Fuel Cell Technology for Rail

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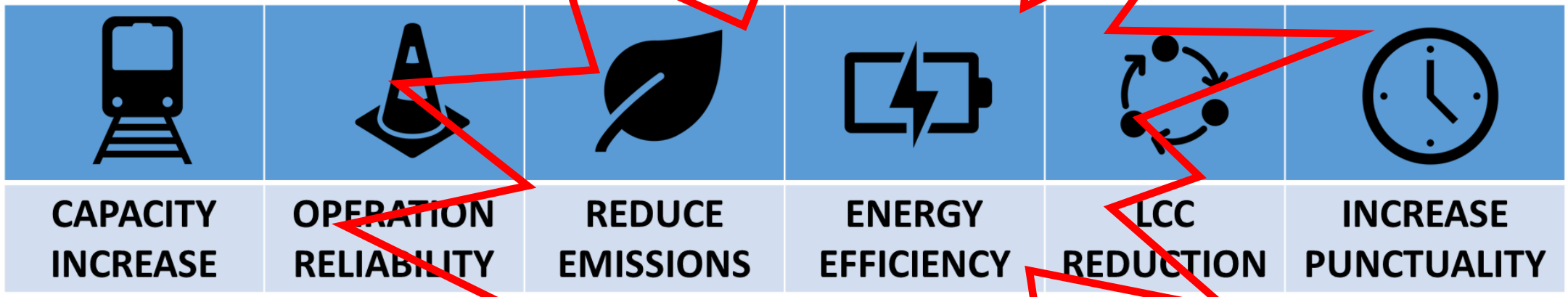
S2R: an Integrated R&I Programme

