



INFRABEL

Alternatives for railway electricification

**UIC Best Practice Workshop – The end
of fossil fuels in the railway sector**

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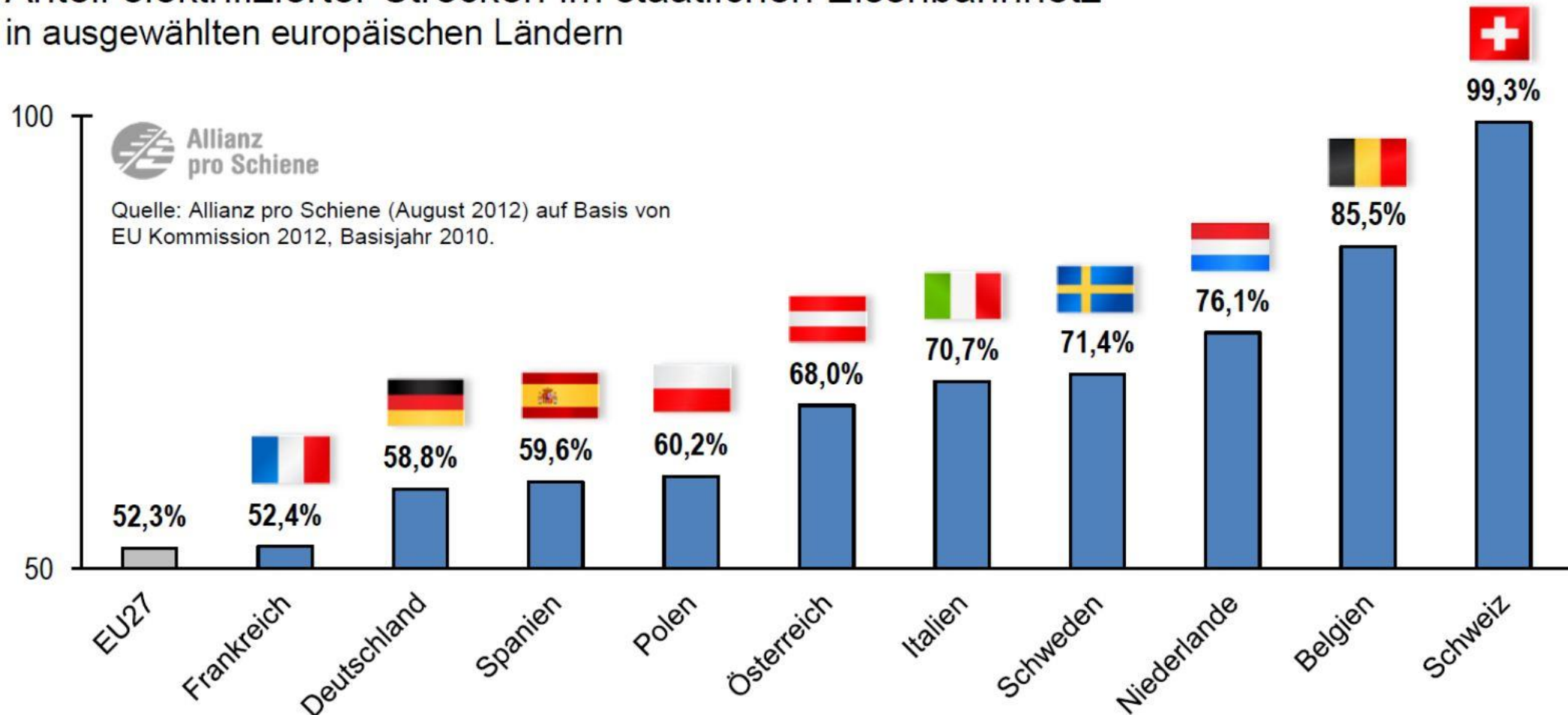


