Support study on the climate adaptation and cross-border investment needs to realise the TEN-T network

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Study background

- The Green Deal and its follow-up (the European Climate Law and the new EU Strategy on adaptation to climate change) paved the way for Europe to become climate-neutral and climate resilient by 2050.

- The European Climate Risk Assessment (EUCRA) and the Communication on managing climate risks from March 2024 confirmed that Europe is the fastest warming continent in the world, with high climate risks for European infrastructure.

- Political Guidelines called for a European Climate Adaptation Plan, to support Member States on preparedness and planning and ensure regular science-based risk assessments.

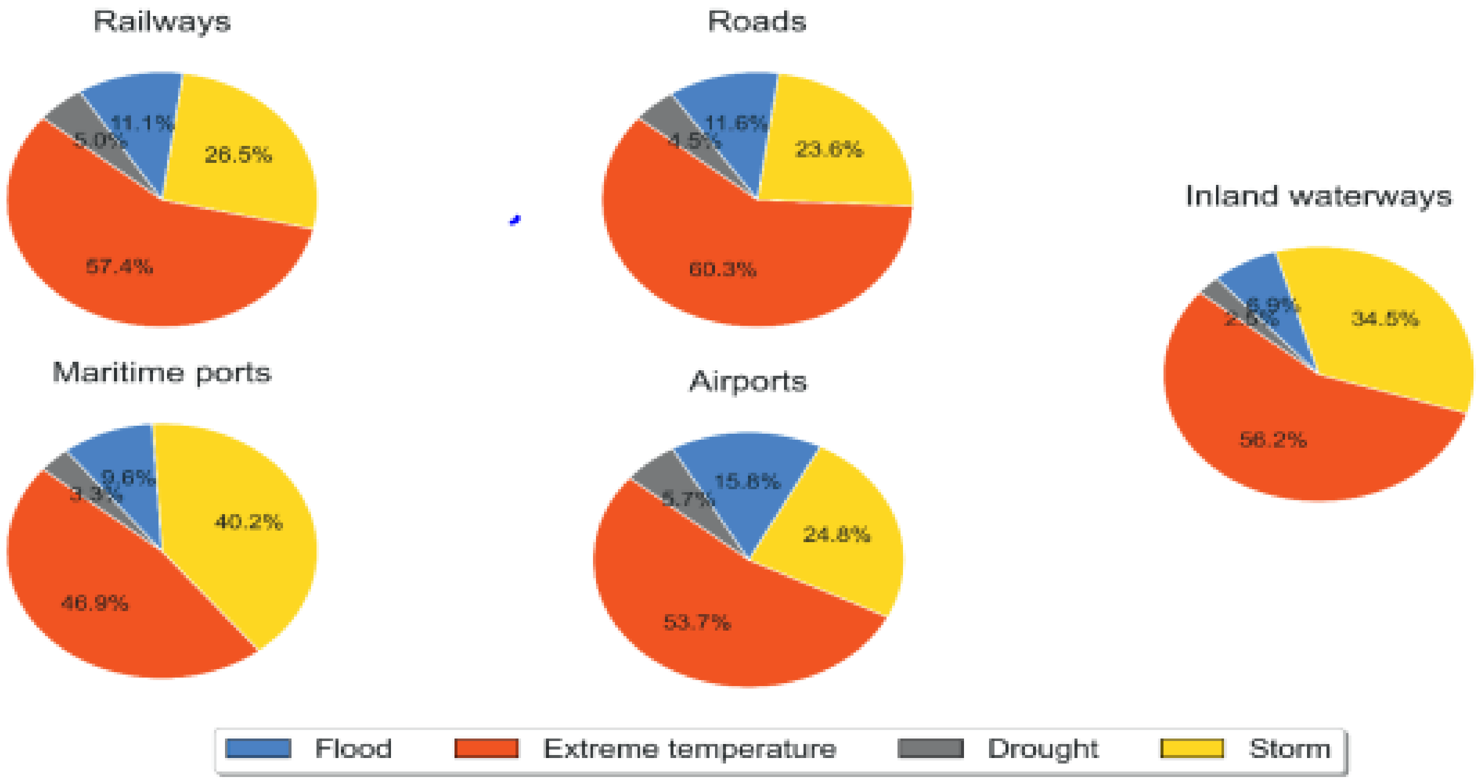
- In December 2024, DG MOVE published a study to address these concerns in the context of the TEN-T network

Objectives and scope

- **Two interrelated objectives**:
  - ✓ To identify past climate impacts and their costs, as well as future climate risks on the TEN-T, adaptation measures to address them, and corresponding investment needs
  - ✓ To identify cross-border investment gaps on the TEN-T core and extended core network

