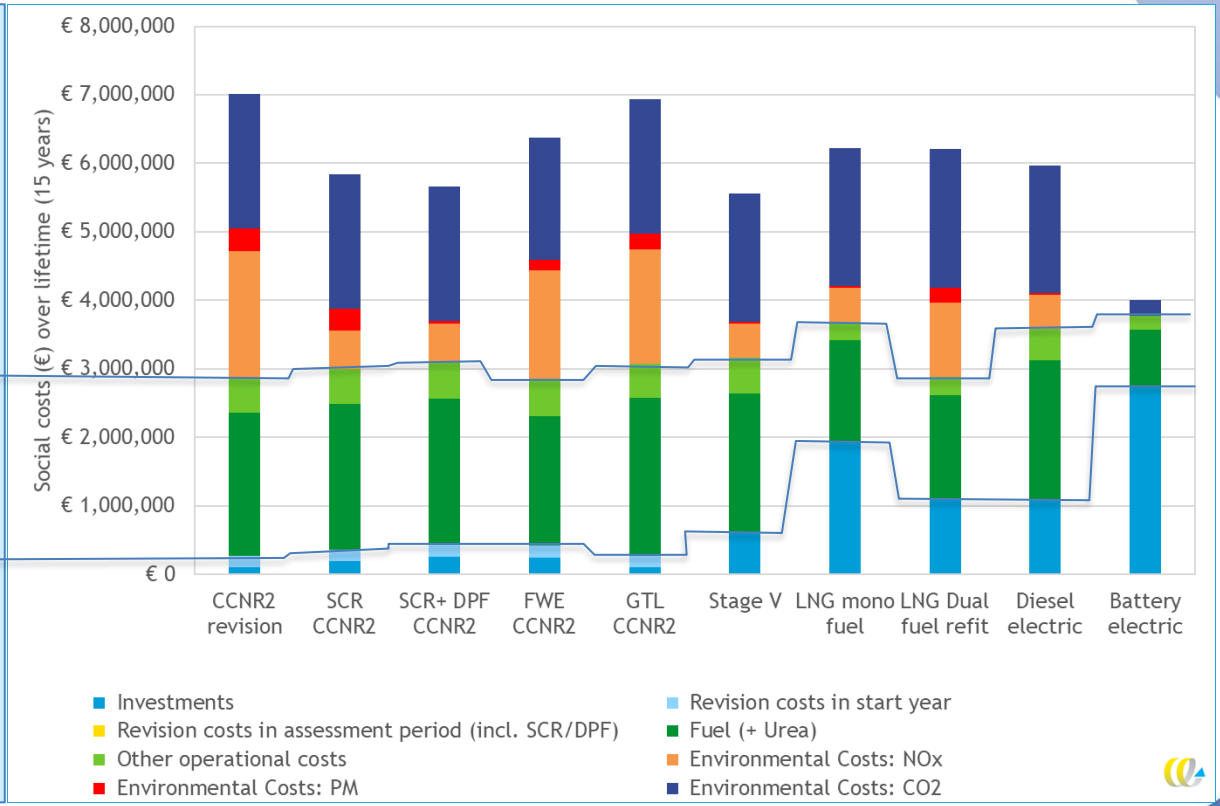
SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Social optimal perspective: lowest total costs

