WP6 Economic Analysis

D6.1 Analysis of the Economic Models for Energy Harvesting Systems

Final Review Meeting 25th February 2020

Matteo Ferraris (LINKS FOUNDATION)

Grant Agreement
Number: 777576

WP6 – Agenda

- WP6 tasks description and work flow methodology
- Grant Agreement goals and main outcomes get from WP6
- Methodological approach (based on a VRM that was developed by us) for:
  - Main scenarios
  - Main technologies
  - Main use cases
- Virtual Route Model (VRM)
  - Definition of the route (e.g., topology, length, etc.)
  - Definition of the functional form and inputs of the model
- SWOT analysis of scenarios involving different TEH systems or technologies
- Economic results
- Conclusions and next steps

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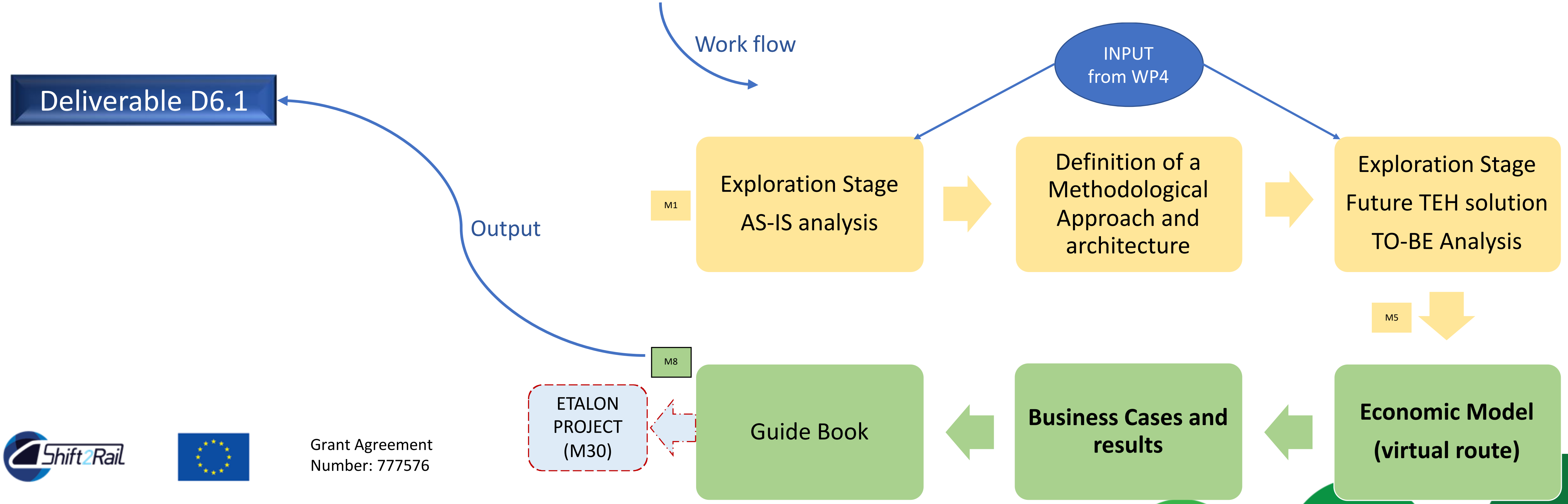
WP6 – Tasks and deadline

Date	Task	Result(s)	Leader	Means of verification	Partners involved
M1-M5	T6.1	Scenario building for Economic Modelling	ARD	Interim report about review of energy harvesting systems from WP4	SIRTI, ARD, ERGOSE
M4-M8	T6.2	Results of the analysis of Economic Models for the TEH systems	LINKS	Release of the final version of D6.1 for public circulation	SIRTI, ARD, ERGOSE



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Main WP6 Goals described in the Grant Agreement

Gap analysis of AS-IS setting (Task 6.1)	• E.g., analysis of inadequate technological performances, risk exposure, diseconomies in operational and maintenance costs, lack of compliance
Portray TO-BE scenarios (Task 6.1)	• Analyse possible future scenarios to be used as backdrop for economic modelling
Cost-Benefit analysis (Task 6.2)	• Incurred for Infrastructure Managers (IMs) in a Total Cost of Ownership (**TCO**) perspective
Trackside EH solution economic analysis (Task 6.2)	• Economic foundations for the selection of **most promising trackside EH solutions** (e.g., short-list of technological opportunities)
Quantitative economic analysis (Task 6.2)	• Perform a **quantitative economic analysis** on a counterfactual basis by juxtaposing possible EH systems with what would have occurred in absence of interventions

Main Outcomes from WP6

DELIVERABLE D6.1

- Methodological approach for a techno-economic analysis of new TEH solution
- Collection of techno-economic (primary and secondary) data
- Capital Budgeting Analysis (Total Cost of Ownership, TCO)
- SWOT Analysis, Market Analysis, Gap Analysis of the migration towards powering with TEH systems
- Virtual Route Model (VRM)
- DSF (spreadsheet) useful for decision makers (i.e., Infrastructure Manager, IM)

TRACKSIDE ONLY (not OTI)

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Economic rationale (gap analysis) for changing trackside power systems

Theft of cables

In one year **134 ton of copper stolen** with a loss of **1.3 million of euro** of direct damage and maintenance costs in Italy

British Transport Police figures also show an **85% increase in live cable thefts** last year

Environmental issues

Reduce pollution from **green energy** for powering object controllers (environmental KPIs as CO_2 equivalent)

Cost Savings

In **rural areas** the cost for cabling and power systems can be more expensive than energy harvesting system

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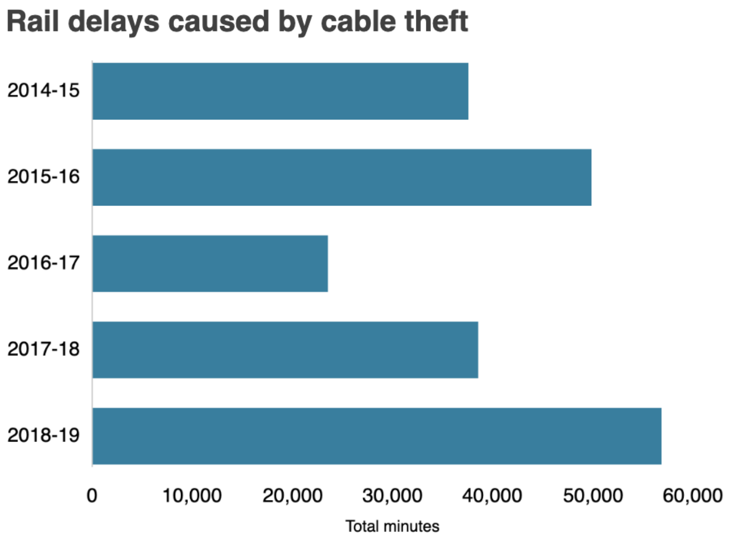
Delays of train