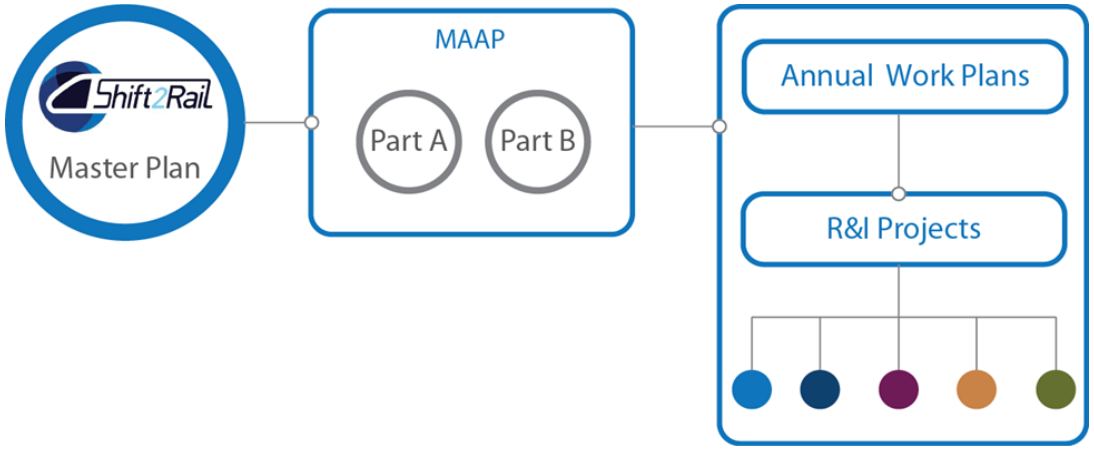


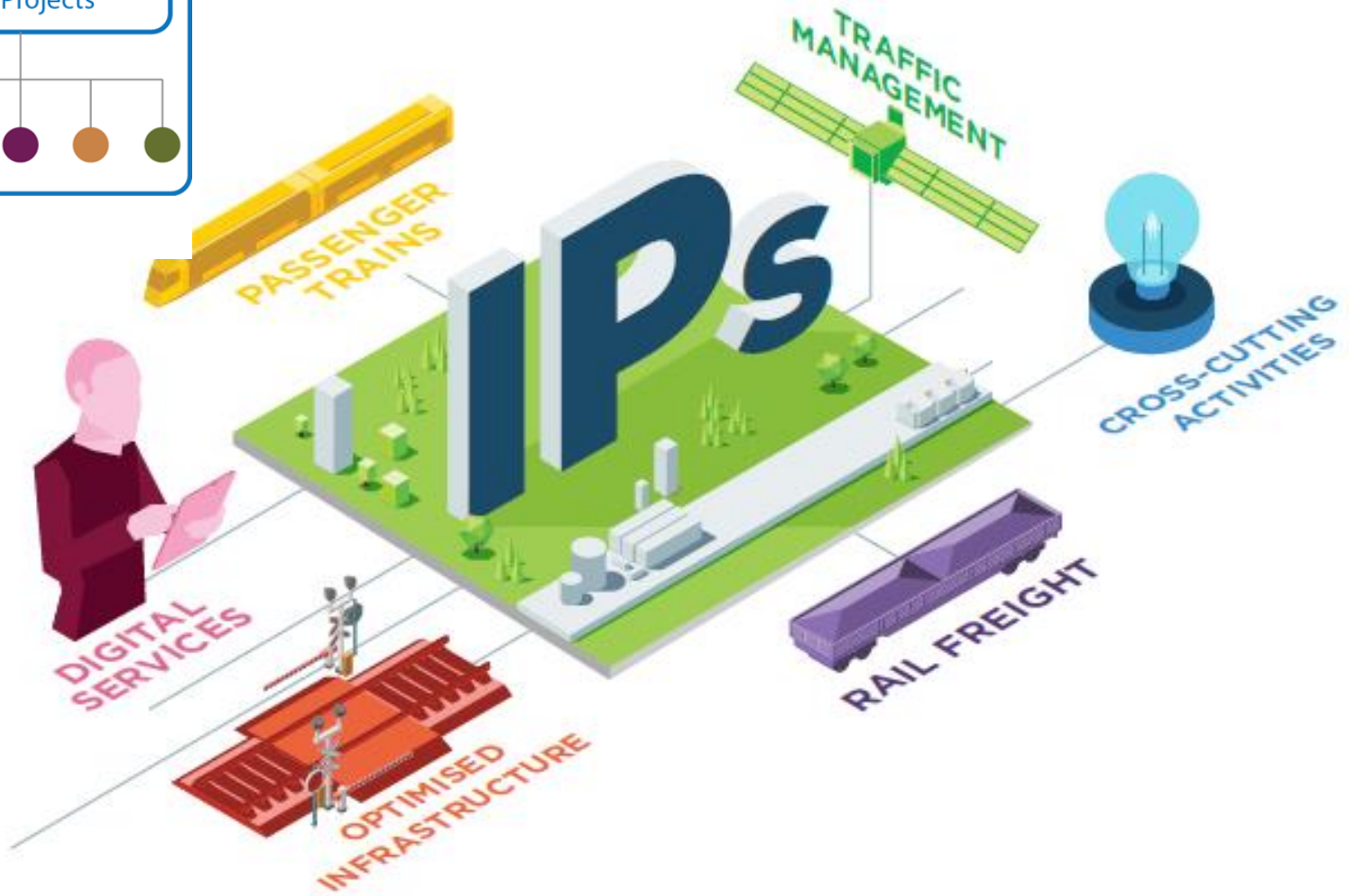
Contributing to the achievement of the Single European Railway Area (SERA)

AN OPEN and ACTIVE ORGANISATION

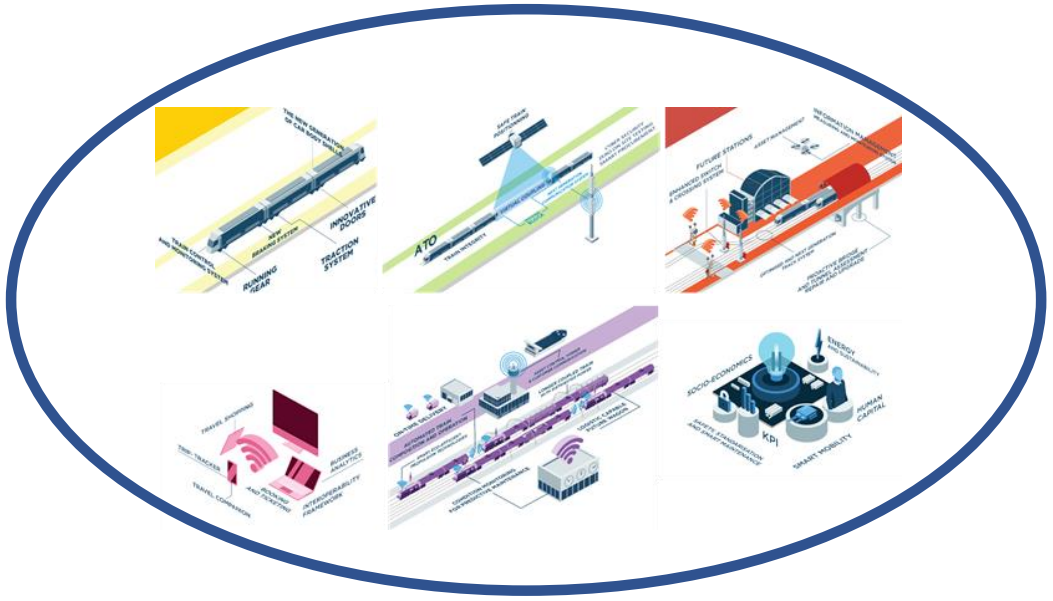
…opening up new Capabilities coming from emerging technologies or concepts!

