University of Antwerp
TPR | Research Group Transport and Regional Economics

Economic Impacts of the Electric Road System Implementation on Rotterdam-Antwerp Corridor

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Research questions

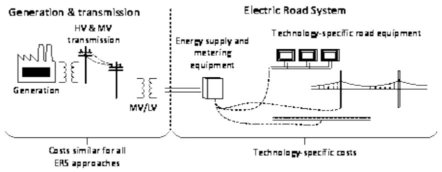
- What are the **potential ERS traffic volumes** that could use the Antwerp-Rotterdam corridor if it were developed? Are those sufficient to justify ERS implementation?
- What is the **required investment**, and can break-even point for profitability to be reached for this corridor in isolation? Or is a wider electrified network required? Would this be a good investment at this scale?
- With alternative road links available between Rotterdam and Antwerp, **which route is best suited** to be electrified from an economic perspective?
- Could **trucks be operated on ERS profitably** in this corridor setting? Is this similar for all ERS technologies or are there substantial differences due to which a specific ERS technology should be preferred?

Methodology

Inputs

Traffic data & Geography

Technology & operation assumptions



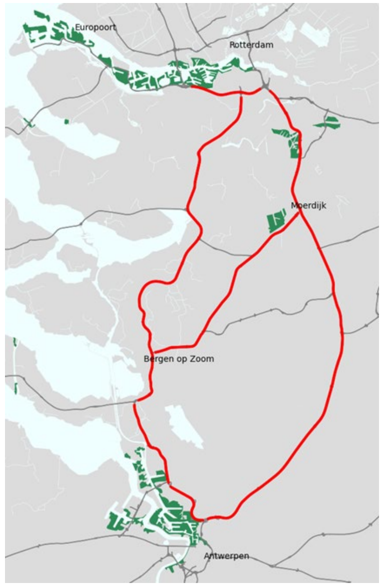
Scenarios

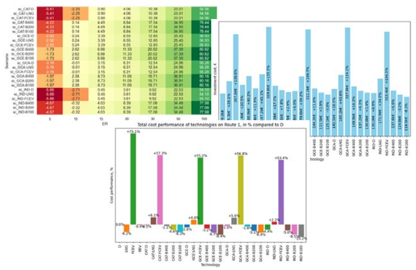
Segment-level calculation

- User costs: investment, energy, operation & maintenance
- ERS operator: investment, admin cost, operating cost & revenue, long distance & regional

Summarising

Corridor-level results

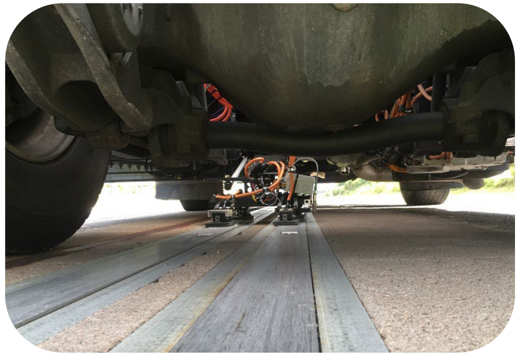




Inputs: Technologies

eHighway

Elonroad



Alstom

Electreon

Inputs: Technologies

Vehicle type	Energy		Investment, €	Energy consumption[1]		Operation & maintenance[1]	
	long distance	regional		long distance, kWh/km	regional, kWh/km	long distance, €/km	regional, €/km
D	D	D	129000[1]	2.46[1]	2.46[1]	0.143	0.143
LNG	LNG	LNG	174000[1,5,6]	2.78[1]	2.78[1]	0.143	0.143
FCEV	H2	H2	324000[3]	2.25[1]	2.25[1]	0.137	0.137
BEV800	GEL	GEL	163600[2]	1.42[4]	1.42[4]	0.126	0.126
BEV1200	GEL	GEL	190400[2]	1.42[4]	1.42[4]	0.126	0.126
CAT-D	CAT	D	152000[1,2]	1.51[4]	2.46[1]	0.107	0.143
CAT-LNG	CAT	LNG	197000[1,2,5&6]	1.51[4]	2.78[1]	0.107	0.143
CAT-FCEV	CAT	H2	347000[1,2,3]	1.51[4]	2.25[1]	0.107	0.137
CAT-B400	CAT	CATEL	159800[2]	1.51[4]	1.42[4]	0.107	0.126
CAT-B200	CAT	CATEL	146400[2]	1.51[4]	1.42[4]	0.107	0.126
CAT-B100	CAT	CATEL	139700[2]	1.51[4]	1.42[4]	0.107	0.126
GCE-D	GCE	D	144000[1,2]	1.51[4]	2.46[1]	0.107	0.143
GCE-LNG	GCE	LNG	189000[1,2,5&6]	1.51[4]	2.78[1]	0.107	0.143
GCE-FCEV	GCE	H2	339000[1,2,3]	1.51[4]	2.25[1]	0.107	0.137
GCE-B400	GCE	GCEEL	151800[2]	1.51[4]	1.42[4]	0.107	0.126