The delay of train for this rationale has been computed in **20.2 days**

In 2010-2011 there were 995 cable thefts on British railways causing more than **1,000 minutes of delays each day**

There were nearly **950 hours of delays** in 2018 across more than 7,000 journeys in England, Wales and Scotland



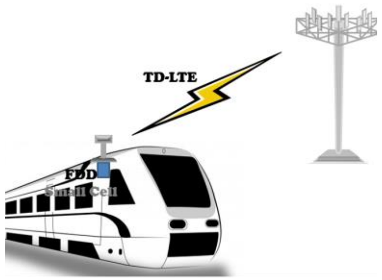
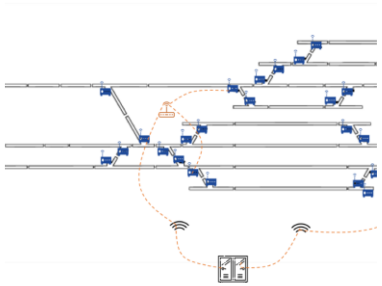
Source: National Rail https://www.bbc.com/news/uk-47901062

Three main selected Scenarios with focus on Smart Wayside Object Controllers (SWOC)

3 Scenarios

2 Use Cases

3 Technologies

AS-IS Scenario 0	TO-BE Scenario 1	TO-BE Scenario 2
		
Wired signalling systems	LTE network	Wireless Sensor Network (WSN)
with cabling for powering object controllers (OCs)	wireless systems powered by TEH	wireless systems powered by TEH

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Two main Use Cases

3 Scenarios

2 Use Cases

3 Technologies

Zone A (high density area)

Large Number of Fields Elements

Short Distance to Station Centre

Presence of mains powered signalling equipment (e.g., stations, stabling areas, etc.)

Zone B (low density area)

Low Number of Fields Elements

High Distance to station centre

Justified use case for freight and regional medium density lines with moderate number of field objects and medium-large distances between stations (e.g., remote areas between stations, difficult to access area, non electrified sections)

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Three main candidate TEH Technologies

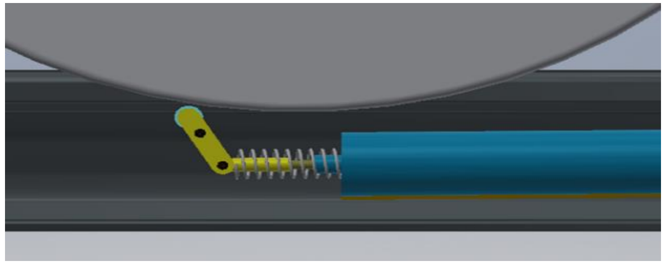
3 Scenarios

2 Use Cases

3 Technologies

- Vibration Harvester (VH)

- Linear Generator/Displacement Harvester (LG)



- Solar Panel (SP)

For further technical explanation, see WP4 and WP5

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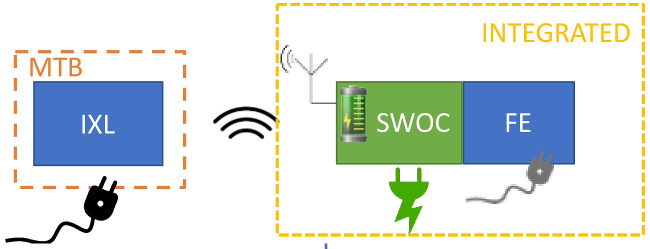
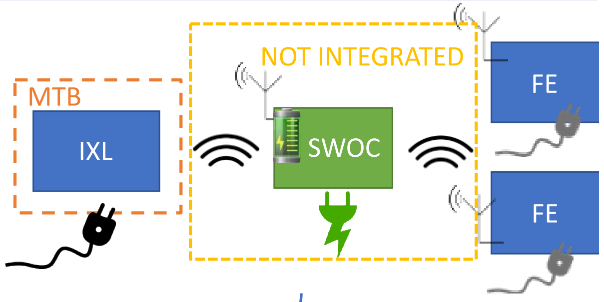
Communication OCs, FEs and EH systems

	SWOC integrated with FEs	SWOC not integrated with FEs
Characteristics	Small EH	Medium/large EH
No. OCs controlled	One object controller for one field object	One object controller for several field objects
Interface OC-IXL	Radio communication powered by an energy harvester	Radio communication powered by an energy harvester
Interface FE-SWOC	Internal interface	Radio communications, partially powered by an energy harvester
Goal	Main ETALON scenario for technical analysis	In ETALON considered only for economic analysis





SWOC = Smart Wayside Object Controller
Future generation **ultra low-power object controller**

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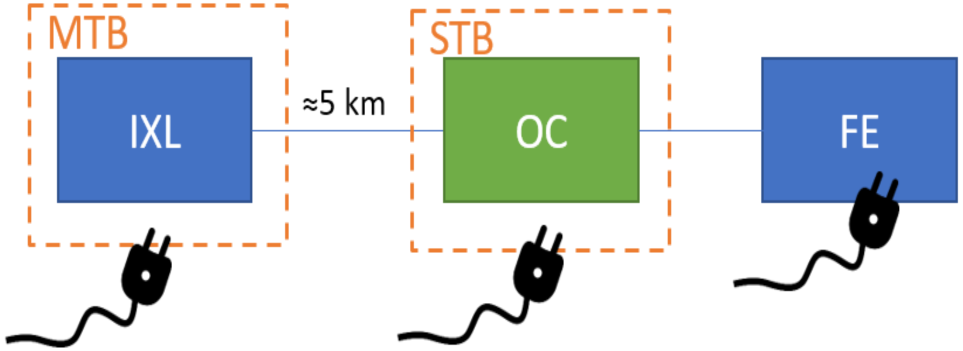
Scenario 0: Current Cabling System

Object Controllers

Current 'centralized' wired trackside solutions

Scenario 0 (Current)