External costs

Variable costs

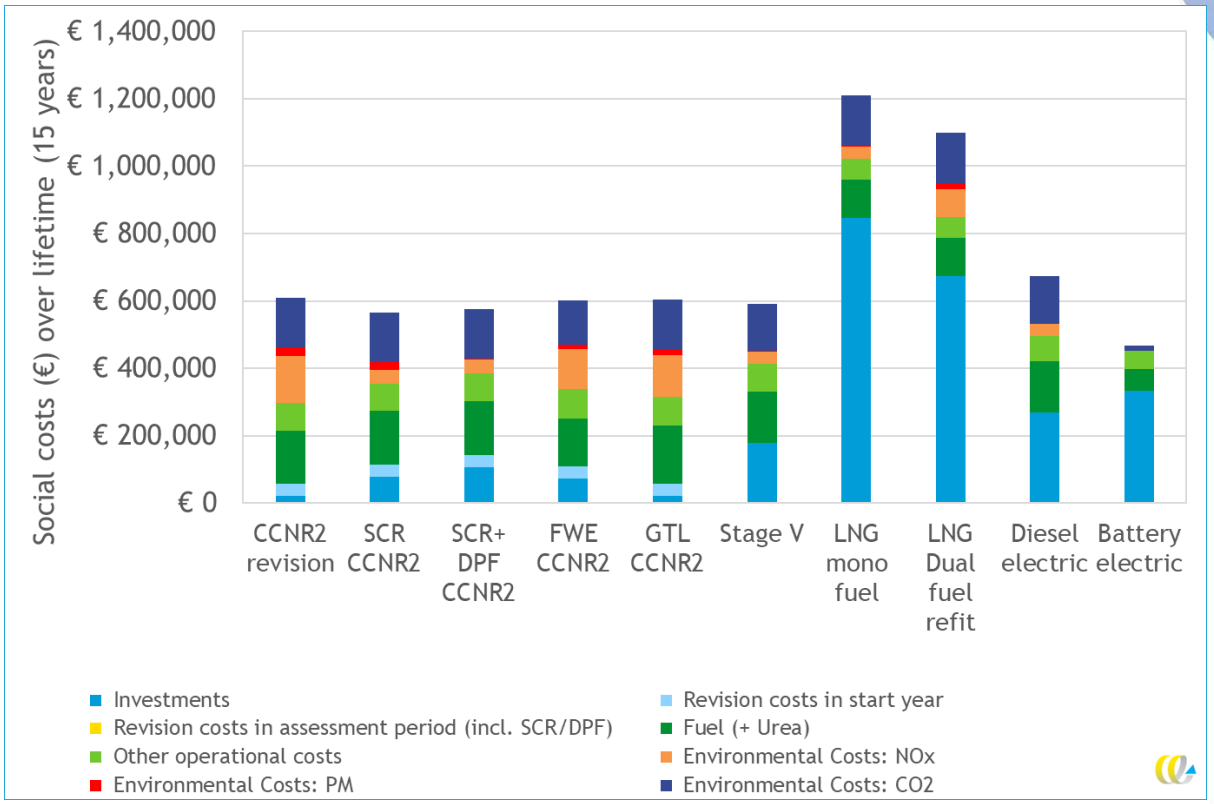
Investments



110 m ship average fuel use

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Social optimal perspective: lowest total costs



<80 m ship
Low fuel use

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Results: social optimal perspective: CCNR 2

Vessel category	Low fuel use	Average fuel use	High fuel use
Passenger vessel <250 kW	GTL CCNR2	GTL CCNR2	Stage V
Passenger vessel 250 - 500 kW	GTL CCNR2	SCR CCNR2	Stage V
Passenger vessel 500 - 1000 kW	GTL CCNR2	SCR CCNR2	Stage V
Passenger vessel >1000 kW	Stage V	Stage V	Stage V
Push boats <500 kW	Stage V	Stage V	Stage V
Push boats 500-2000 kW	Stage V	Stage V	Stage V
Push boats ≥2000 kW	LNG mono fuel	LNG mono fuel	LNG mono fuel
Motor vessels <80 m. length	Stage V	Stage V	Stage V
Motor vessels dry cargo typical 80 and 86 m ship	Stage V	Stage V	Stage V
Motor vessels dry cargo typical 105 m ship	Stage V	Stage V	Stage V
Motor vessels dry cargo 110 m ship	Stage V	Stage V	Stage V
Motor vessels dry cargo >130 (135 m ship)	Stage V	Stage V	Stage V
Motor vessels liquid cargo 80-109m length (typic	Stage V	Stage V	Stage V
Motor vessels liquid cargo 110 m ship	Stage V	Stage V	Stage V
Motor vessels liquid cargo >130 (135 m ship)	Stage V	Stage V	Stage V
Coupled convoys	Stage V	Stage V	Stage V
Ferry	GTL CCNR2	GTL CCNR2	SCR CCNR2
Tugboat and workboat	GTL CCNR2	SCR CCNR2	Stage V