The S2R Programme implementation





IPx: Functional System Architecture



Functional System Architecture

mastering complex systems to deliver value to the customers

Ongoing Activities

- autonomous railway vehicles “train-centric”
- disruptive technologies
- industry 4.0 (automated industry and industry as a service), railway clouds and decentralised ownership
- A.I. for railways Digital solutions

S2R System Architecture and Conceptual Data Model

1. comprehensive model/architecture, technologies and strategy for implementation of a new encompassing railway system approach
2. aligning all ongoing modelling initiatives in terms of modelling principles and digital data integration

Objectives

1. Improve operational efficiencies
2. Adapting to game changers
3. Sustainable business models

Study focus applications

- We analysed the potential of fuel cell and hydrogen technology for rail transport for three application areas
- Most activity visible in multiple unit application area (products already being launched
- First insights suggest attractive use cases and good market potential

Multiple units

- Passenger operation in regional transport
- First FCH trains in operations since September
- up to 1,000 km[1)]
- up to 140 km/h
- 30 years

Shunters

- Shunting and short distance operation
- ?
- 200-1,000 km[1)]
- up to 50 km/h
- 35 years

Mainline Loco-motives

- Med. + long distance freight + passenger service
- ?
- 500-1,100 km[1)]
- up to 120 km/h
- 30 years

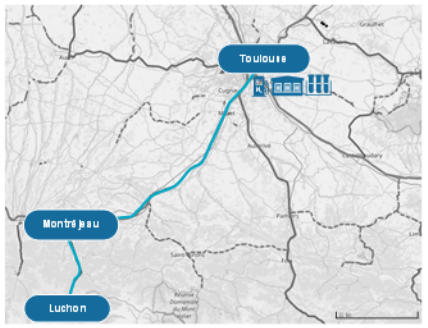
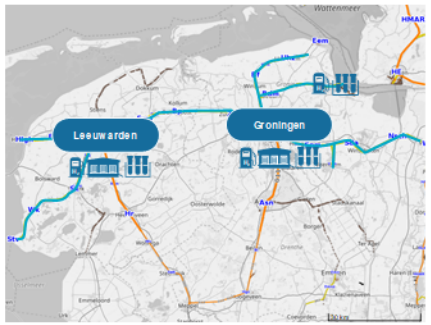
1) Depending e.g. on # cargo/passengers, stops and topography

Application | Maturity of technology | Range | Speed | Lifetime | Market entry

Source: Alstom, ÖBB, Roland Berger

Multiple Unit Case Studies

Overview of route specifications

	Montréjeau – Luchon, France	Aragon, Spain	Groningen & Friesland, Netherlands
			
Track length	140 km	165 km	300 km
Rolling stock	3x 4 car trains (bi-mode)	2x 4 car trains (bi-mode)	70x 3 car trains
H_2 consumption	0.36 kg/km	0.31 kg/km	0.22 kg/km
	245 kg/day	240 kg/day	16,500 kg/day
Total CAPEX	EUR 25 m	EUR 14 m	EUR 398 m
Characteristics	Partly electrified route with a low utilisation on 36 km	Cross border connectivity and long route without electrification	Fast trains for intercity connections

Total cost of ownership [EUR/km_{train}]