Cabling



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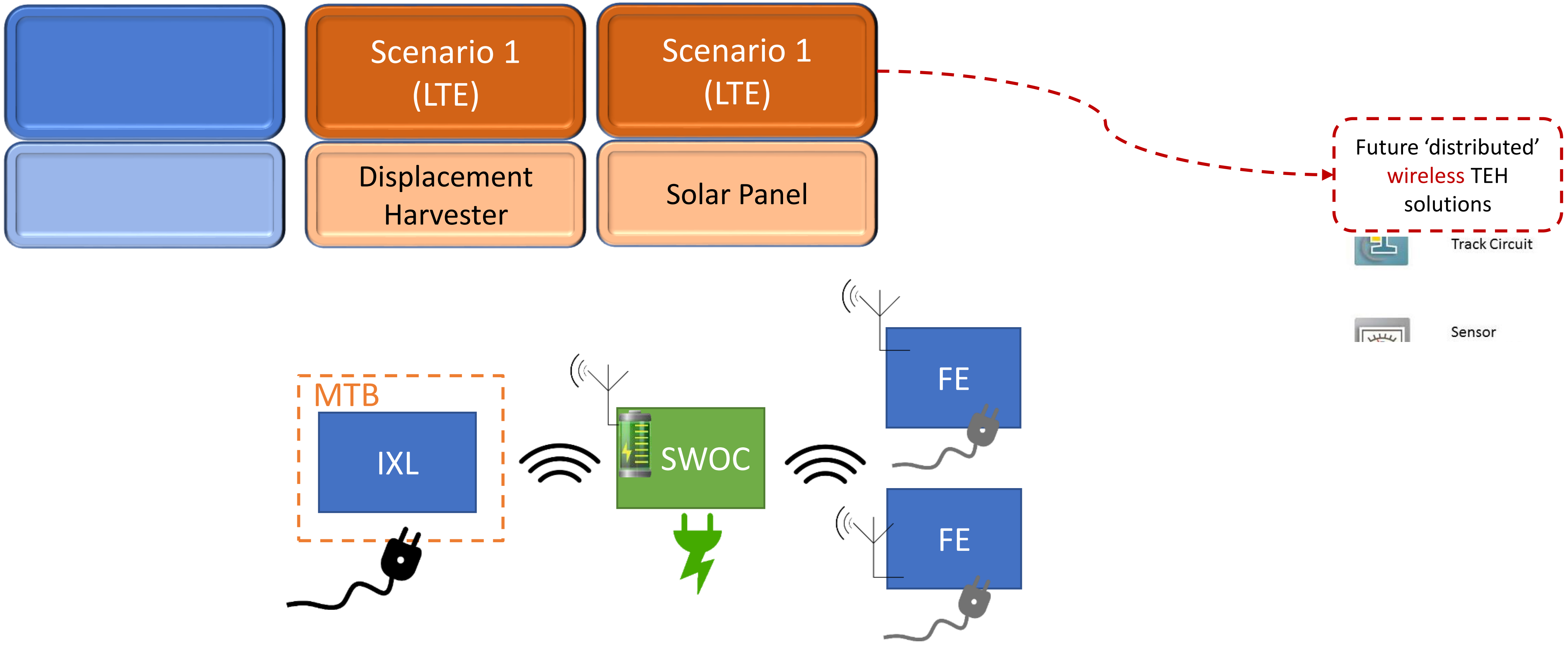
Scenario 1: LTE network



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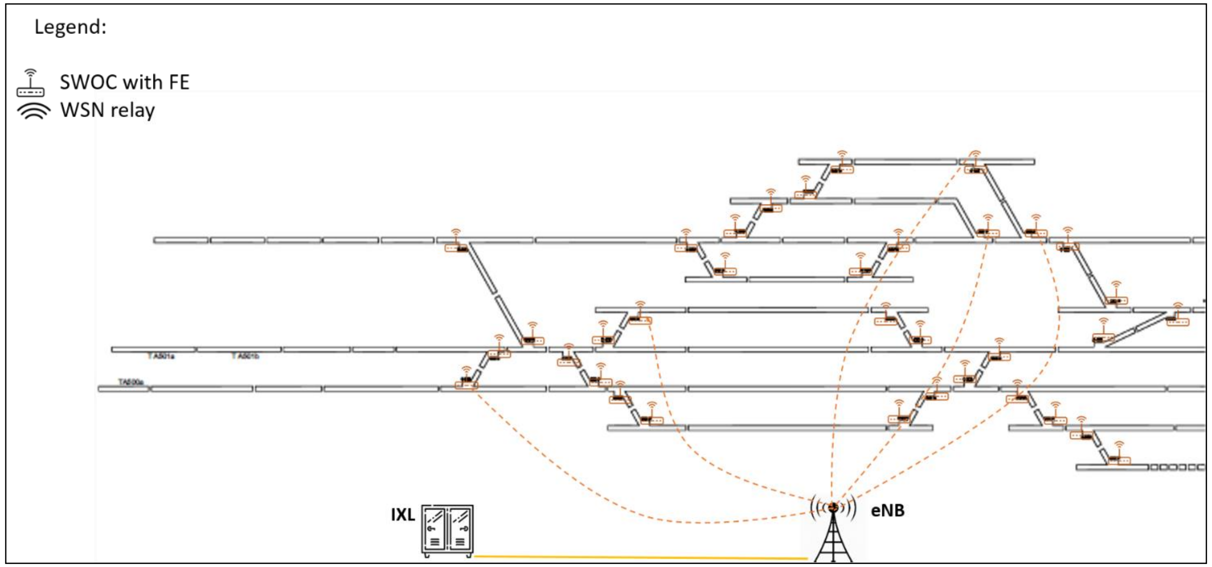
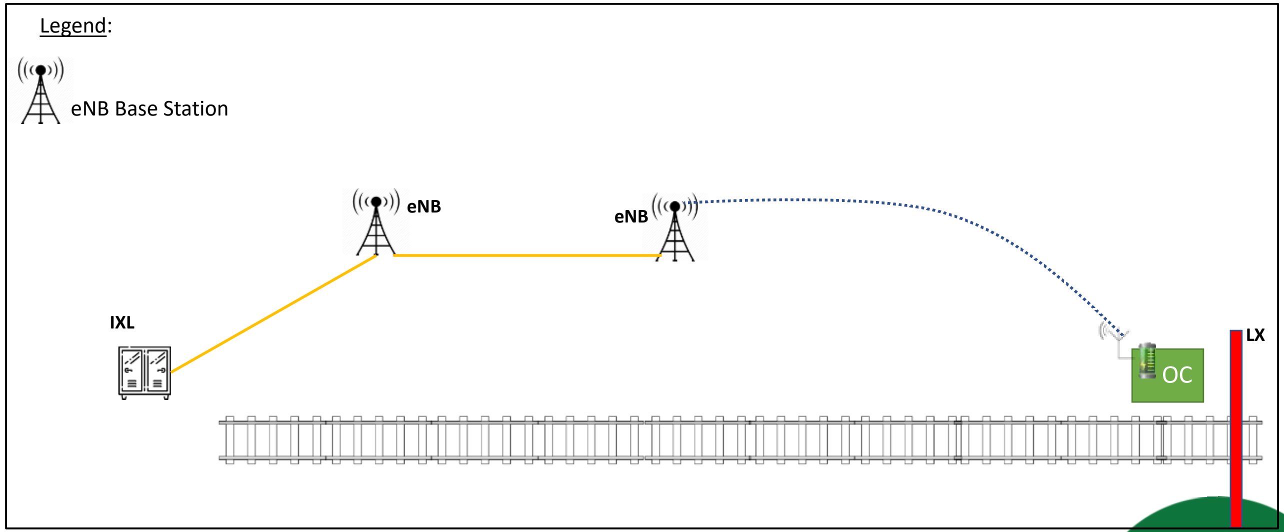
Scenario 1 (LTE): SWOC and FE (Zone A and B)