- **Scope**
  - ✓ TEN-T as defined by the 2021 proposal for a revision of the TEN-T Regulation (excluding RRTs and urban nodes)
  - ✓ Investment needs timeframe: 2030 and 2040
  - ✓ Hazards analysed: droughts, heatwaves, river floods, wildfires, tropical cyclones, and sea level rise driving coastal floods
  - ✓ Out of scope: cold waves, landslides, flash floods, windstorms

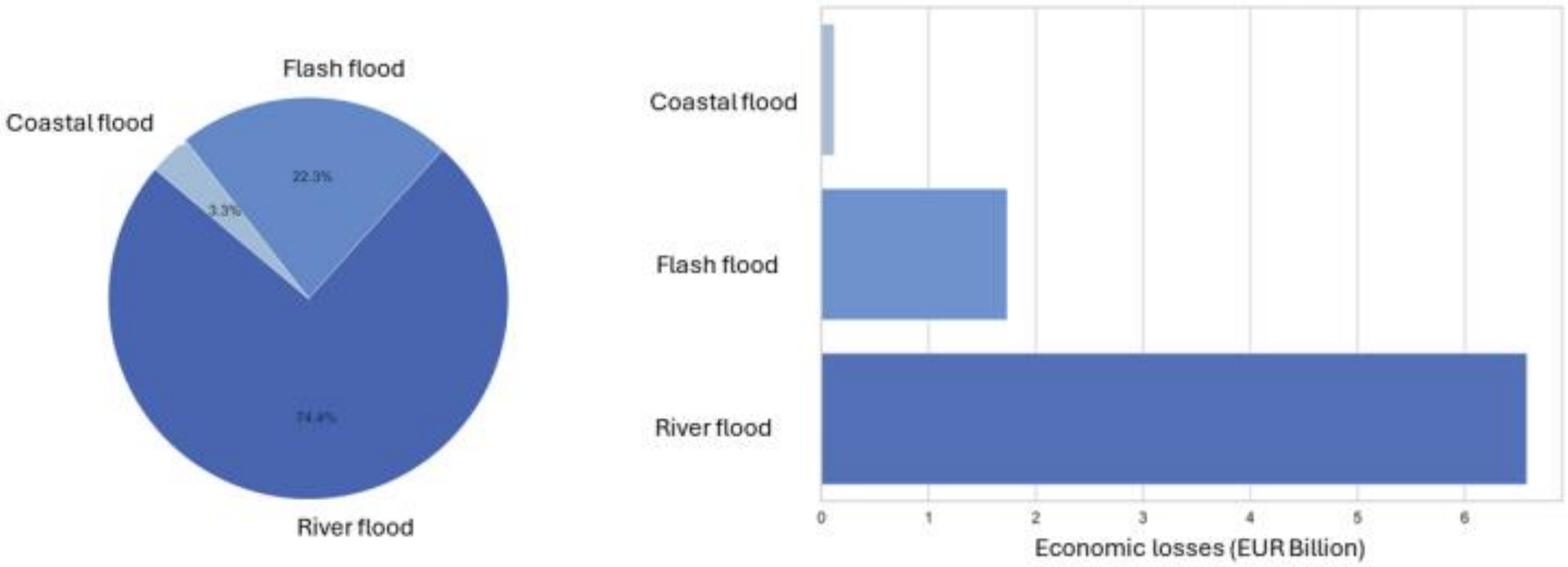
TEN-T infrastructure exposure to climate extremes 2010-2018



Source: VUB's processing - GDIS database

Figure 4.2 The TEN-T transport infrastructure modes exposed to climate extremes in the period 2010-2018, considering the GDIS events polygons extensions.

Past climate extremes: flood damage losses railways and roads



Source: DRMKC-Risk Data Hub

Figure 4.9 Economic losses reported for railways and roads for Europe due to flooding (2010-2022)

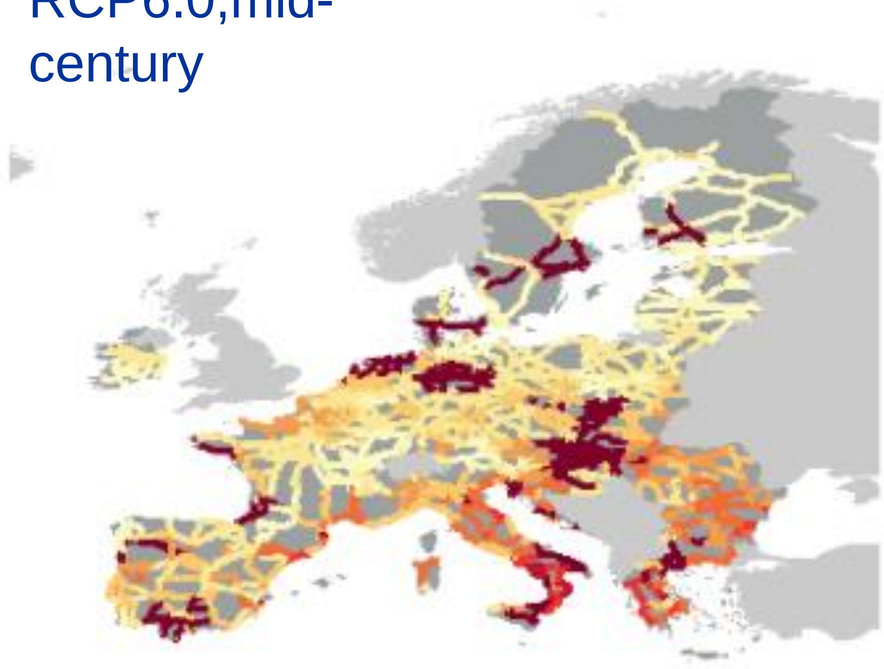
Future TEN-T exposure to climate extremes: all transport modes