Batter-electric not considered up to 2035

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Results: social optimal perspective: CCNR 0/1

Vessel category	Low fuel use	Average fuel use	High fuel use
Passenger vessel <250 kW	GTL CCNR0	Stage V	Stage V
Passenger vessel 250 - 500 kW	GTL CCNR0	Stage V	Stage V
Passenger vessel 500 - 1000 kW	SCR CCNR0	Stage V	Stage V
Passenger vessel >1000 kW	Stage V	Stage V	Stage V
Push boats <500 kW	Stage V	Stage V	Stage V
Push boats 500-2000 kW	Stage V	Stage V	Stage V
Push boats ≥2000 kW	LNG mono fuel	LNG mono fuel	LNG mono fuel
Motor vessels <80 m. length	Stage V	Stage V	Stage V
Motor vessels dry cargo typical 80 and 86 m ship	Stage V	Stage V	Stage V
Motor vessels dry cargo typical 105 m ship	Stage V	Stage V	Stage V
Motor vessels dry cargo 110 m ship	Stage V	Stage V	Stage V
Motor vessels dry cargo >130 (135 m ship)	Stage V	Stage V	Stage V
Motor vessels liquid cargo 80-109m length (typical 86 m ship)	Stage V	Stage V	Stage V
Motor vessels liquid cargo 110 m ship	Stage V	Stage V	Stage V
Motor vessels liquid cargo >130 (135 m ship)	Stage V	Stage V	Stage V
Coupled convoys	Stage V	Stage V	Stage V
Ferry	GTL CCNR0	GTL CCNR0	Stage V
Tugboat and workboat	GTL CCNR0	Stage V	Stage V

Batter-electric not considered up to 2035

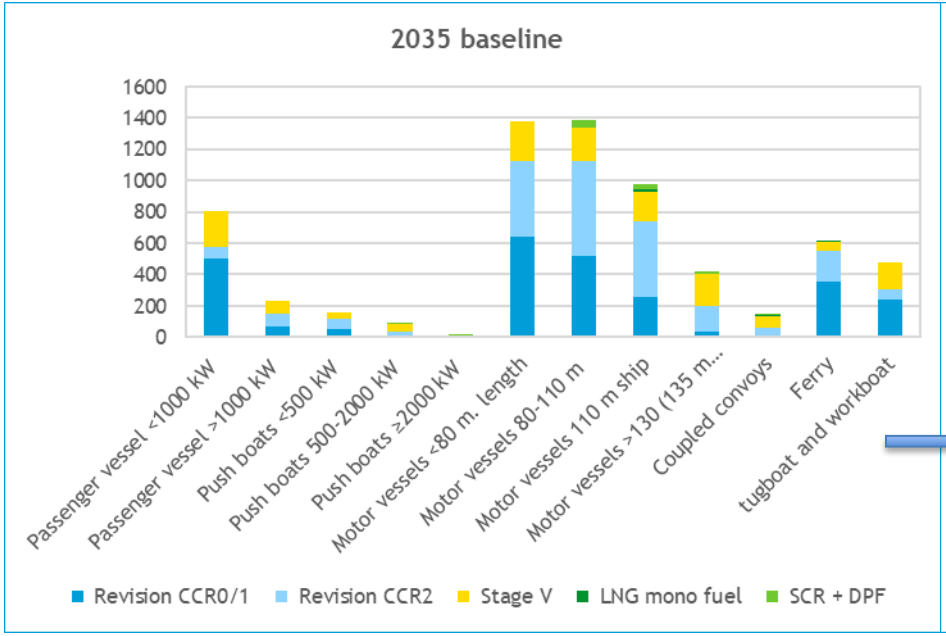
SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