For further technical explanation, see WP3



LTE (Zone A)

LTE (Zone B)



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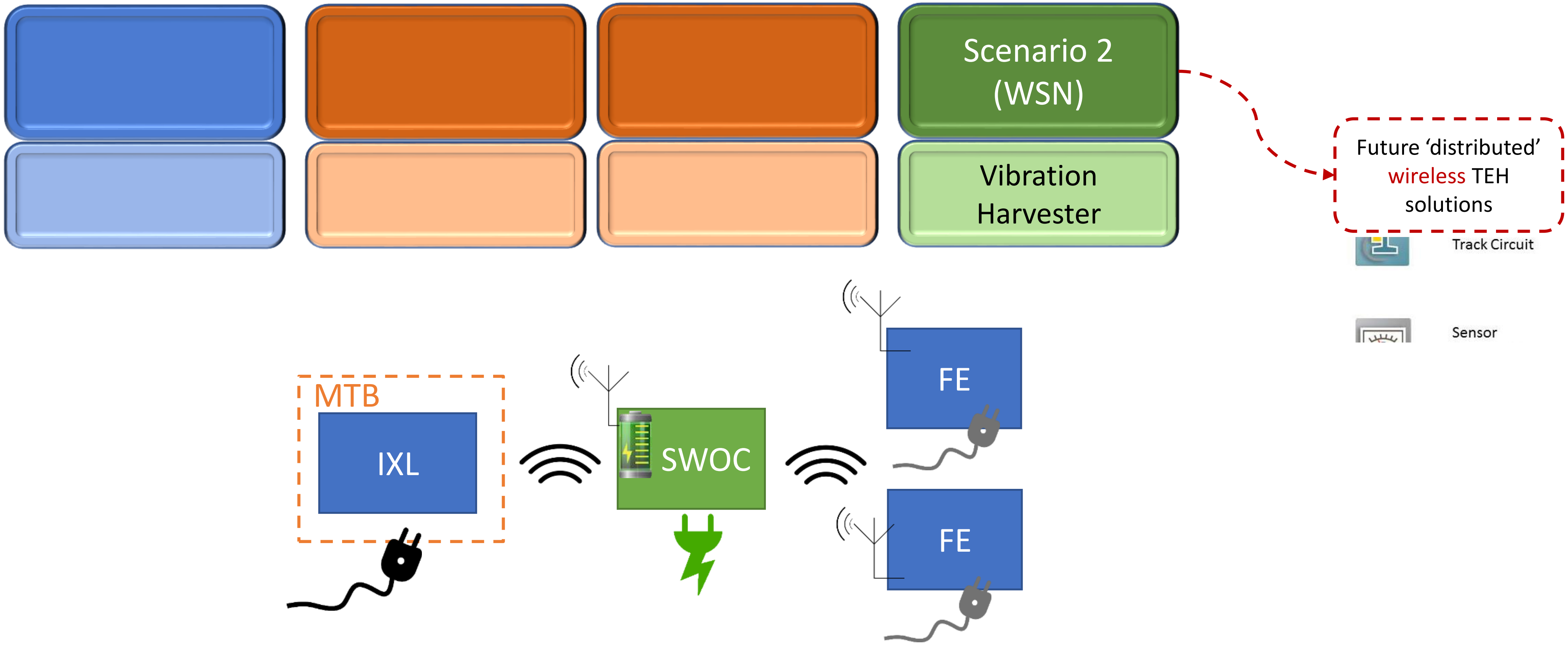
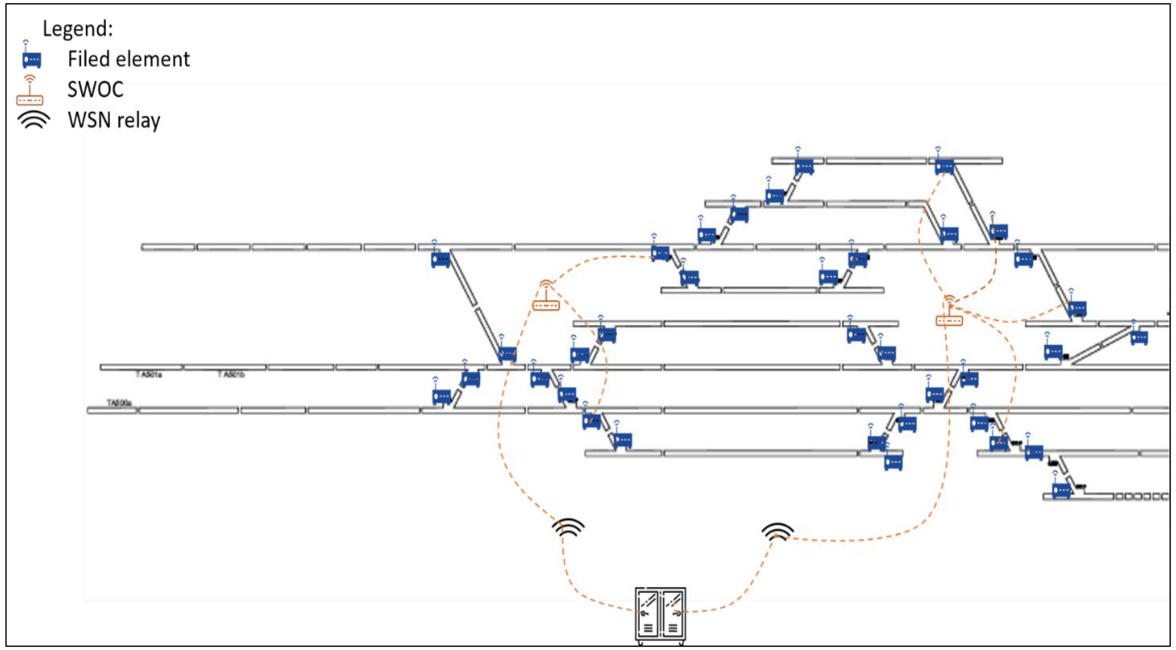
Scenario 2: WSN architecture