…

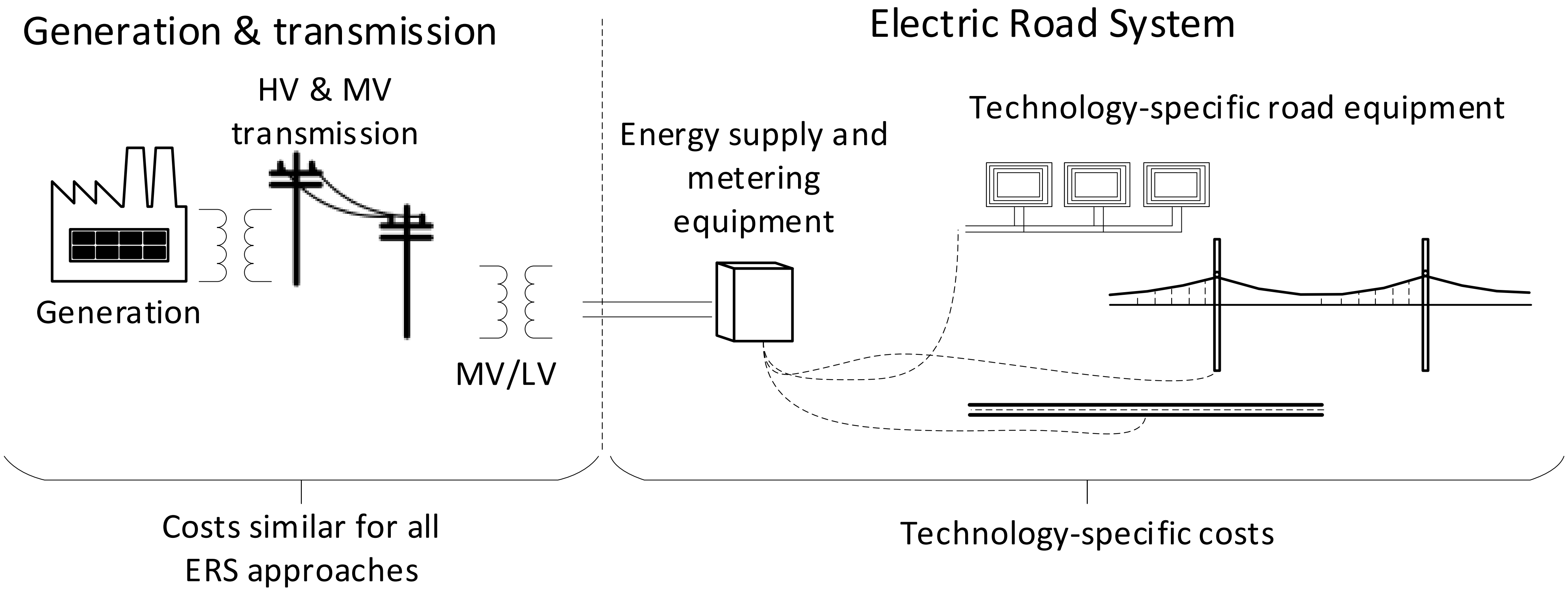
Sources: (1) Based on Gnann et al. (2017), operation and maintenance costs exclude driver wage and administrative overheads, (2) Estimation based on the following: 1) a hybrid truck without engine, battery and ERS equipment costs € 110 thousand; 2) eHighway pantograph system costs € 23 thousand, Elonroad mechanism system costs € 15 thousand, Alstom mechanism system costs € 21 thousand, and Electreon coils and electronics cost € 8 thousand; 3) battery costs 67 €/kWh in 2030 based on manufacturer and expert forecasts as summarised in Advanced Propulsion Centre UK (2021), (3) Gnann et al. (2017) and Transport & Environment (2020), (4) Movares (2020), (5) Smajla et al. (2019), (6) Mottschall et al. (2020).

Inputs: Energy price and cost, €/kWh

Energy	Cost	Price
D	-	0.149
LNG	-	0.082
H_2	-	0.248
GEL	-	0.20
[ERS]	0.08	0.22
[ERS]EL	0.08	0.22

Energy type abbreviations: D – diesel, LNG – Liquified/compressed natural gas, H_2 – hydrogen, [ERS]EL – electricity supplied by ERS operator (any technology) for use off the network, ERS – electricity supplied by ERS operator (any technology) for direct use on ERS network, GEL – grid electricity