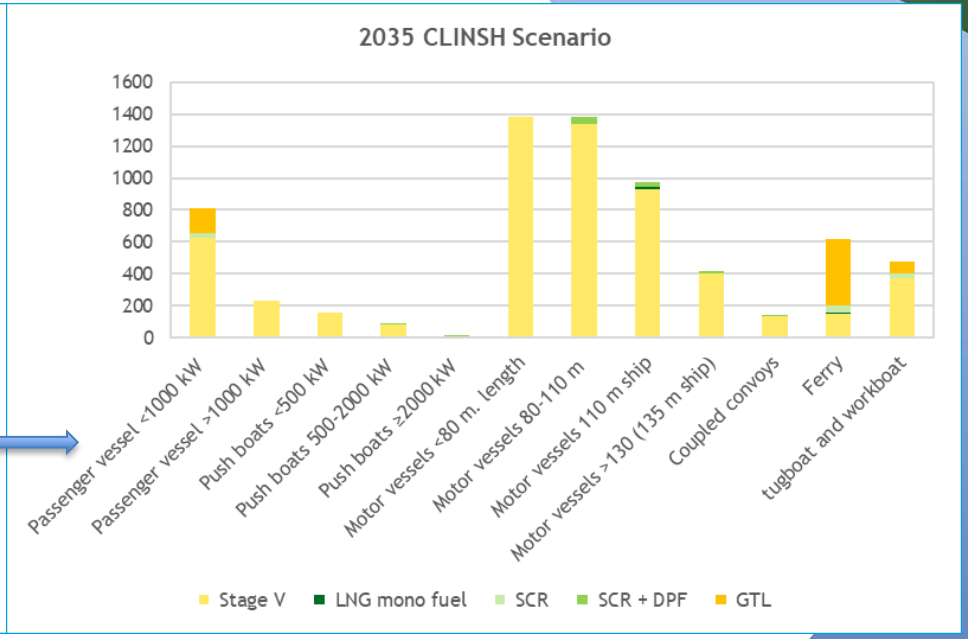
CLINSH Scenario results

- *Stage V in most cases lowest social costs*
  - Higher efficiency combined with lowest Nox and PM levels
- *For some smaller ships GTL is a suitable alternative;*
- *SCR is attractive for some smaller ships with higher fuel consumption*