1. Comparison of EMU, DMU, BEMU, FC-trains



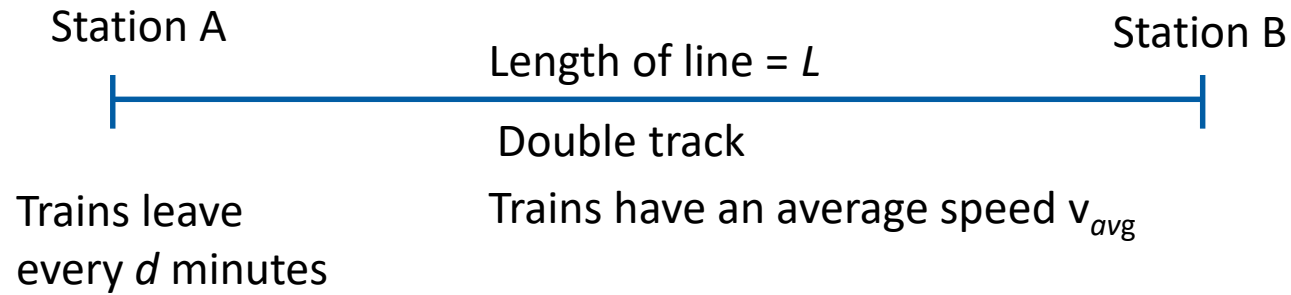
Railway electrification in Europe

Anteil elektrifizierter Strecken im staatlichen Eisenbahnnetz
in ausgewählten europäischen Ländern



Comparison of costs for alternatives for railway electrification

Topology:



Type of
transportation:

Freight transportation

Mainline locomotives

Passenger transportation

Multiple
units

Mainline
locomotives

Shunters

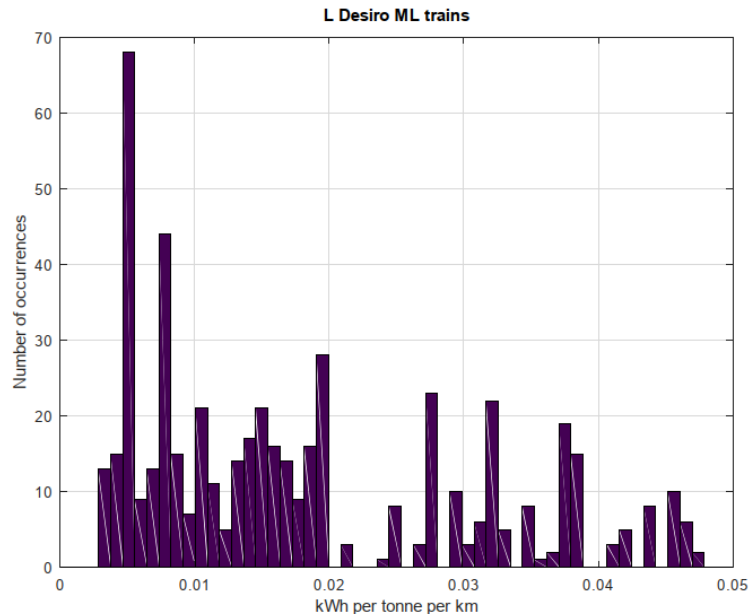
Locomotives

- DMU
- EMU
- BEMU
- FC-trains

Take multiple unit trains of 3 units (190 tonnes).
Reason: Talent 3 BEMU has 3 units, Coradia iLint FC-train has 2 units. Belgian railways use Desiro EMUs.

Consumption of energy

- Reference is a 3-unit EMU
- FC-train: consumption is $3/2 \times 0.28 \text{ kgH}_2/\text{km}$ where $0.28 \text{ kgH}_2/\text{km}$ is the consumption of the 3-unit Coradia iLint FC-train
- DMU: 1.2 liter/km
- EMU: 0.025 kWh/(t.km)
- BEMU: $0.025 \text{ kWh}/(\text{t.km}) / (\eta_{\text{charge}} \eta_{\text{discharge}})$ with $\eta_{\text{charge}} = 0.95$ and $\eta_{\text{discharge}} = 0.85$



Infrabel simulations
For 650+ Siemens Desiro
3-unit EMUs (L-trains:
stop-trains)