Inputs: Infrastructure cost

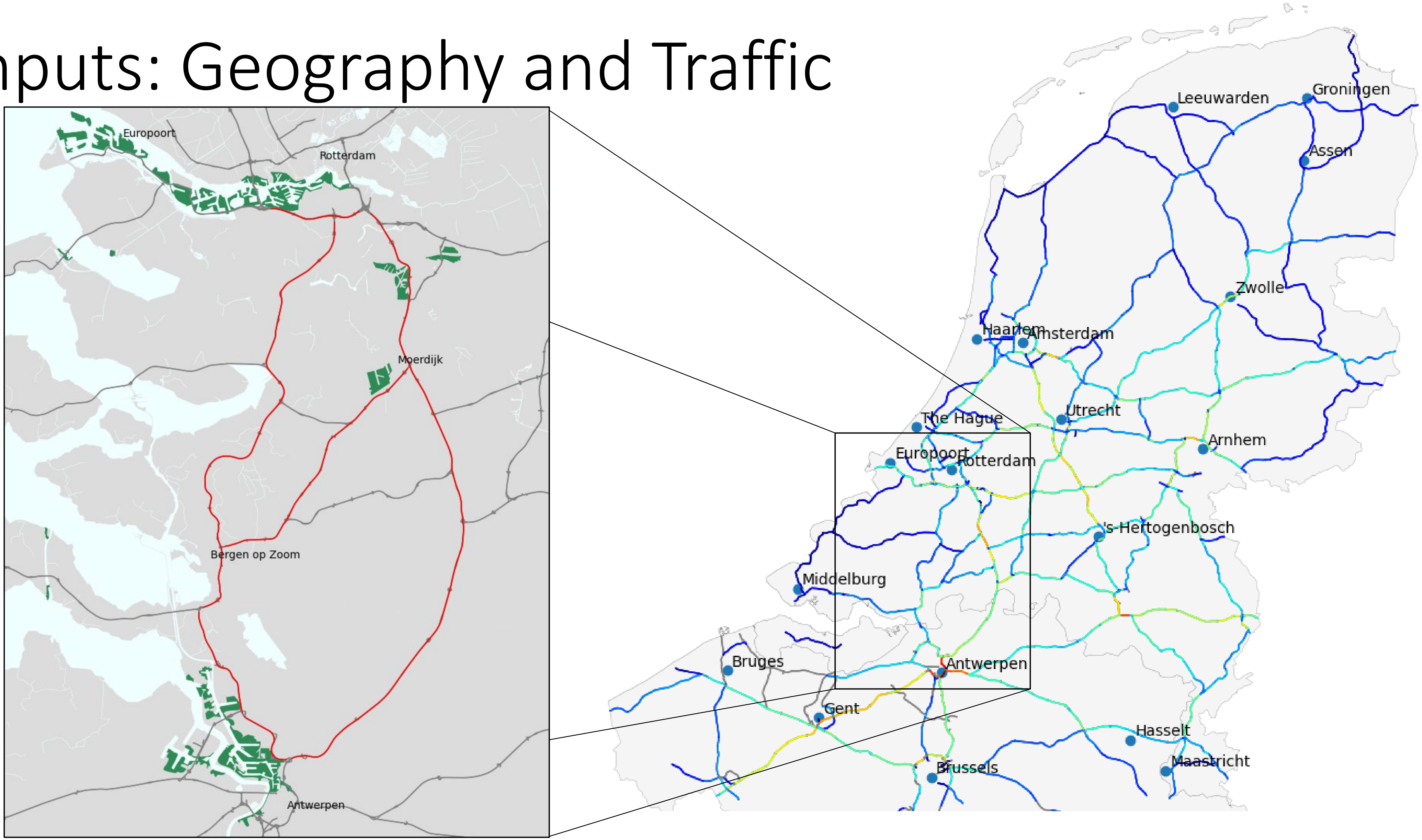


Inputs: Infrastructure cost depending on freight traffic volume and ERS coverage

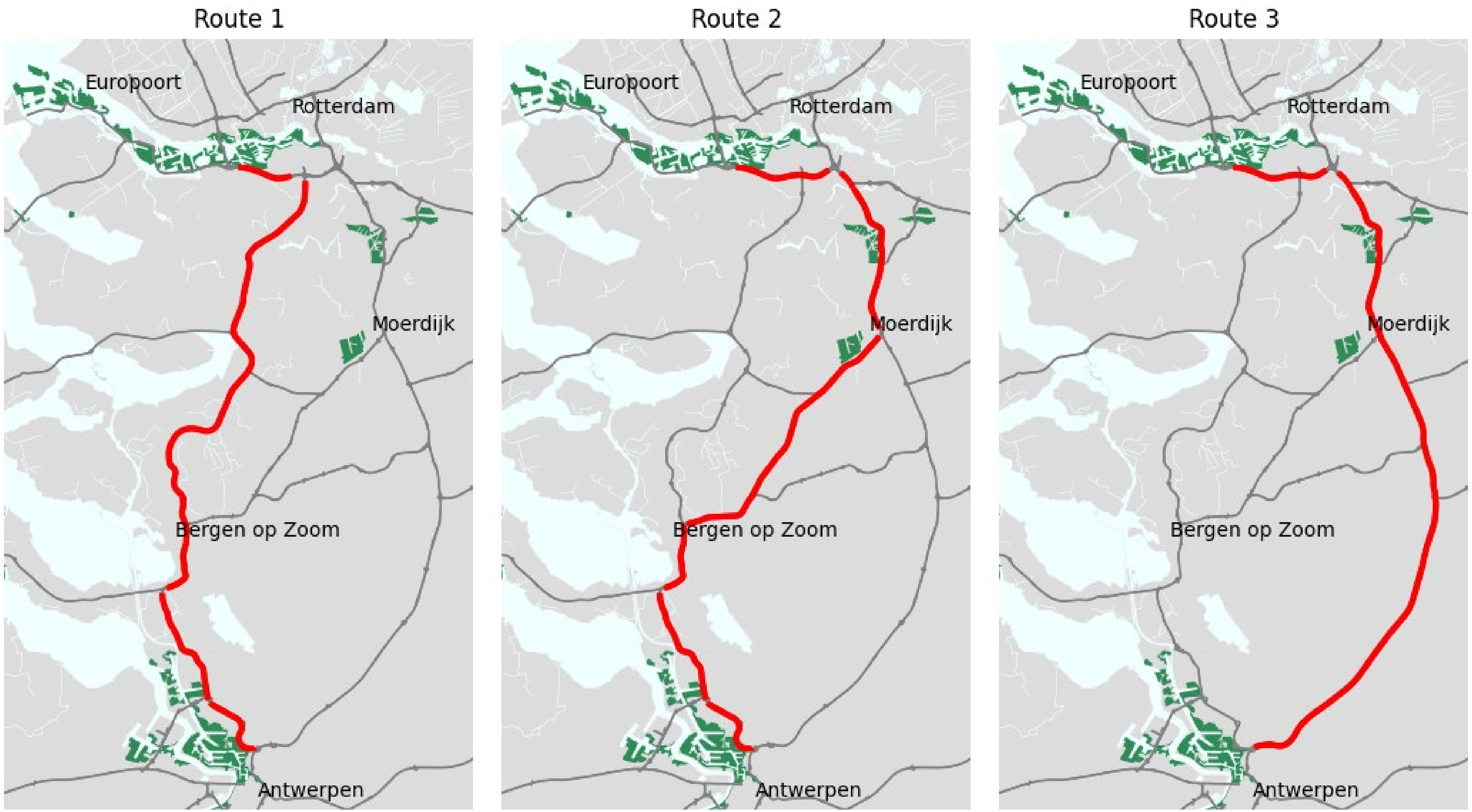
		ERS cost per km in one lane, million €			
Daily ERS traffic volume	**Power per electrified km, kW**	**CAT**	**GCE**	**GCA**	**IND**
< 2000	500	0.96	0.67	0.70	1.01
< 6000	1250	0.96	0.72	1.00	1.03
< 12000	2500	1.04	0.92	1.33	1.04
< 20000	4000	1.12	1.19	1.42	1.06
ERS coverage		80%	80%	40%	100%

CAT – eHighway catenary electric road system, GCE – Elonroad ground conductive, GCA – Alstom ground conductive, IND – Electreon ground inductive