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

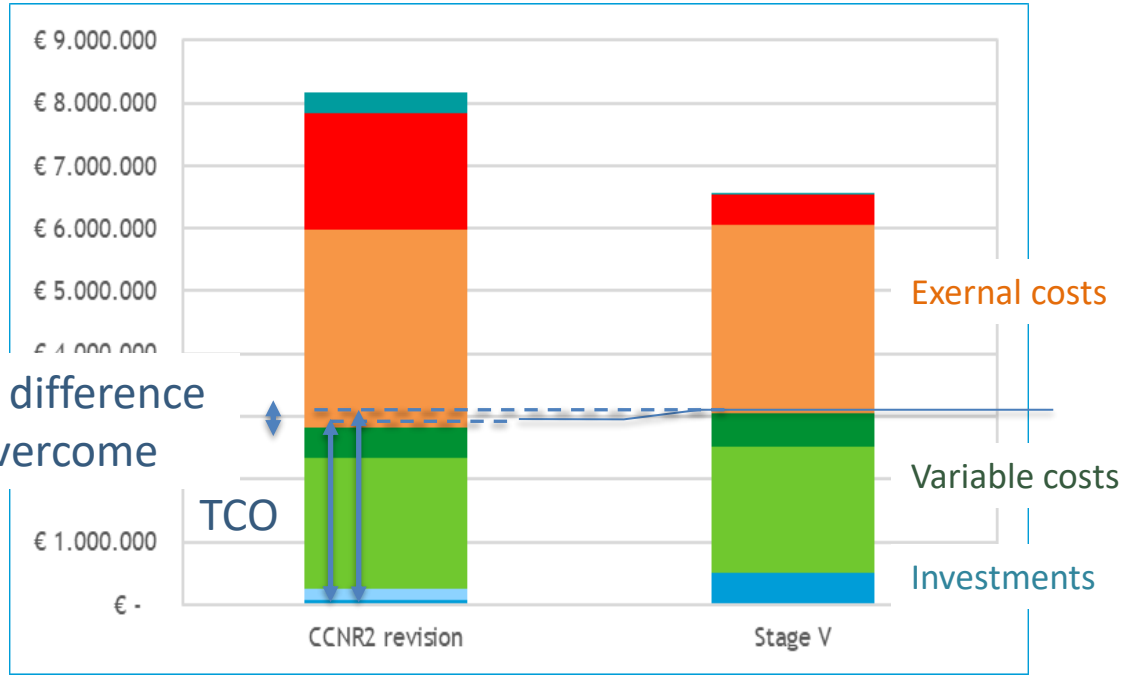
CLINSH scenario results





SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Policy Instruments needed to overcome cost difference



SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Socio-economic impacts CLINSH Scenario

Costs for greening the total fleet

	Total social costs Baseline scenario 2020- 2035	Total social costs CLINSH scenario in 2020-2035	Difference
Number of vessels involved, West-Europe*	6,572	6,572	
Social costs with 15 years lifetime (mio €), consisting of:	€ 26,139	€ 21,280	**€ -4,859**
TCO (Total cost of ownership) with 15 years lifetime (mio €)	*€ 10,751*	*€ 11,512*	***€ 761***
CO_2 costs with 15 years lifetime (mio €)	*€ 8,074*	*€ 7,867*	*€ -207*
NOx costs with 15 years lifetime (mio €)	*€ 6,051*	*€ 1,788*	*€ -4,263*
PM costs with 15 years lifetime (mio €)	*€ 1,264*	*€ 112*	*€ -1,151*
Initial investment costs (mio €)	€ 1,123	€ 2,393	**€ 1,270**
Diesel consumed over 15 years (mio litres)	14,662	14,286	-376
TCO increase per litre of diesel (€ per litre)	€ 0.733	€ 0.806	**€ 0.053****

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Questions

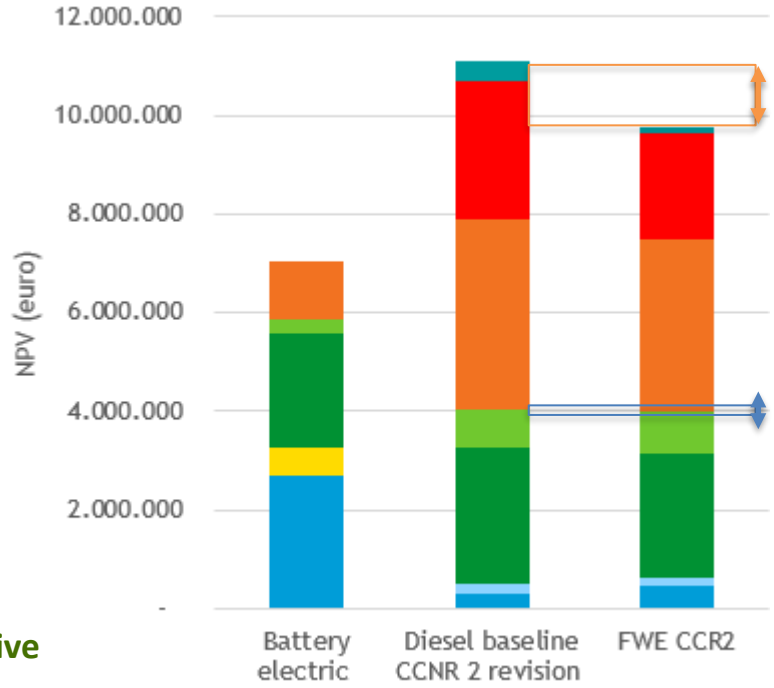
SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