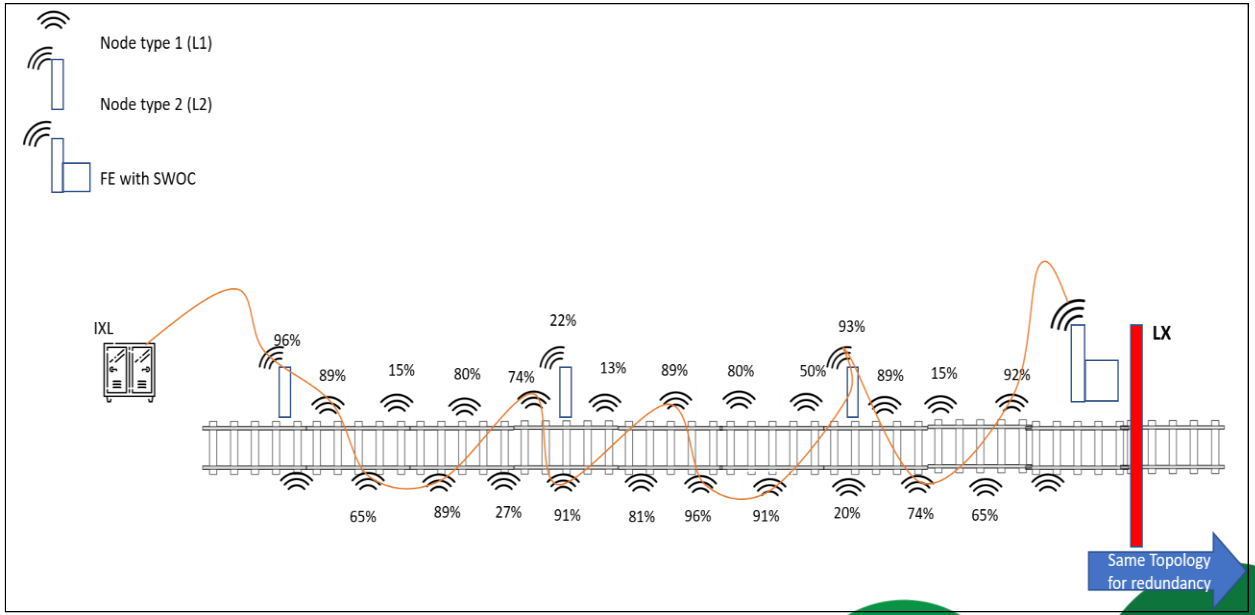
Scenario 2 (WSN): SWOC and FE (Zone A and B)

For further technical explanation, see WP3



WSN
(Zone A)

WSN
(Zone B)



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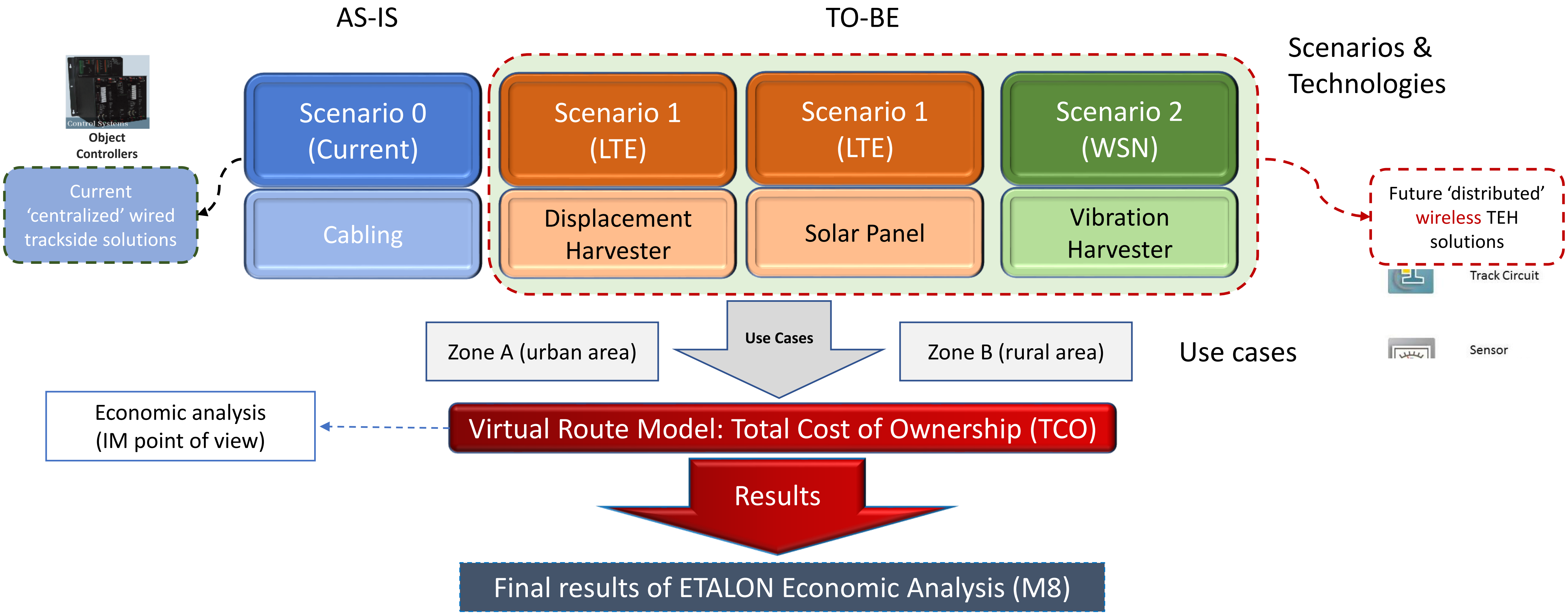
Synthesis: Scenarios, Technologies and Use Cases (flow chart)