Inputs: Geography and Traffic



Rotterdam - Antwerp corridor, selected routes

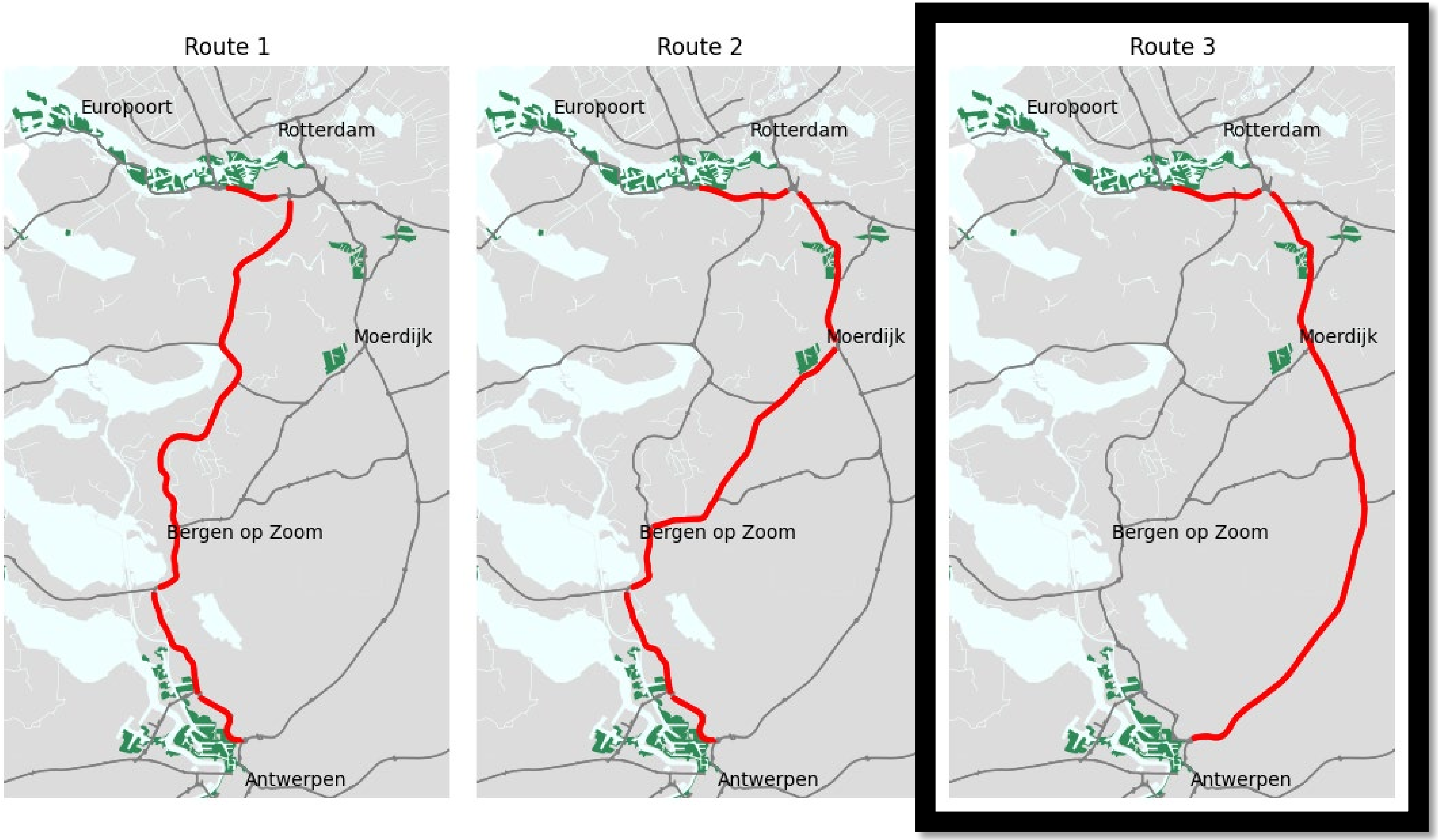


Modelled scenarios

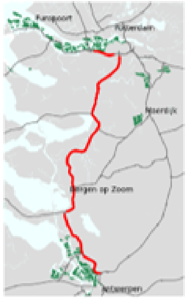
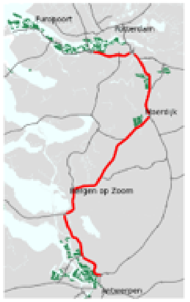
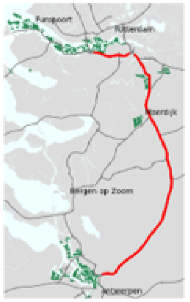
Scenarios	Technology adoption shares				
	D	LNG	FCEV	BEV-	CAT-, GCE-, GCA-, IND-
				800, 1200	D, LNG, FCEV, B400, B200, B100
BASE	99.76%	0.22%	0%	0.03%	0%
Single-technology scenarios	100% for simulated technology				
Introduction mix scenarios	99.76 - x%	0.22%	0%	0.03%	x = 5%, 10%, 15%, 20%, 30%, 40%, 50%

Abbreviations for heavy goods vehicle technologies: D – diesel, LNG – Liquefied/compressed natural gas, FCEV – fuel cell electric, BEV-xxxx – battery electric (index xxxx shows battery usable size in kWh), CAT-xxxx – eHighway catenary hybrid (xxxx shows the type of technology it is combined with), GCE-xxxx – Elonroad ground conductive hybrid, GCA-xxxx – Alstom ground conductive hybrid, IND-xxxx – Electreon ground inductive hybrid, index Bxxx for battery hybrid vehicles shows battery usable size in kWh.

Findings: The best route



Findings: Investment cost

Route	ERS technology	Optimal coverage	Investment cost range
Route 1 	CAT	80 %	167.2 – 167.8 m€
	GCE	80 %	117.4 – 120.3 m€
	GCA	40 %	122.3 – 133.4 m€
	IND	100 %	176.3 – 177.0 m€
Route 2 	CAT	80 %	180.5 - 181.6 m€
	GCE	80 %	126.8 - 131.0 m€
	GCA	40 %	132.0 - 145.8 m€
	IND	100 %	190.3 - 191.1 m€
Route 3 	CAT	80 %	172.7 - 174.8 m€
	GCE	80 %	121.3 - 128.0 m€
	GCA	40 %	126.3 - 143.7 m€
	IND	100 %	182.0 - 183.0 m€