CLINSH Scenario results

Vessel type	Revision CCR0/1	Revision CCR2	Stage V	LNG mono fuel	LNG Dual fuel refit	SCR	SCR + DPF	Diesel electric	Battery electric	FWE	GTL
Passenger vessel <250 kW			79%								21%
Passenger vessel 250 - 500 kW			75%			6%					19%
Passenger vessel 500 – 1,000 kW			68%			27%					5%
Passenger vessel >1,000 kW			100%								
Push boats <500 kW			100%								
Push boats 500-2,000 kW			97%				3%				
Push boats ≥2,000 kW			97%				3%				
Motor vessels <80 m. length			100%								
Motor vessels dry cargo typical 80 and 86 m ship			97%				3%				
Motor vessels dry cargo typical 105 m ship			97%				3%				
Motor vessels dry cargo 110 m ship			97%				3%				
Motor vessels dry cargo >130 (135 m ship)			97%				3%				
Motor vessels liquid cargo 80-109m length (typical 86 m ship)			97%				3%				
Motor vessels liquid cargo 110 m ship			95%	2%			3%				
Motor vessels liquid cargo >130 (135 m ship)			97%				3%				
Coupled convoys			96%	1%			3%				
Ferry			24%	1%		8%					68%
Tugboat and workboat			77%			7%					16%
Total			87%			2%	2%				10%

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Cost efficient or social optimal



Medium environment effect

Very low extra costs, even negative

Example 110 - meter ship

- Environmental Costs: NOx
- Environmental Costs: CO2
- Other operational costs
- Fuel (+ Urea)
- Revision costs in assesment period (incl SCR/ DPF)
- Revision costs in start year
- Investments

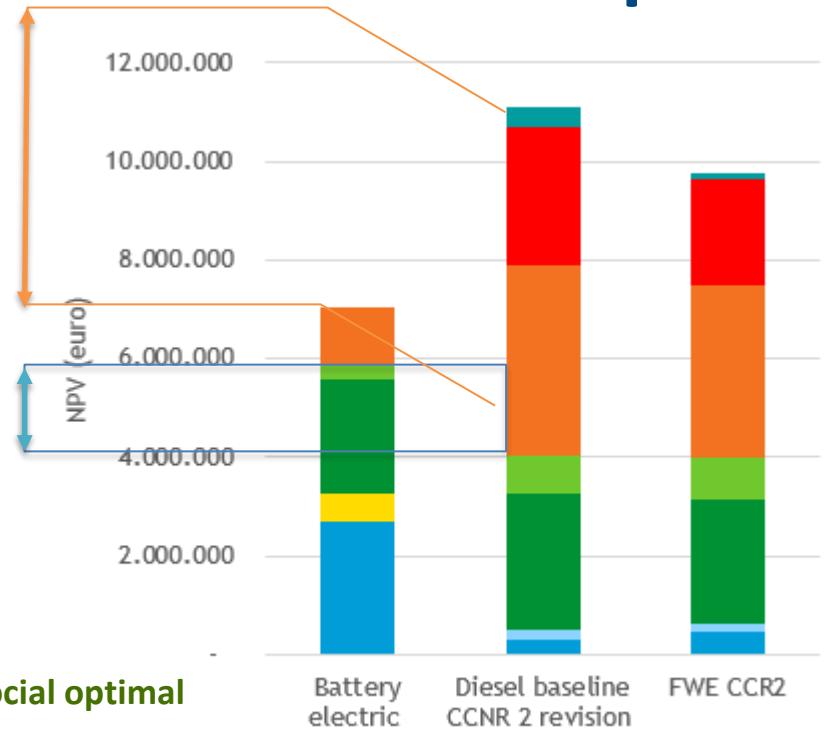
FWE = Most cost-effective

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Cost efficient or social optimal