Furthermore: CO2-emissions

- EMU and BEMU: 0,231 kgCO₂/kWhe (Belgian electricity mix)
- DMU: 2,9802 kgCO₂/l (UIC Code 330)
- FC-train: uses electricity from an equal share of solar (27 gCO₂/kWhe) and wind (11 gCO₂/kWhe)

Unit costs of investments

See accompanying Excel-file for references and explanation

FC-trains:

Component	Unit cost	Number of components	Lifetime
PEM-electrolyser (incl. water purification) – 60 % efficiency	2600 \$/kWe	1	50.000 h
Storage tank for hydrogen	10,000 \$/MWhH ₂	1	20 y
Filling system	0.8 M\$/device	1	10 y
Compressor 180 bar	70 \$/kWhH ₂	2	20 y
Compressor 700 bar	300 \$/kWhH ₂	2	20 y
FC-train	7.5 M€	8	30 y
Pipelines, meters, controllers, electric wiring...	10 % of the cost of the stationary components	1	30 y

DMU-trains:

Component	Unit cost	Number of components	Lifetime
DMU	4.5 M€	8	30 y
Stationary diesel infrastructure	10 % of the DMU-cost	1	20 y

EMU-trains:

Component	Unit cost	Number of components	Lifetime
EMU	4.5 M€	8	30 y
Traction substations	3.5 M€	Vision Infrabel: Every 10 km a small traction substation (for the 3 kV grid)	40 y
Catenary	1 M€/km (for double tracks)	Length of line	60 y

BEMU-trains:

Component	Unit cost	Number of components	Lifetime
BEMU	6.5 M€	8	30 y
Traction substations	5 M€ (Big Ssts: cfr Talent 3 BEMU: 440 kWh charged in 10 minutes → 2.6 MW)	A Sst for each charging “island”, plus one in each end station	40 y
Catenary	1 M€/km (for double tracks)	Length of line	60 y

Charging islands?

Bombardier Talent3 BEMU: can ride 40-100 km on its battery; battery can be charged in 7-10 minutes while driving. Therefore the following concept:

In the end stations:
point charging:
300 m charging roster.
Probably rail catenary
due to high currents.
Assumption: 300 m rail
cat. costs as much as 1
km normal cat.