Findings: Required use and network scale

- ERS operator profitability per adoption scenario, Route 3, m€

Scenario	5	10	15	20	30	50	100
sc_CAT-D	-3.51	1.83	7.17	12.51	23.19	44.55	97.84
sc_CAT-LNG	-3.51	1.83	7.17	12.51	23.19	44.55	97.84
sc_CAT-FCEV	-3.51	1.83	7.17	12.51	23.19	44.55	97.84
sc_CAT-B400	-2.20	4.45	11.09	17.74	31.03	57.61	123.97
sc_CAT-B200	-2.20	4.45	11.09	17.74	31.03	57.61	123.97
sc_CAT-B100	-2.20	4.45	11.09	17.74	31.03	57.61	123.97
sc_GCE-D	-0.94	4.40	9.74	15.07	25.70	47.04	100.17
sc_GCE-LNG	-0.94	4.40	9.74	15.07	25.70	47.04	100.17
sc_GCE-FCEV	-0.94	4.40	9.74	15.07	25.70	47.04	100.17
sc_GCE-B400	0.37	7.02	13.66	20.30	33.54	60.10	126.30
sc_GCE-B200	0.37	7.02	13.66	20.30	33.54	60.10	126.30
sc_GCE-B100	0.37	7.02	13.66	20.30	33.54	60.10	126.30
sc_GCA-D	-1.19	4.15	9.49	14.79	25.15	46.42	99.39
sc_GCA-LNG	-1.19	4.15	9.49	14.79	25.15	46.42	99.39
sc_GCA-FCEV	-1.19	4.15	9.49	14.79	25.15	46.42	99.39
sc_GCA-B400	0.12	6.77	13.41	20.01	32.99	59.48	125.52
sc_GCA-B200	0.12	6.77	13.41	20.01	32.99	59.48	125.52
sc_GCA-B100	0.12	6.77	13.41	20.01	32.99	59.48	125.52
sc_IND-D	-3.97	1.37	6.70	12.04	22.70	44.05	97.43
sc_IND-LNG	-3.97	1.37	6.70	12.04	22.70	44.05	97.43
sc_IND-FCEV	-3.97	1.37	6.70	12.04	22.70	44.05	97.43
sc_IND-B400	-2.67	3.98	10.62	17.27	30.54	57.11	123.56
sc_IND-B200	-2.67	3.98	10.62	17.27	30.54	57.11	123.56
sc_IND-B100	-2.67	3.98	10.62	17.27	30.54	57.11	123.56

ERS adoption on Route 3, %

- Implementation of ERS on a small scale is sub-optimal

Findings: Factors influencing ERS operator profitability

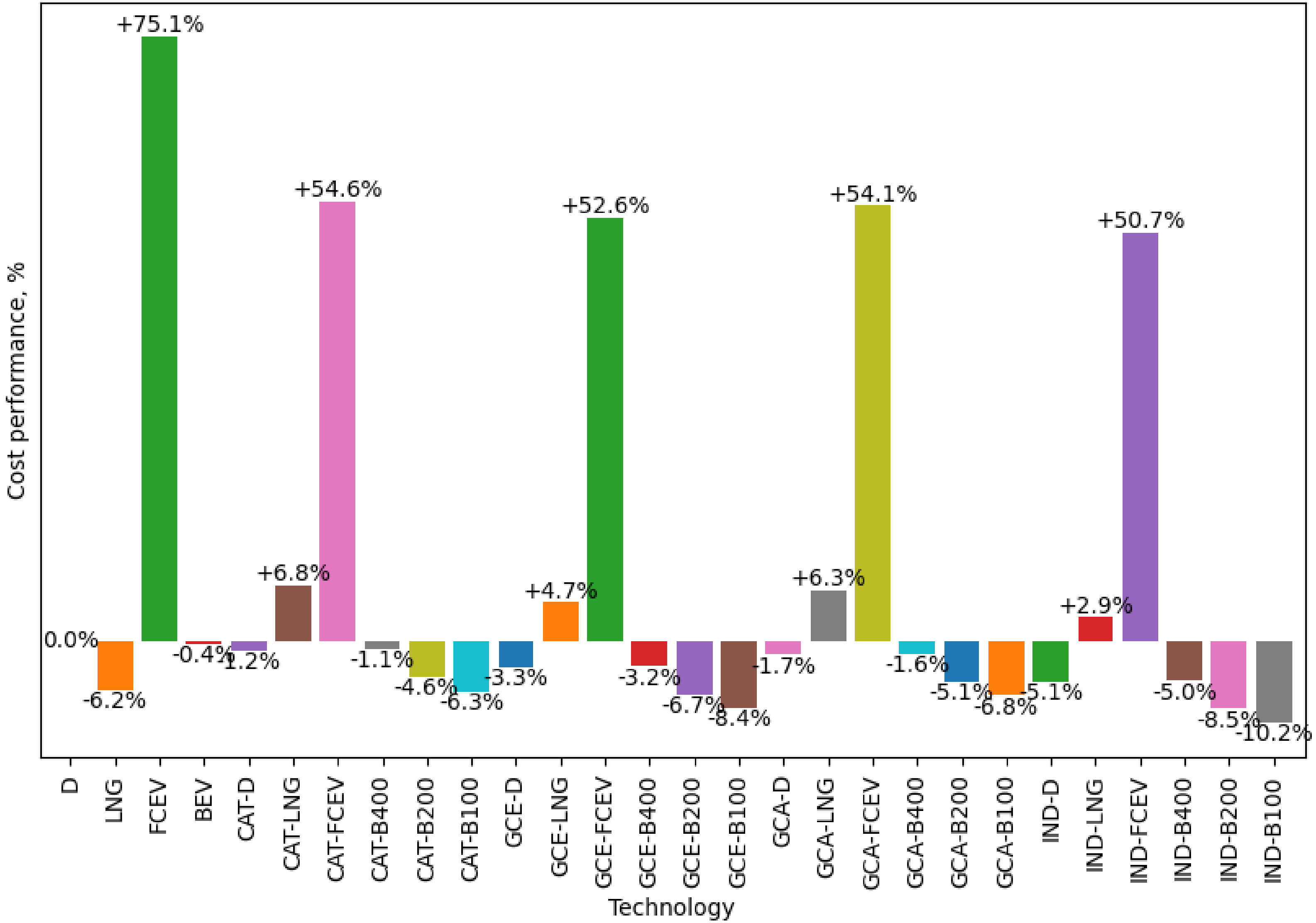
Break-even of the investment and operation of ERS infrastructure depends on two factors:

- the electricity sale price
- the technology adoption level

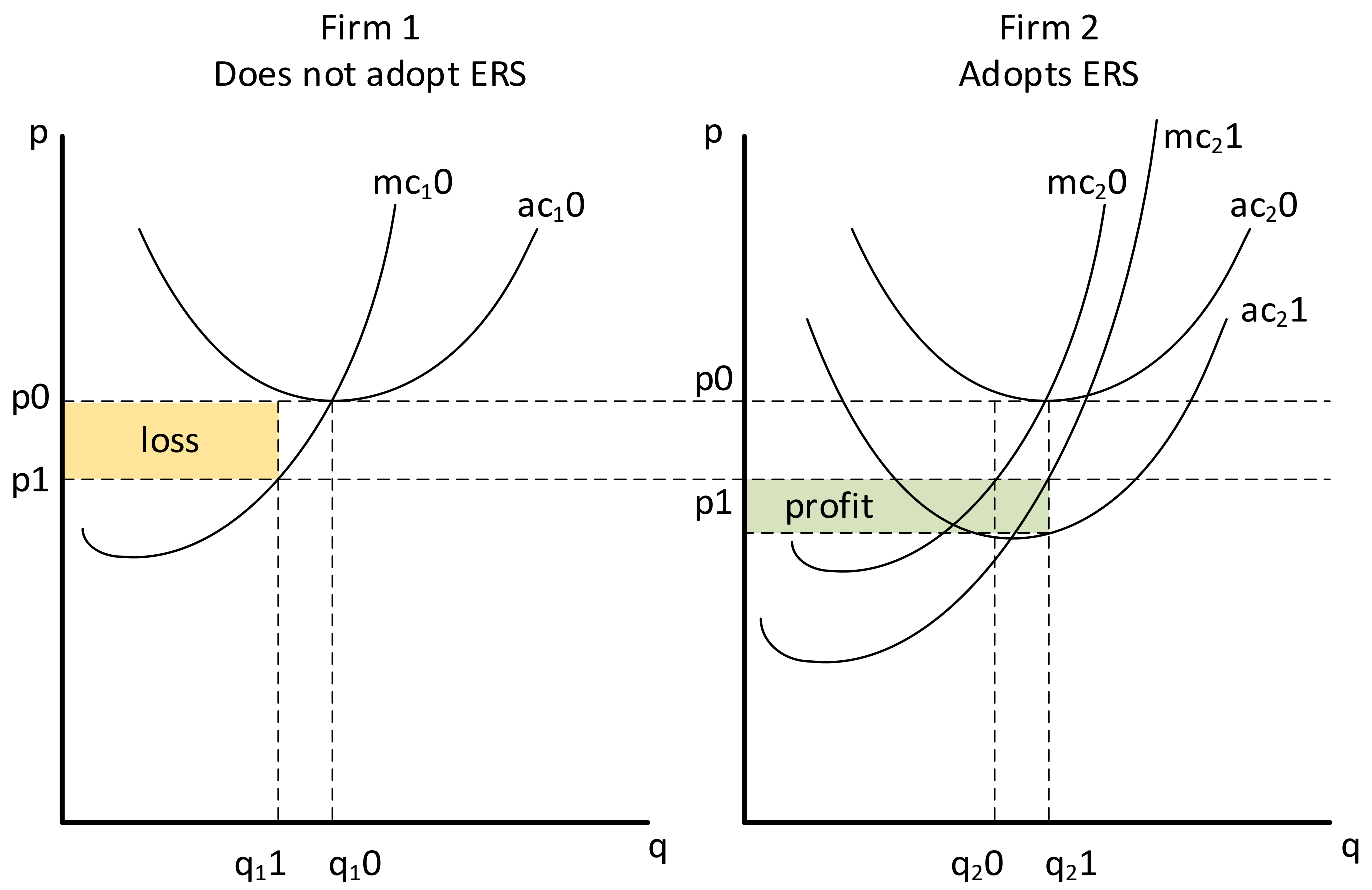
- Scenarios where ERS is adopted with a technology that uses fuel (D, LNG or FCEV) are not as profitable for the operator as the ones where ERS is used in conjunction with a battery