High environment effect

High cost difference



Battery electric = social optimal

Example 110 - meter ship

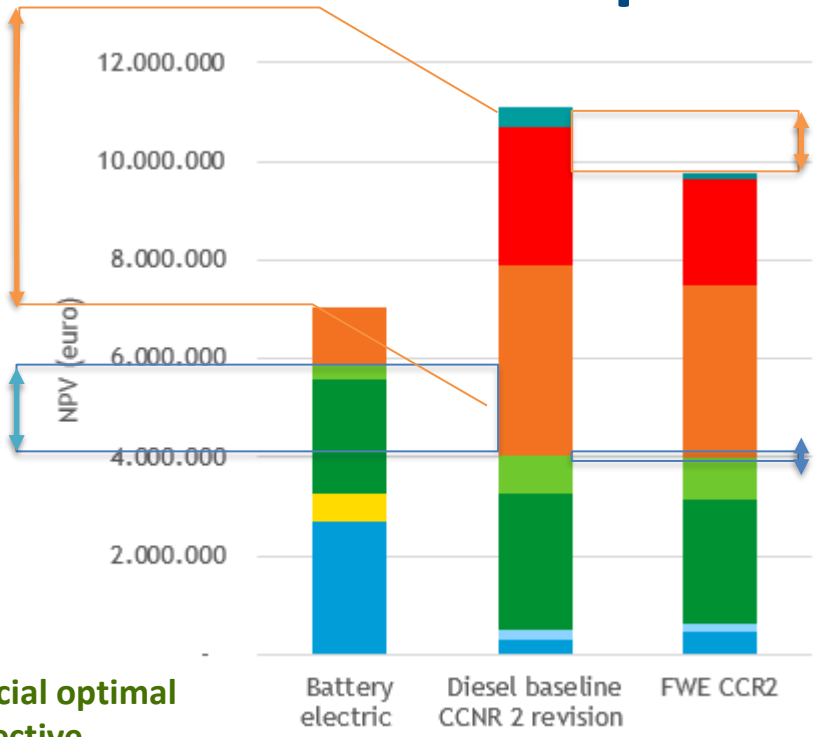
- Environmental Costs: NOx
- Environmental Costs: CO2
- Other operational costs
- Fuel (+ Urea)
- Revision costs in assesment period (incl SCR/ DPF)
- Revision costs in start year
- Investments

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Cost efficient or social optimal

High environment effect

High cost difference



Medium environment effect

Very low extra costs, even negative

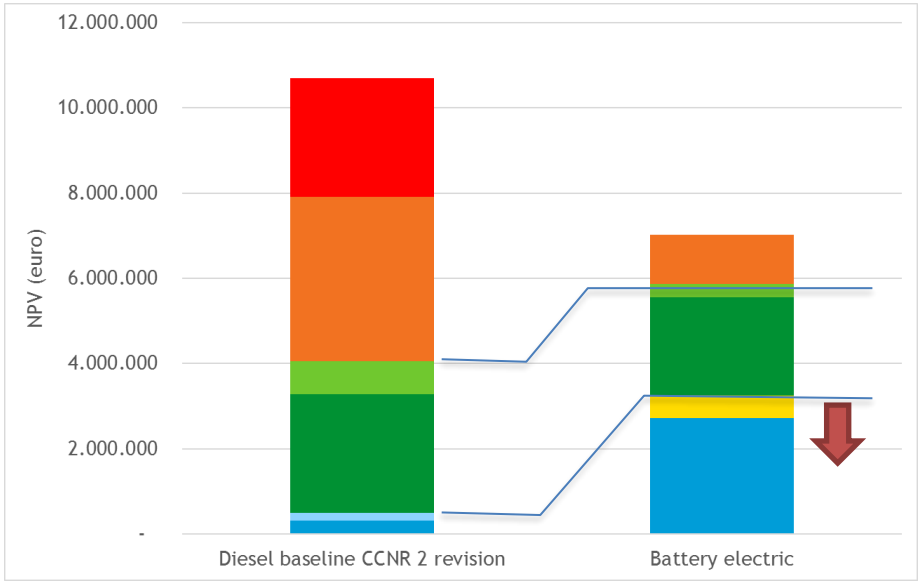
Example 110 - meter ship

- Environmental Costs: NOx
- Environmental Costs: CO2
- Other operational costs
- Fuel (+ Urea)
- Revision costs in assesment period (incl SCR/ DPF)
- Revision costs in start year
- Investments