Charging ‘island’: length = 10 minutes
Powered by 1 large (powerful) substation

Station A

Distance between islands = 60 kms

Station B

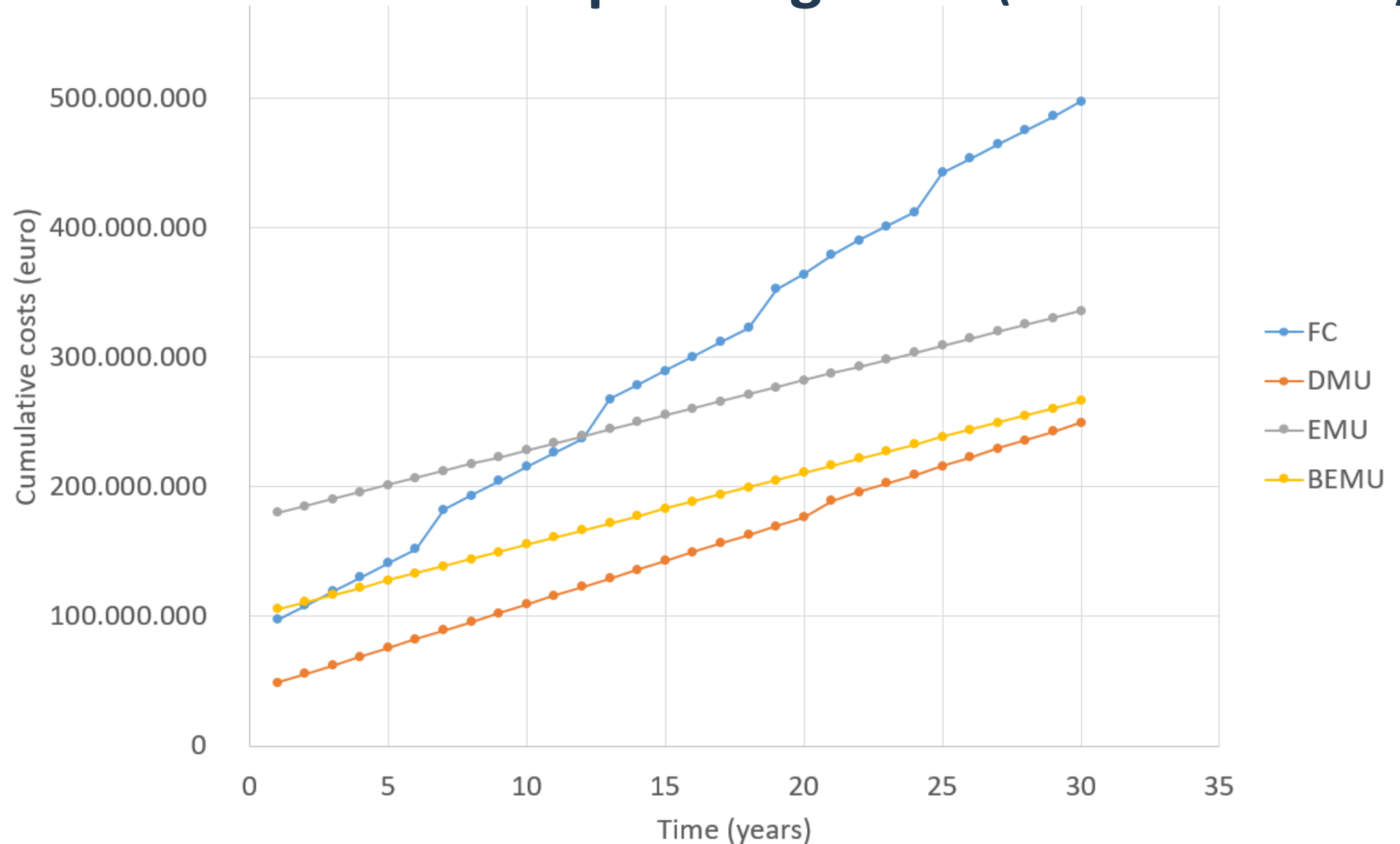
Distance between first island and end station = 30 kms