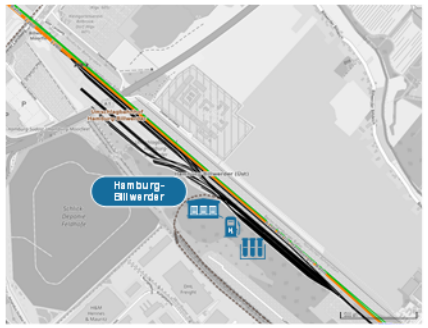
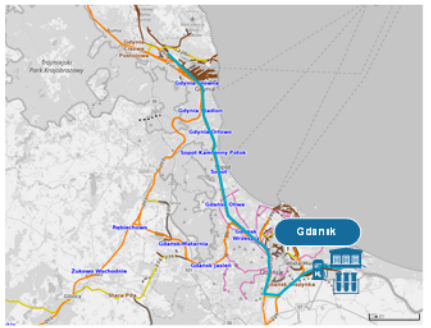
Diesel	18.5	9.3	4.8
FCH	**21.2**	**12.4**	**5.0**
Catenary	27.5	22.6	4.5
Battery	19.9	13.7	5.3

Environmental analysis

CO_2 savings [tons per year]	1,334 t	767 t	56,389 t

Source: Market research, Expert interviews, Roland Berger

Shunter Case Studies

	Hamburg-Billwerder, Germany	Riga Node, Latvia	Gdansk, Poland
Overview of route specifications			
Track length	10 km	100 km	35 km
Rolling stock	15 Shunters	15 Shunters	10 Shunters
H_2 consumption	0.39 kg/km	0.49 kg/km	0.72 kg/km
	480 kg/day	850 kg/day	180 kg/day
Total CAPEX	EUR 40 m	EUR 29 m	EUR 21 m
Characteristics	Shunting yard in a large urban area and next to Hamburg port	Shunting operation between several port terminals	Marshalling yard in collocation of the refinery supplying hydrogen

Total cost of ownership [EUR/km_{train}]

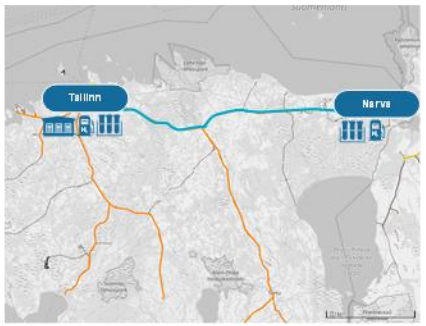
	Hamburg-Billwerder, Germany	Riga Node, Latvia	Gdansk, Poland
Diesel	10.1	20.9	32.1
FCH	**12.9**	**20.4**	**36.7**
Catenary			
Battery	11.7	21.8	36.9

Environmental analysis

	Hamburg-Billwerder, Germany	Riga Node, Latvia	Gdansk, Poland
CO_2 savings [tons per year]	1,969 t	3,350 t	339 t

Source: Market research, Expert interviews, Roland Berger

Mainline Locomotive Case Studies

	Tallinn – Narva, Estonia	Frankfurt (Oder) – Hamburg, Germany	Kalmar - Linköping, Sweden
Overview of route specifications			
Track length	210 km	720 km	230 km
Rolling stock	2 Locomotives	5 Locomotives	5 Locomotives
H_2 consumption	0.67 kg/km	0.82 kg/km	0.48 kg/km
	670 kg/day	1,500 kg/day	3,000 kg/day
Total CAPEX	EUR 14 m	EUR 38 m	EUR 48 m
Characteristics	Cross-border operation between Russia and Estonia	Long range freight transport from border to port	Passenger and freight transport between two cities

Total cost of ownership [EUR/km_{train}]

Diesel	22.6	9.2	5.7
FCH	**22.8**	**11.9**	**6.7**
Catenary	24.4	6.4 [10]	22.0
Battery			

Environmental analysis

CO_2 savings [tons per year]	2,556 t	12,874 t	4,980 t

Source: Market research, Expert interviews, Roland Berger

No barriers are show-stoppers for FCH rail technology, but R&I projects are required to realise a broader commercial potential

Barriers for FCH trains

> **No** principle **show-stoppers** to the deployment of FCH technology in the rail environment exist