Battery electric = social optimal
FWE = Most cost-effective

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Policy Instruments needed

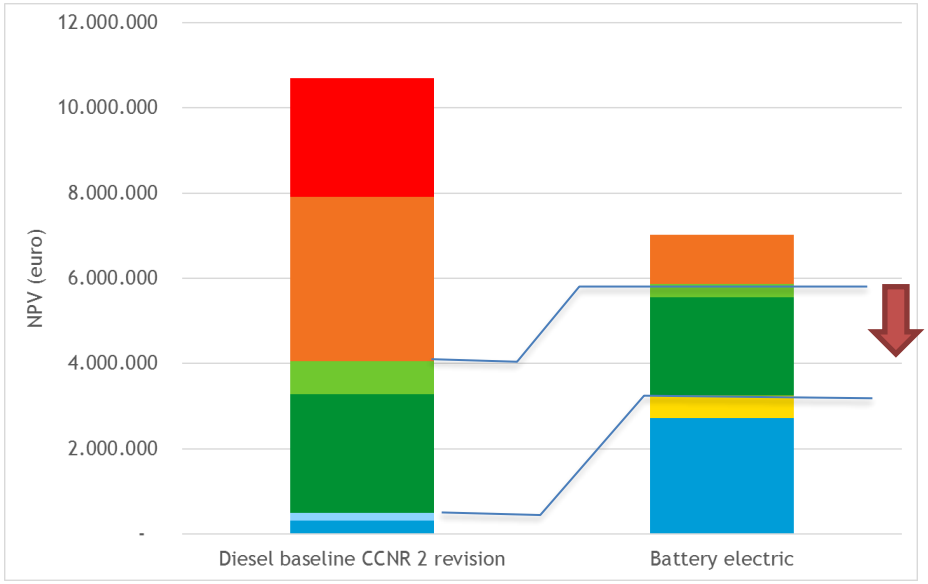


Investment subsidy

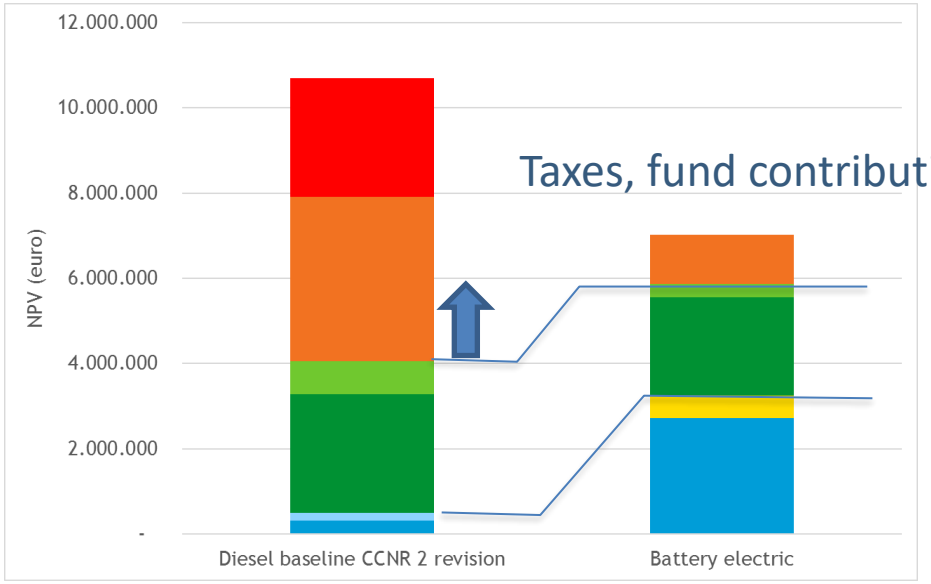
- Environmental Costs: NOx
- Environmental Costs: CO2
- Other operational costs
- Fuel (+ Urea)
- Revision costs in assesment period (incl SCR/ DPF)
- Revision costs in start year
- Investments

SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Policy Instruments needed



Policy Instruments needed



SUSTAINABLE WATERWAY TRANSPORT, CLEAN AIR

Policy Instruments needed