OPEX costs

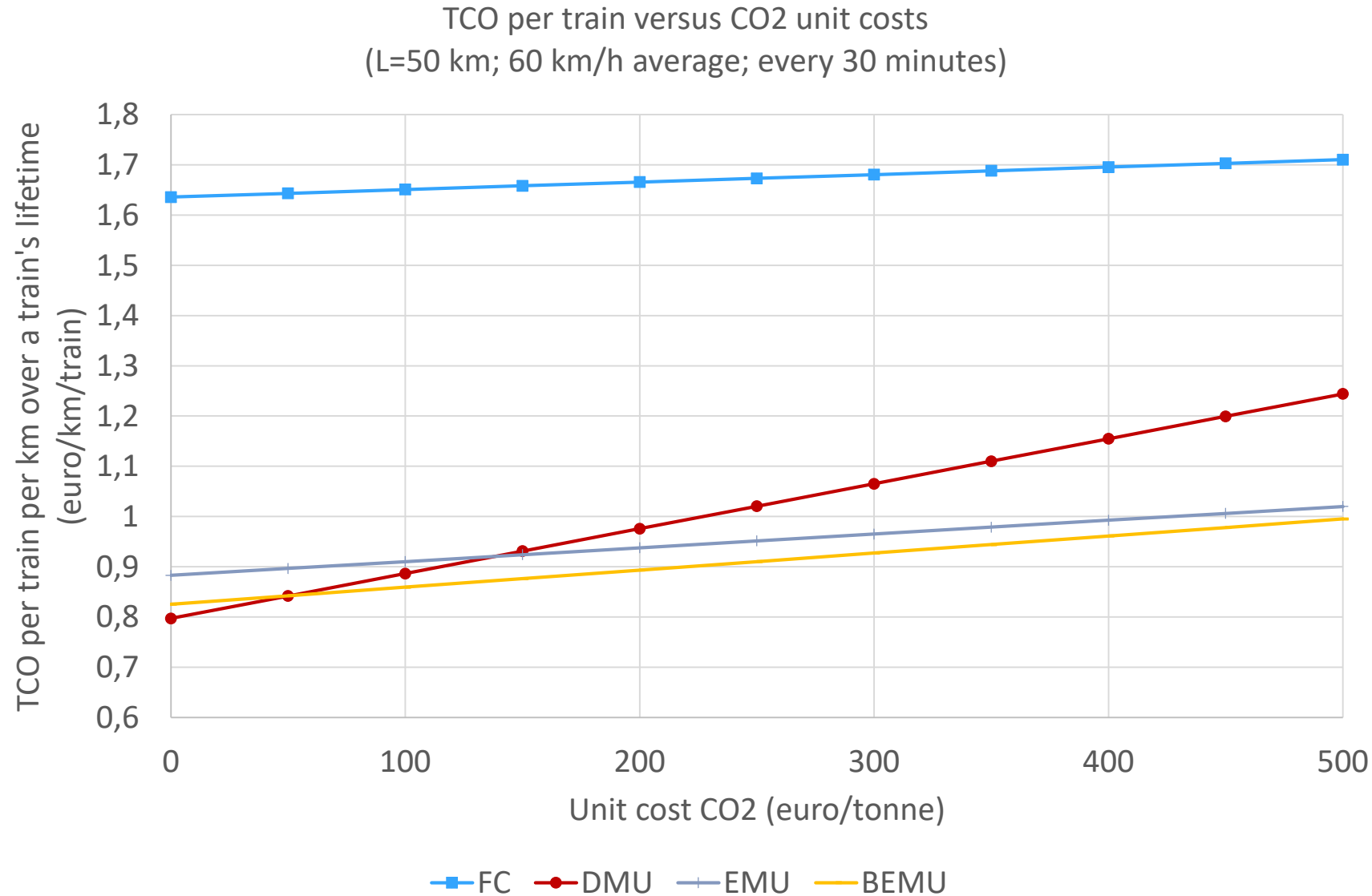
1. Comparison of EMU, DMU, BEMU and FC-trains

	For all technologies	FC-trains	DMU	EMU	BEMU
Unit cost labor	50,000 €/y/FTE				
Unit cost electricity	80 €/MWh				
Unit cost diesel			0,7 €/l		
Unit cost water		2,71 €/m ³			
Cost of CO2:	220 €/tCO2				
Cost of maintenance of trains		For 1 train: 0,72 €/km	For 1 train: 0,79 €/km	For 1 train: 0,4 €/km	For 1 train: 0,56 €/km
Cost of maintenance of stationary installations		180,000 €/y	10,350 €/y		
Cost of maintenance of traction sst				38,300 €/y	38,300 €/y
Cost of maintenance of catenary				2,800 €/km/ intervention	2,800 €/km/ intervention

Results: investments and operating costs (without CO2-cost)



Results: variation of CO2 unit cost



Possible to use hydrogen in internal combustion engines instead of fuel cells?

- Cheaper than a FC of the same power rating
- More established technology; less complex
- Size: scale advantages with increasing power. FCs scale linearly with increasing power. → internal combustion engines are ideal for freight trains
- If an alarm occurs → stop H₂ combustion and switch back to diesel fuel
- H₂ internal combustion engines don't need very pure H₂ while PEM-FCs need highly purified hydrogen

Example: dual fuel (H₂ and diesel) internal combustion engine developed by Anglo-Belgian Corporation & Compagnie Maritime Belge