Findings: Advantages for road freight operators

Total cost performance of technologies on Route 3 for road freight transport operators, in % compared to D

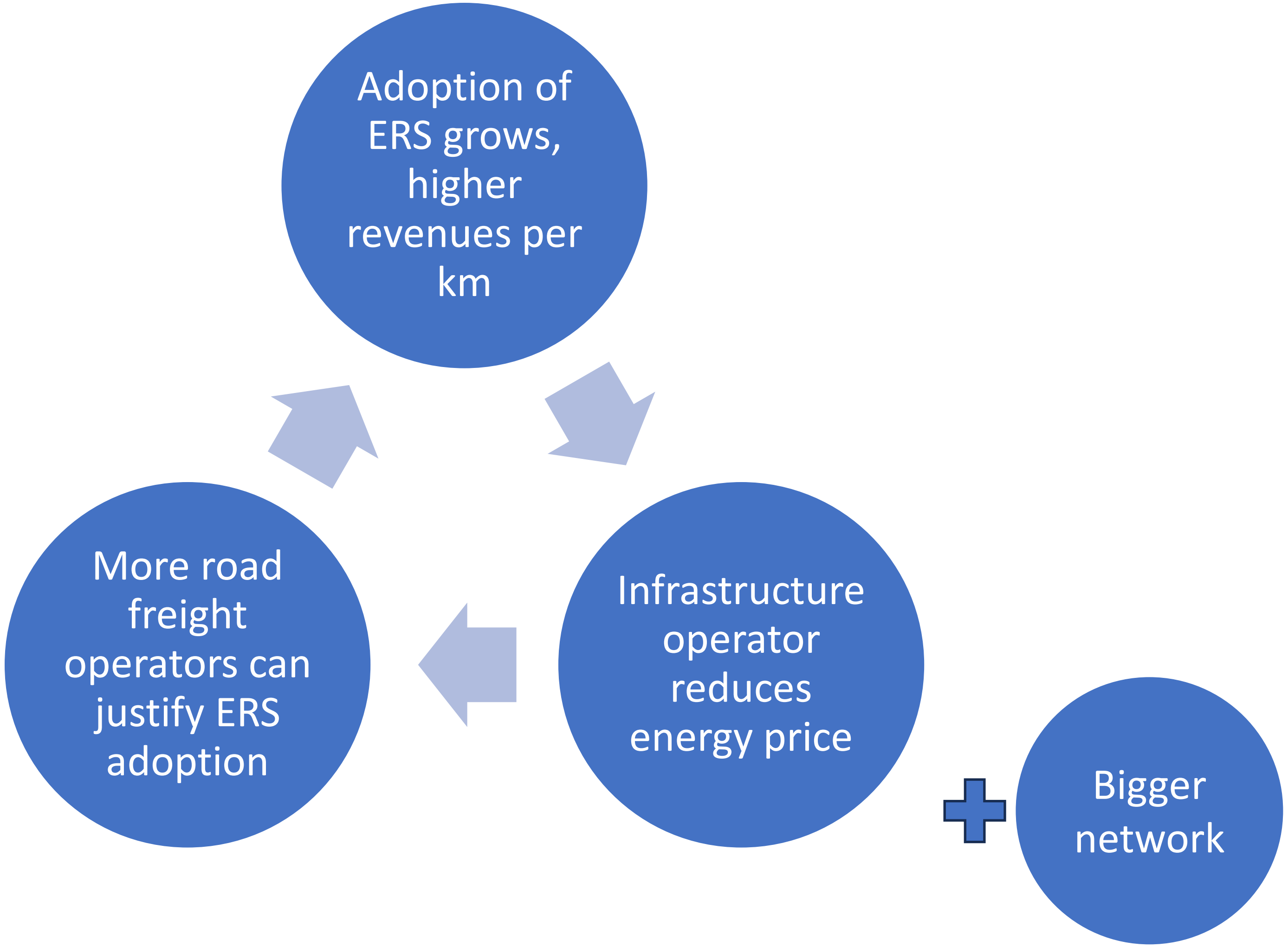


Findings: Early adopter advantages



p – price, q – quantity, mc – marginal cost curve, ac – average cost curve, 0 – equilibrium before technological change, 1 – equilibrium after technological change

Findings: Potential for a flywheel effect



Findings: The best ERS technology

- Economic analysis is not sufficient to identify the best ERS technology
- It cannot be claimed that lower costs make a technology superior
- Other ERS technology performance characteristics should be considered:
  - power transfer capability
  - longevity
  - vehicle equipment cost and performance characteristics
  - other operational characteristics and issues
  - etc.
- The best ERS is one that will be built


Questions?