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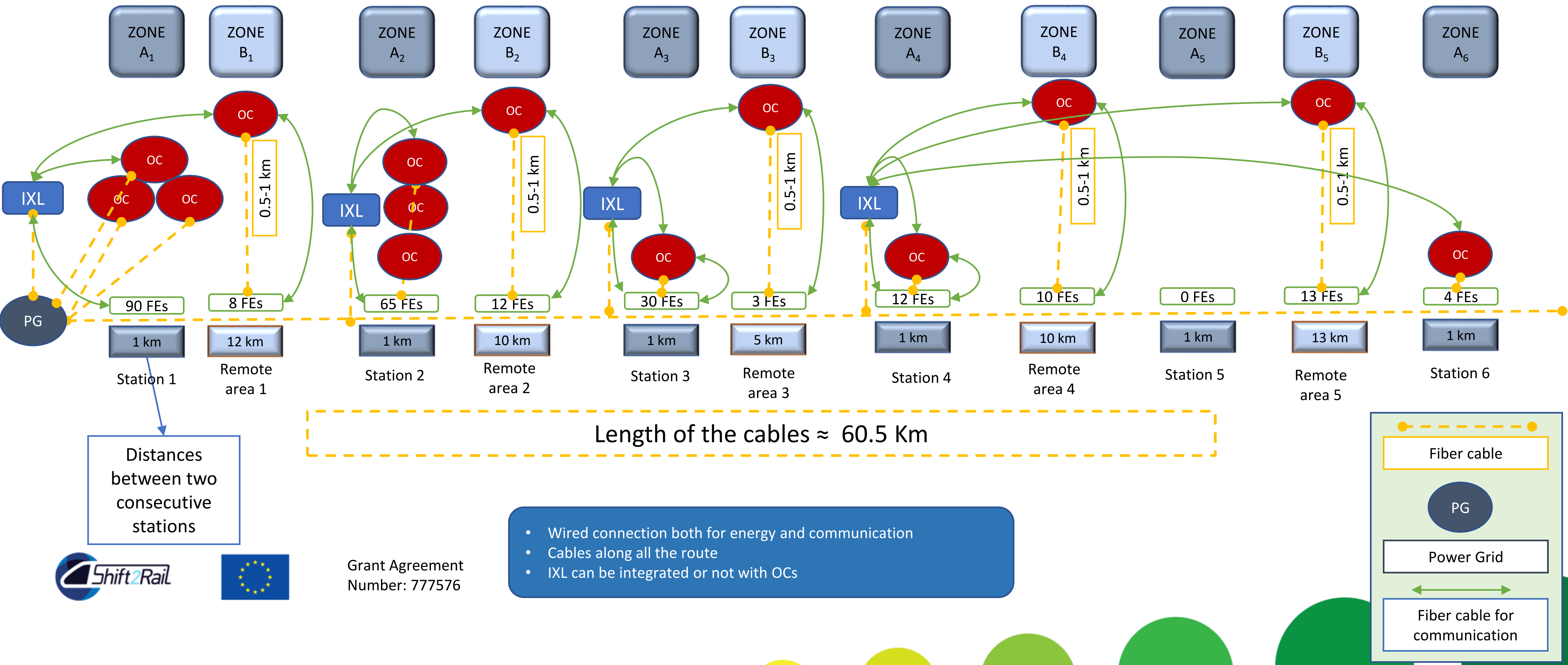
THE VIRTUAL ROUTE – AS-IS

AS-IS (Current)



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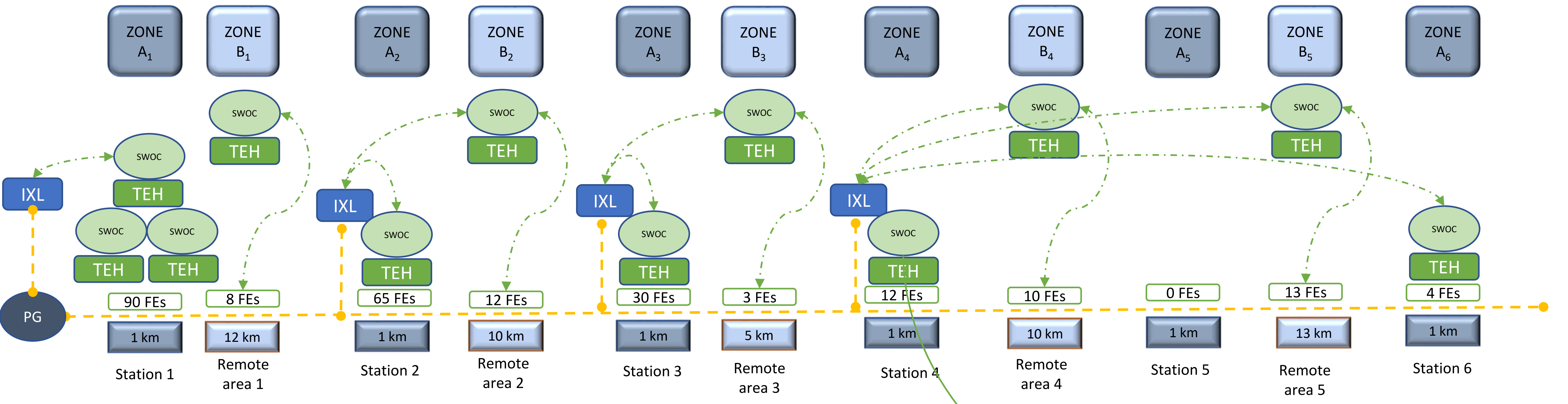
- Wired connection both for energy and communication
- Cables along all the route
- IXL can be integrated or not with OCs

THE VIRTUAL ROUTE – TO-BE

TO-BE (Future TEH)



- Less km of cables
- Less energy consumption for each SWOC
- Lower cables theft
- Wireless communication

SWOC = Smart Wayside Object Controllers or Future Generation OC

Fiber cable

PG

Power Grid

Wireless Communication

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THE MODEL – AS-IS Capital Budgeting Analysis (Cables)

STOCK

Total Cost of Ownership (TCO)

CapEx of current Energy System

Cost of installation for Energy Equipment (including labor cost)

- Cabinet to host electric equipment
- Transformer
- UPS
- PLC control
- Catenary filter
- Isolated transformer
- Mono-phase voltage stabiliser
- etc.

Cost for deploying cables (including labor cost)

It depends on how many OCs to be built in a line (including labour cost), it is a function of km of line and it depends also on the composition and size of the cable (i.e., aluminium, copper) and on the labour cost

Cost for Object Controllers

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THE MODEL – AS-IS Capital Budgeting Analysis (Cables)

FLOWS

Total Cost of Ownership (TCO)

OpEx of current Energy System

Cost of Energy Supply	For maintenance of energy equipment, per year
Cost of maintenance cables	For substituting cables when they are damaged, including labour cost, cost for transportation to disposal and dismantling, per year
Cost of consumption energy	For each object controllers, per year
Cost of cables theft (direct and indirect costs)	• Cost of restore the line and the cables after the theft that it could be quite different across countries • Direct costs (from purchasing cables) • Indirect costs (interruption of line, delays, etc.)