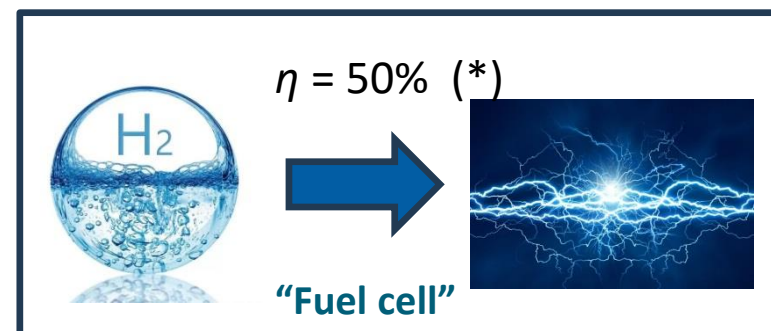
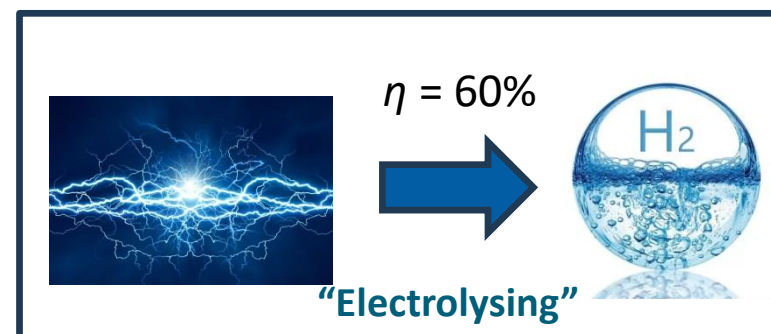
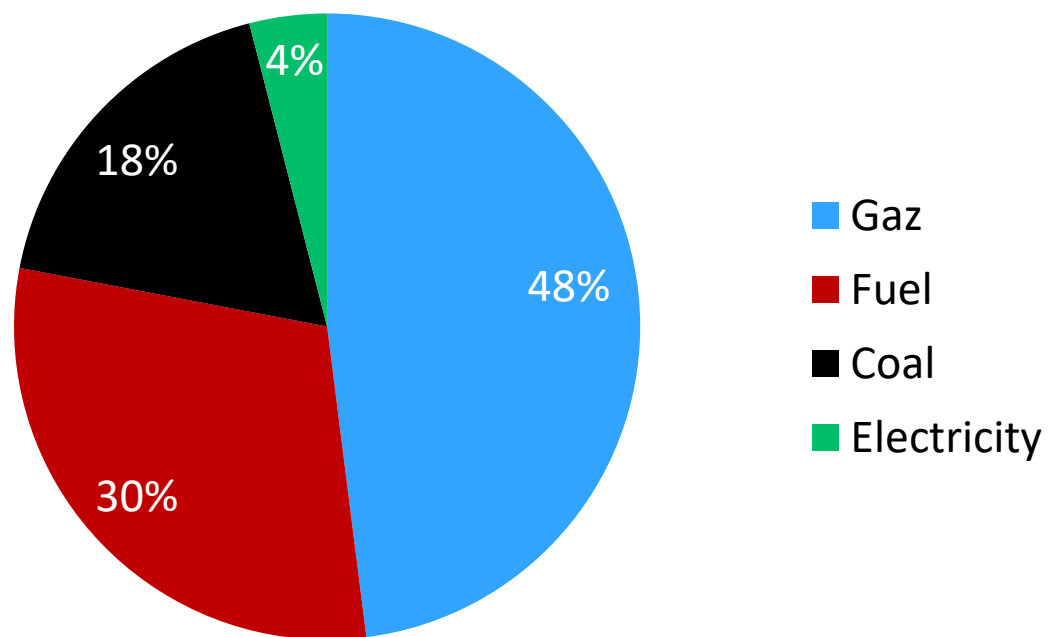
- Based on DZ-series of diesel internal combustion engine
- 65-85% H₂, rest is diesel (%: on an energy basis)
- 0.7 – 2.8 MW
- 6 – 8 liter, V12 and V16
- H₂ is injected at 10 bar in the cylinder

2. Infrabel and hydrogen



Hydrogen?

Production of hydrogen - world



Hydrogen?



Reduce Own Diesel Consumption



Better use of grid connections



Avoid expensive electrifications



- Start with some vans
- Try with a shunting locomotive?
- Own filling station?