> **High priority barriers** are related to **financing** FCH train deployment, **lack of standard scalable design** and **H_2 storage optimisation**

Suggested Research and Innovation (R&I)

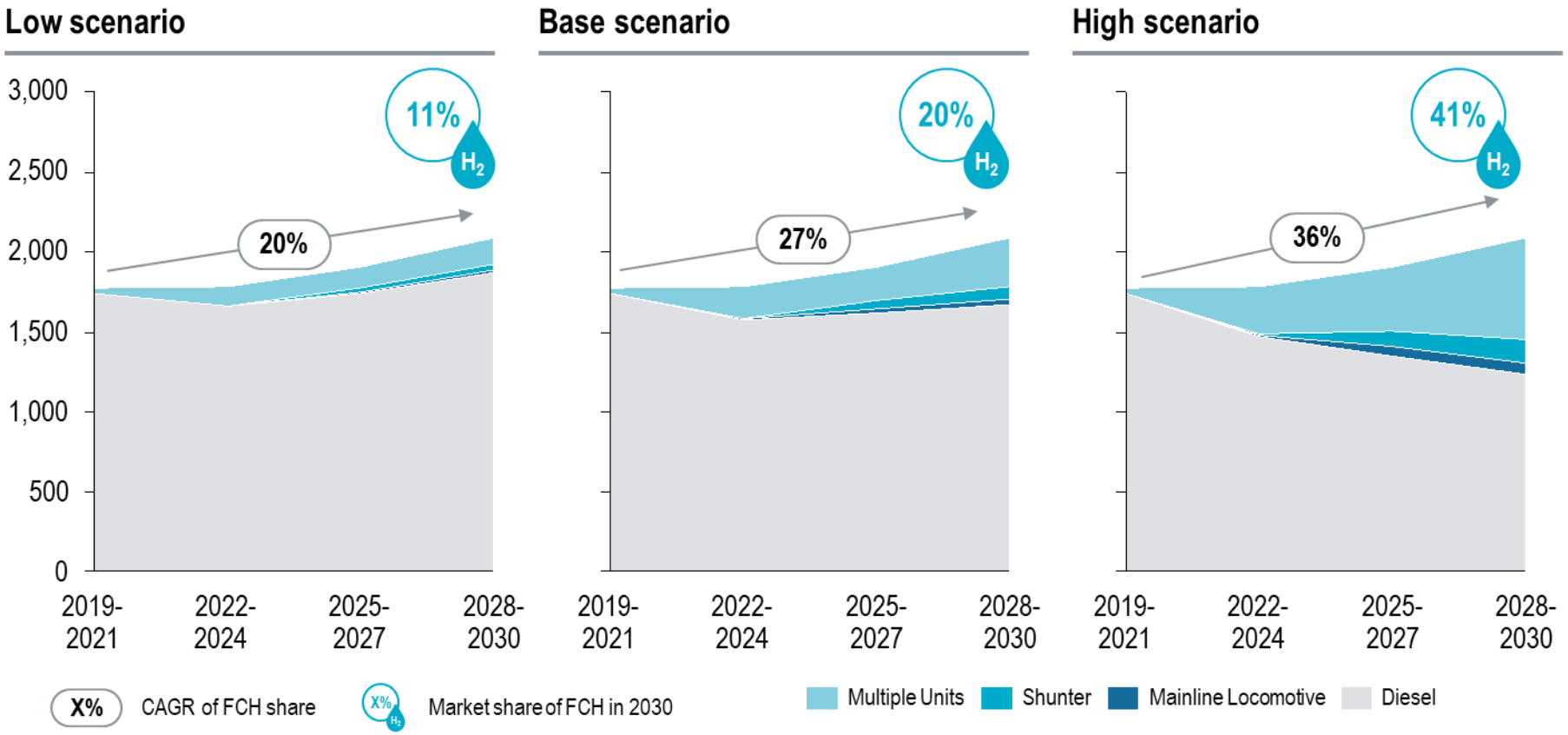
> **R&I projects** can bring FCH technology significantly closer to commercialisation by **addressing high priority barriers**

> Three key project topics
  - **Large-scale demonstration** of Multiple Units fleets
  - **Prototype devel.** and testing of Shunters or Mainline Locomotives
  - Research and **tech. dev.** of **optimised H_2 storage** system