- Exposure analyses conducted for two time horizons (mid-century 2024-2075 and 2049-2100 end-of-century)
- 3 emission scenarios (low RCP2.6, medium-high RCP6.0) and very-high (RCP8.5)
- Results are presented for RCP6.0, because it most closely resemble the extrapolation of current climate policies into the future (with a best-estimate outcome of around 3°C increase by 2100)
- Different futures including those in line with RCP2.6 and RCP8.5 are possible depending on our future collective actions

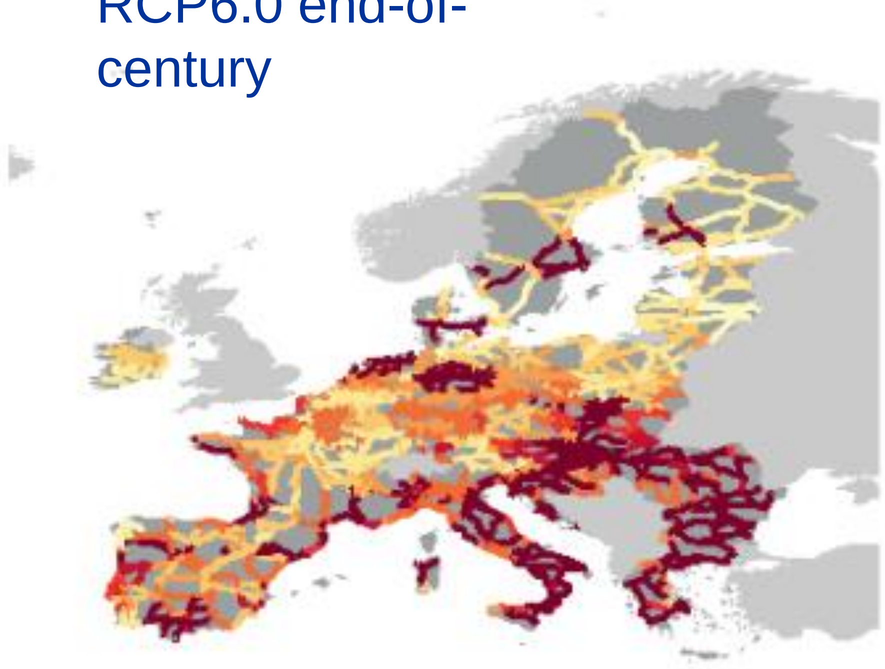
Future TEN-T exposure to climate extremes: heatwaves/railways