2. Infrabel and hydrogen

Hydrogen?



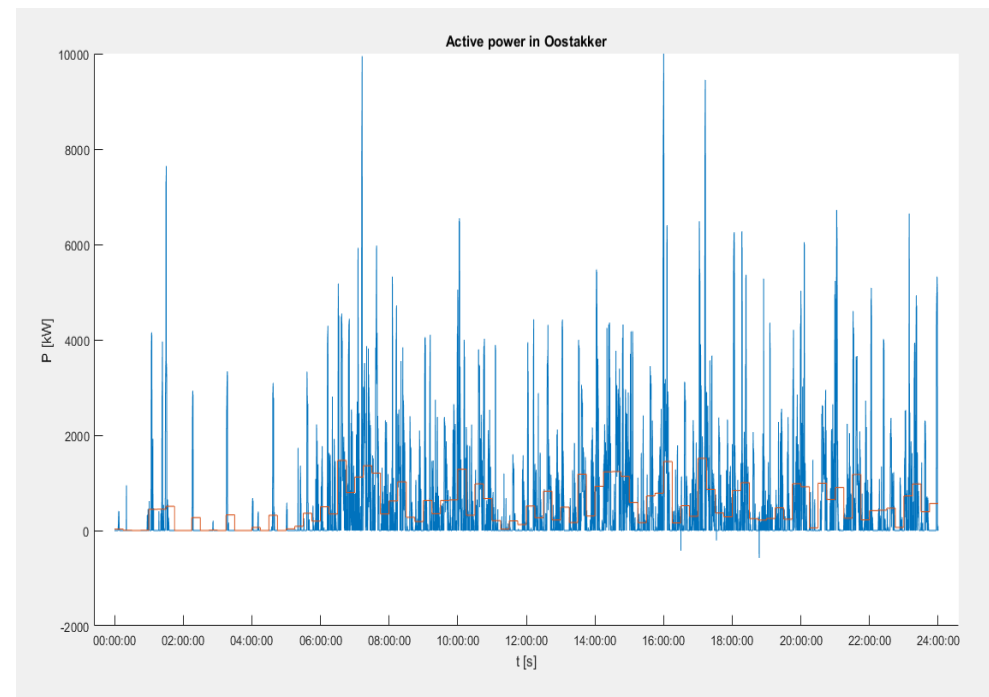
Reduce Own Diesel Consumption



Better use of grid connections



Avoid expensive electrifications



- Decrease ratio
(peak power)/(mean power)
- Own production of H₂
- At low marginal cost?