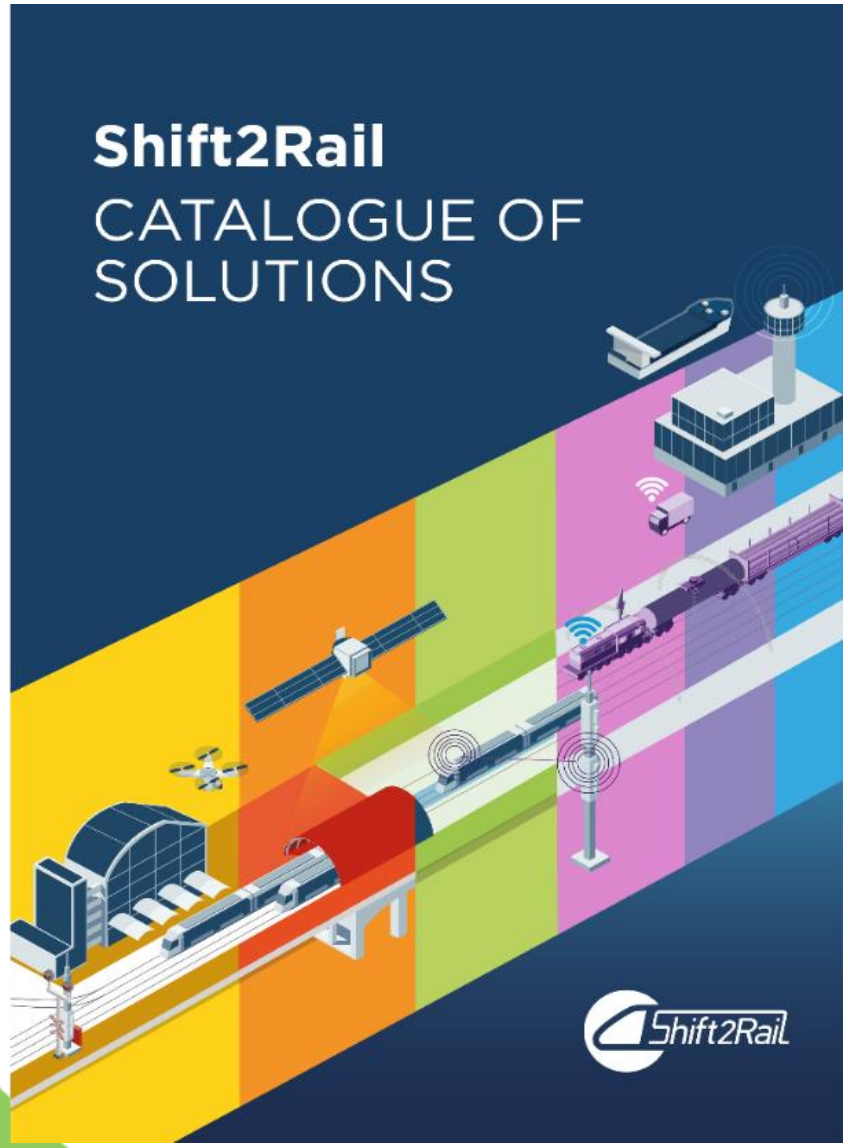
> **Medium**, **low** priority **barriers can integrated** in the same R&I project

Source: Expert interviews, Roland Berger

EU market potential FCH trains – scenario comparison [standard units]



Source: Market research, Expert interviews, Roland Berger



54 SOLUTIONS

Who benefits?