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Time Horizon = 20 years

THE MODEL – TO-BE Capital Budgeting Analysis (LTE and WSN)

STOCK

Total Cost of Ownership (TCO)

CapEx of future TEH System

Cost of new equipment	Cost of new TEH systems, battery, etc., included labour costs
Cost of dismantling cables	It is a function of km of dismantling for substituting with new EH systems
Cost of new Object Controllers (SWOC)	Expected value of new low consumption object controllers (i.e., SWOC)
Subsidies for green energy + Revenues from cables market	Possible residual value from dismantling cables and equipment, selling cables to the market, etc. and government subsidies for green investments (if any)

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THE MODEL – TO-BE Capital Budgeting Analysis (LTE and WSN)

FLOWS

Total Cost of Ownership (TCO)

OpEx of future TEH System

Cost of maintenance	Cost for maintenance EH systems, Including labour cost
Cost of equipment	Cost for substituting equipment, per year (e.g., battery, etc.)
Cost of theft of EH systems	Direct and indirect costs
Salvage value	Possible residual value from substituting EH systems during the years

Time Horizon = 20 years

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'Short list' of variables and parameters used in the model

Primary data from Italy, Spain and Greece

Parameters	Description
Type of line	High Speed Line (HSL), mainline, regional line, freight line, length
Capacity of a route	Number of train in a route, traffic density, ridership (PPHPD)
Energy equipment and budget supply	Type, cost, metrics
Cables	Length (number of km in a route), cost of deployment, cost of dismantling in case of substituting with new EH systems
Cost of restore the line after cable theft	Additional cost for railway operators in case of theft of cables, damage of equipment, additional test on-site, deployment in the night, etc.
Operational (ordinary) maintenance	Costs and frequency of maintenance
Power consumption or energy efficiency	Metrics to measure energy efficiency of current cabling to be compared with the TEH systems
Geography	Urban, remote area (rural, regional area) and 'difficult to access' area (mountain, tunnels) where independent equipment could be needed
Suppliers of trackside technology for OCs	Names, size of enterprises
Labor Cost	Number of employee involved in the deployment and maintenance of current and future system
Theft of cables	Average economic value
Financial variables	Interest rate, etc.

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SWOT ANALYSIS

STRENGTHS

- Lower maintenance cost from cables reduction
- Lower cost from cables theft
- Decreasing costs for the energy power supply mainly in rural areas
- Spillover effect on RUs (costs decreasing since usually IMs could recharge the energy power costs to the RUs)
- Decreasing costs from the dismantling of optical fiber for communication systems (wireless communication solutions)
- More feasibility/ease to substitute new EH materials with respect to cables substitution

OPPORTUNITIES

- Environmental quality improvement (spillover effect)
- Improvement of railway QoS in more remote areas
- Public incentive (e.g. subsidies) for the deployment for green energy or for LTE and WSN technologies in easier way

WEAKNESSES

- Difficulties to implement the EH systems in the short run
- Need to have more than one TEH system for powering communication OCs
- Difficult to estimate, now, the real costs for EH materials for railway application
- Impossibility to substitute all cables both for OCs and for FEs, at the same time. Indeed, it is difficult that in the short run the EH systems can generate sufficient power for both OCs and FEs. As a consequence, cables could remain also with the introduction of EH systems for SWOC

THREATS

- Not feasible SWOC in the short run
- A better Life Cycle Assessment (LCA) analysis needed to be implemented for each EH system
- Need to have a impact analysis with other stakeholders

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ECONOMIC RESULTS – main conclusions

- ❑ A **methodological approach** for building a robust quantitative techno-economic analysis has been developed by using real data that can be used for other different TEH scenarios and geographical areas
- ❑ TCO of the deployment of cabling system is around **€ 13 millions** (~ € 200,000 per km) while TCOs for substituting current cabling system with new TEH ones are:
  - ✓ **€ 2,543,796** (~ € 39,135 per km) for Scenario 1 (LTE)
  - ✓ **€ 558,086** (~ € 8,586 per km) for Scenario 2 (WSN)
- ❑ Scenario 2 (WSN) is preferred (the most cost-saving scenario) with respect to Scenario 1 (LTE) because of the lower cost of maintenance (OpEx) and less TEH equipment
- ❑ Building **TEH systems in rural** areas generates more savings
- ❑ OpEx of Scenario 0 is always higher than TCO of both TEH Scenario 1 and 2
- ❑ Also comparing (more realistically) OpEx of current Scenario with LTE and WSN Scenarios, it seems always better to deploy **mixed powering systems** (i.e., cabling and TEH)

See next slide!