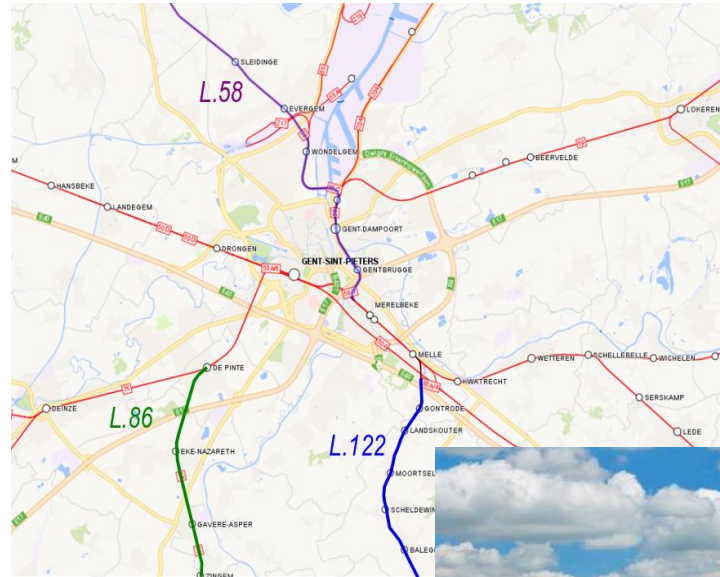
Reduce Own Diesel Consumption



Better use of grid connections



Avoid expensive electrifications

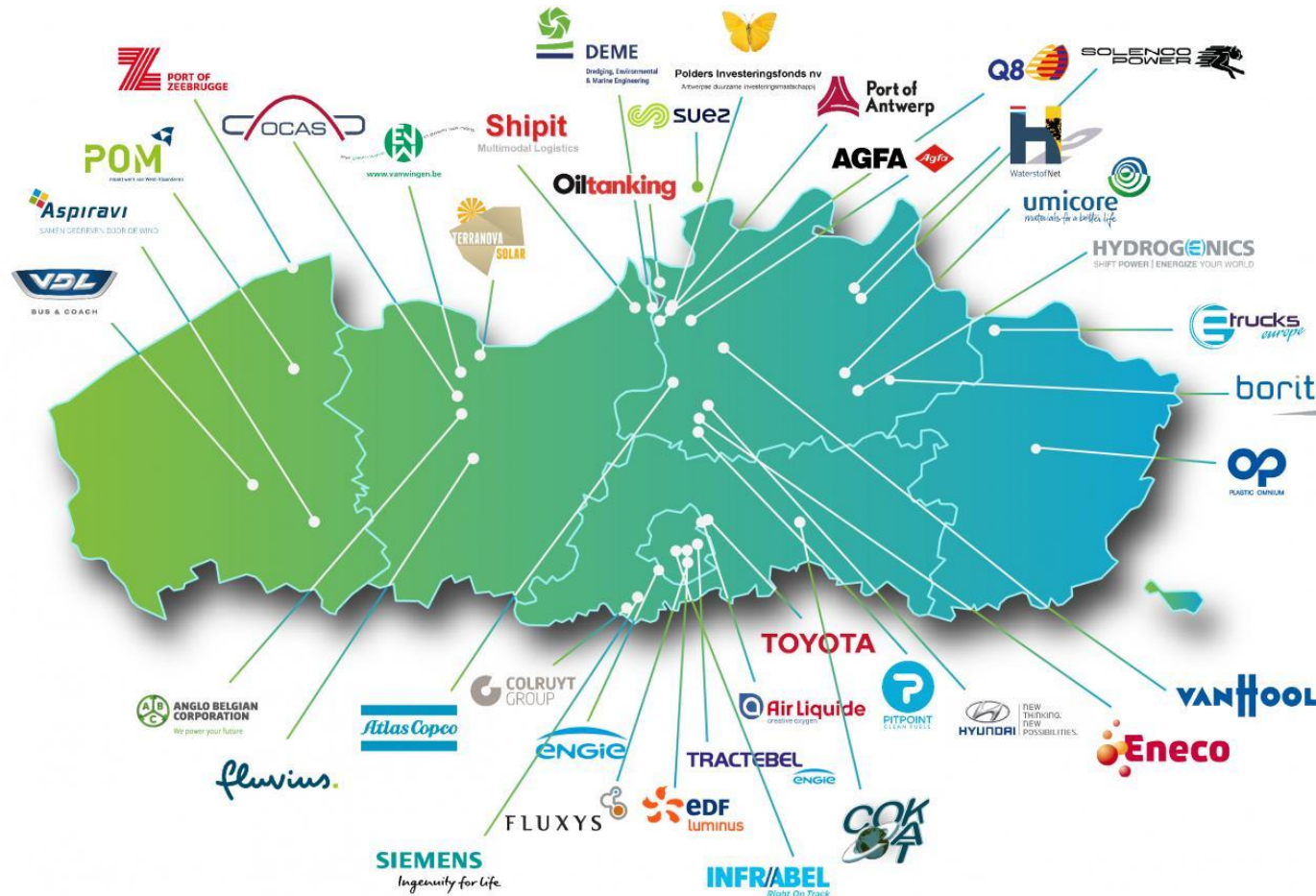


- Only 8% not electrified
- Trade-off in function of traffic
- Overhead lines more efficient
- Supply own H2 to trains?

Example of what could be...



Infrabel is member of Power2Gas-cluster





Thanks for your attention!
Questions?