CUSTOMERS

- FINAL USER
- OPERATOR
- INFRAMAN
- SUPPLIER

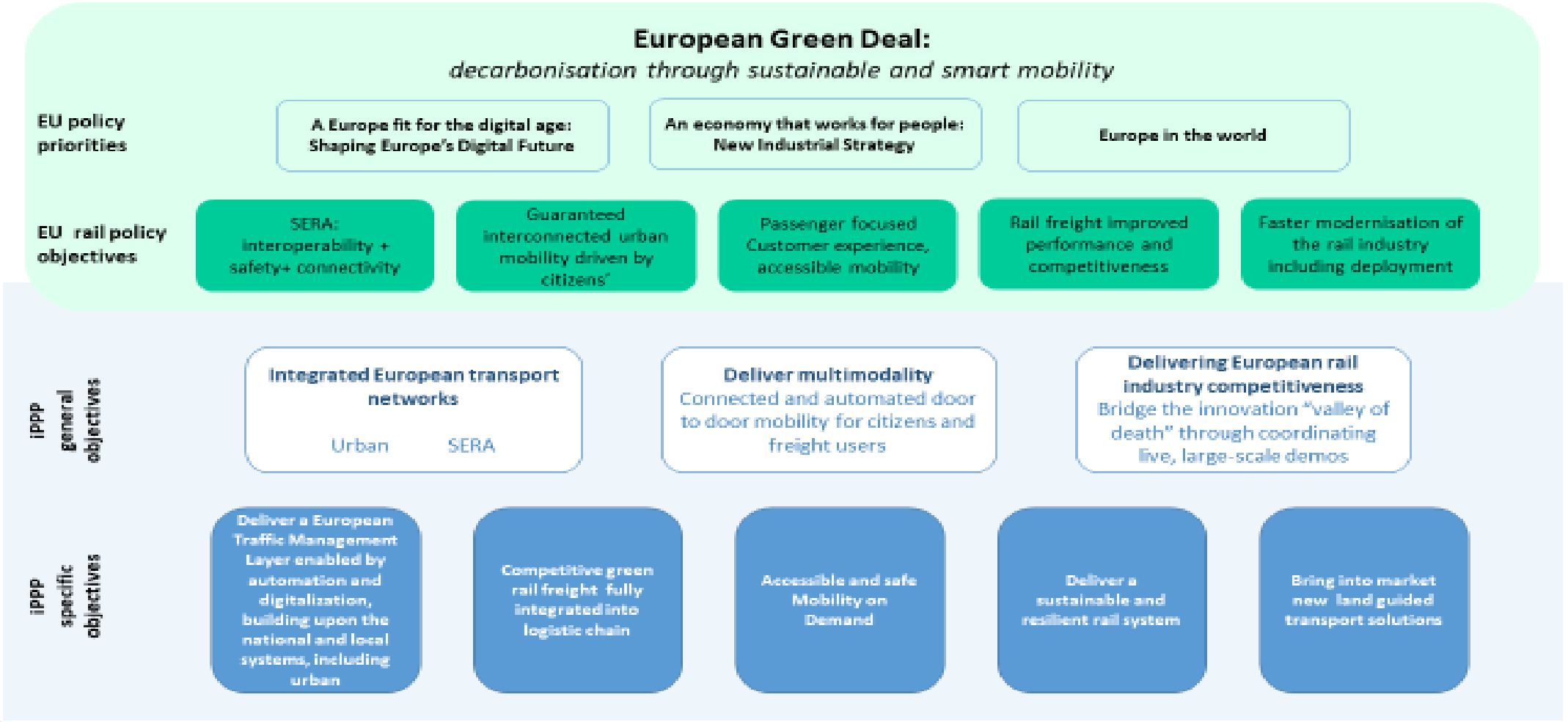
DELIVERY DATE FOR INDUSTRIALIZATION

https://shift2rail.org/publications/catalogue-of-solutions/

EUROPE'S RAIL JU

IN THE MAKING

Common Vision, Objectives & Expected Impacts



Activities: all will be “user-first” oriented

S2R MAAP
Part A: Capabilities
Part B: Technological Demontrators per IP

S2R R&I implementation
S2R Projects xx sub-systems architectures (TD or ITD) and IT models

S2R IPX, Linx4Rail
Railway Functional System Architecture & Conceptual Data Model
Operational vision
Interoperability & modularity vision

Individual stakeholders or other sectors external initiatives

- **Integrated EU rail networks**
- **Door to door mobility for freight/passengers**
- **Innovation in the market**

System Pillar

Operational concepts

Migration plans

A single coordinating body for the whole sector evolution

Functional System of systems Architecture

Open interfaces to other transport modes & businesses

System requirement specifications

Innovation Pillar

Operational solutions for the services of the future

Integrating project for a shared Rail Transport EU Mobility System

European Rail Traffic Management Layer

TSIs and/or standards pre-development

Transforming Projects (sub-system R&I implementations) & **Large scale operational demonstrations**

Thank you

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