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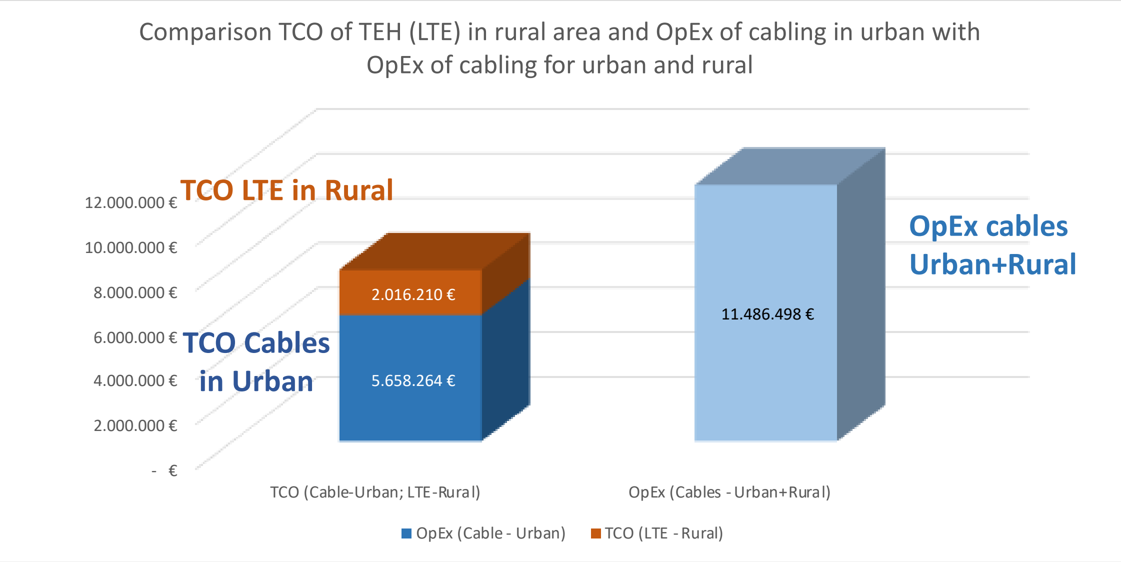
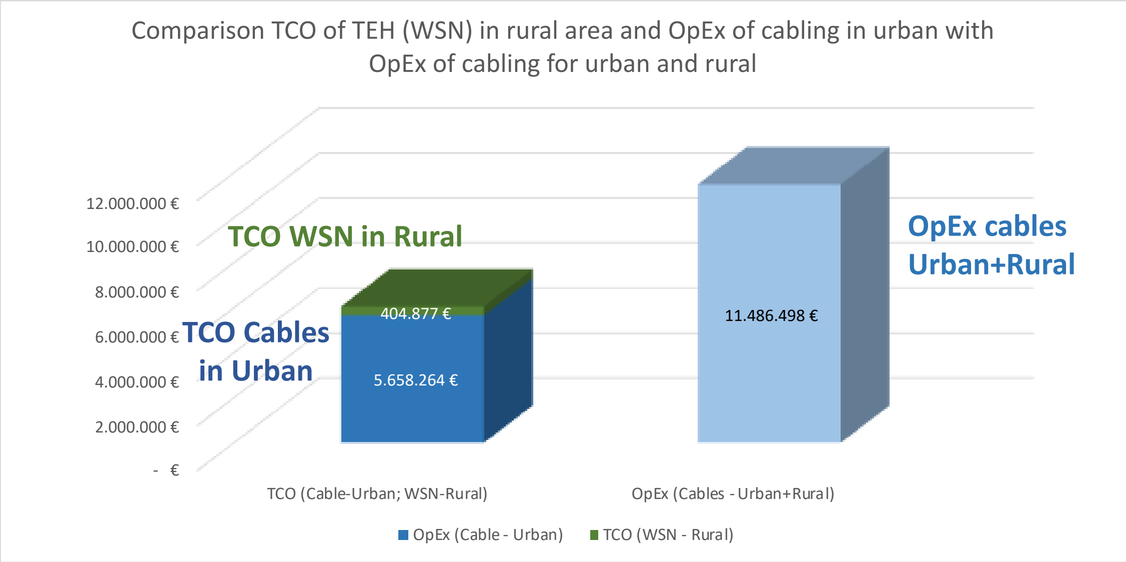
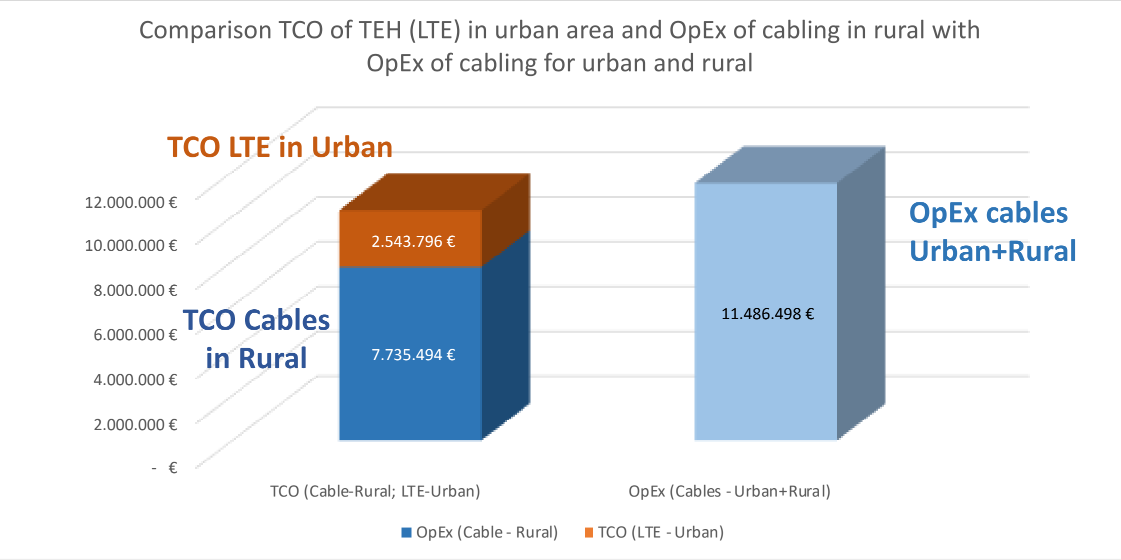
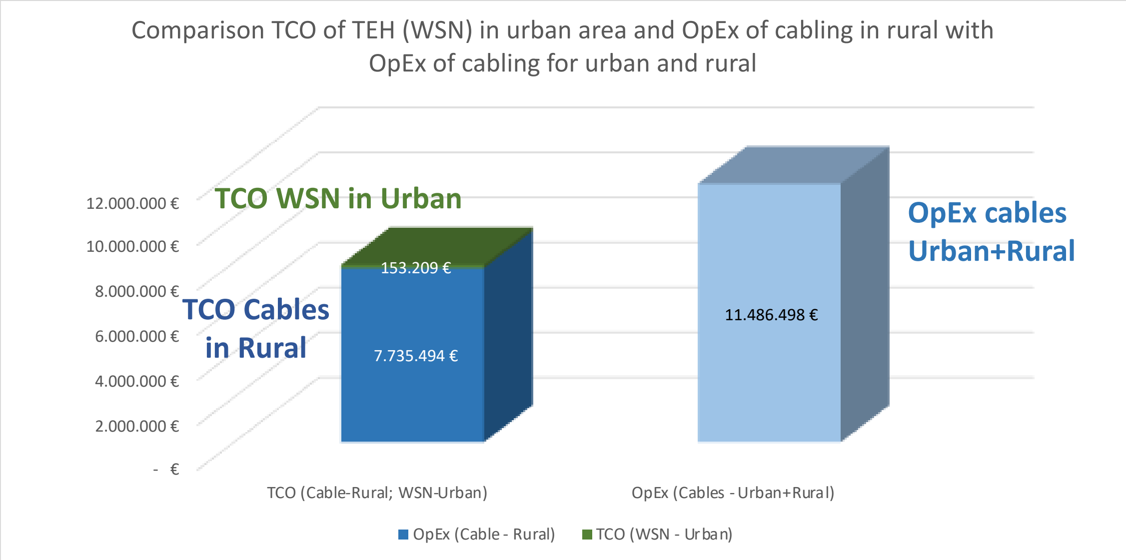
ECONOMIC RESULTS – some figures









NEXT STEPS and FUTURE WORK

- Use the same methodological approach also for the economic analysis of **on-board systems** (i.e., OTI)
- Provide a Cost/Benefit analysis also for **Railway Undertaking** (RUs)
  - Make a future analysis by considering the **daily flow of train** that can affects the production of energy and the opportunity cost in terms of train delays, etc.
- The **DSS** tool (i.e., spreadsheet) can be used for other scenarios:
  - Improve the current analysis with **new (ex-post) real data** get from the results of the Etalon project (mainly for the architecture of the route and for the energy harvesting technologies)

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THANK YOU

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