Railways

Heatwaves, RCP6.0,mid-century



Heatwaves, RCP6.0 end-of-century

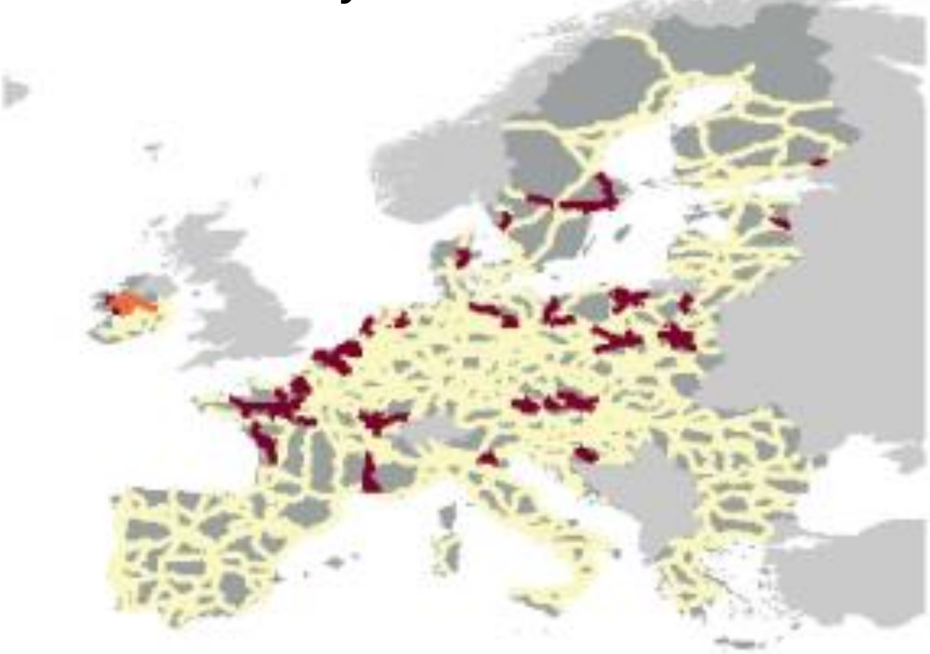


(source: VUB, Lange et al., 2020 Earth's F
Thiery et al., 2021 Science)

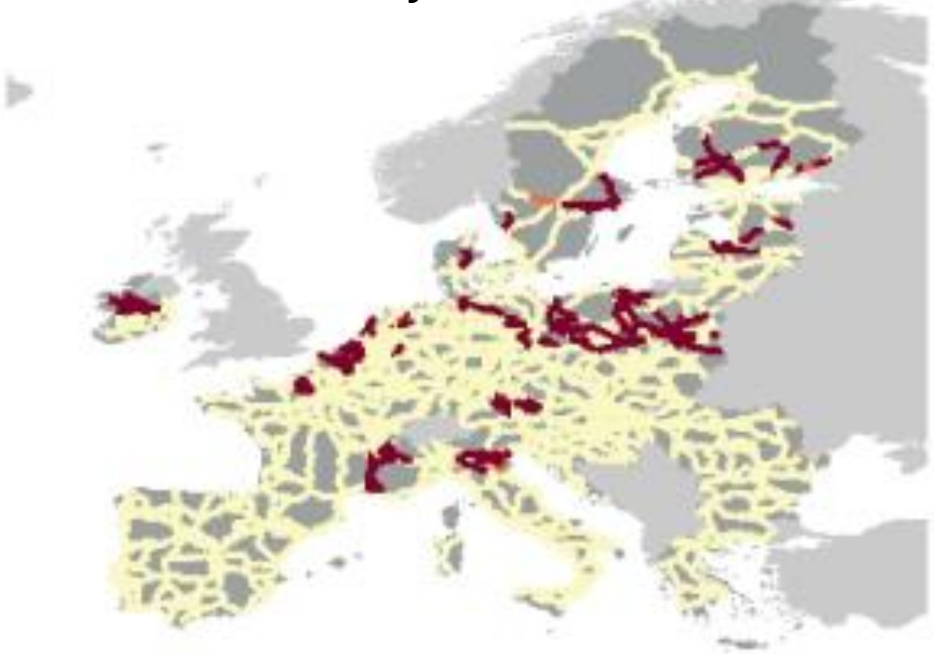
Future TEN-T exposure to climate extremes: river floods/railways

Railways

River floods, RCP6.0,mid-century



River floods, RCP6.0 end-of-century



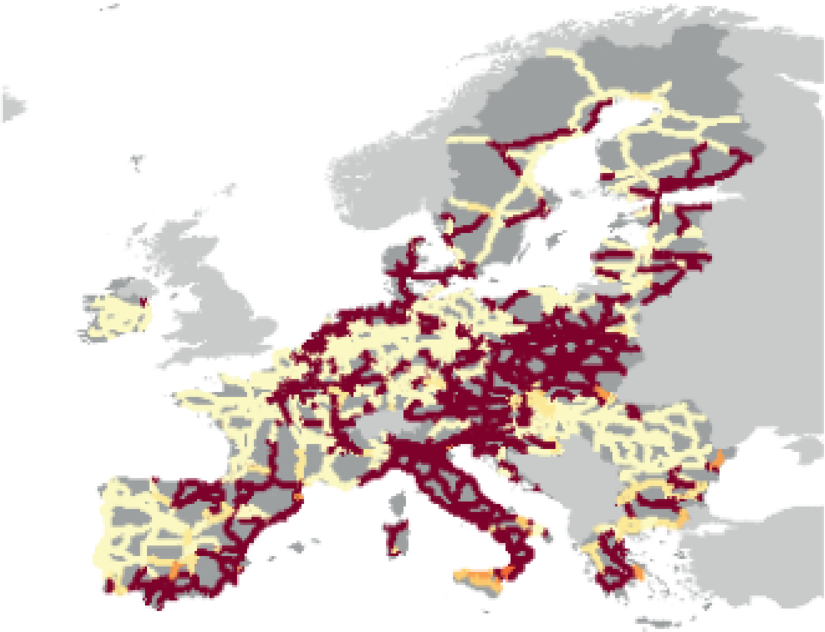
(source: VUB, Lange et al., 2020 Earth's F
Thiery et al., 2021 Science)

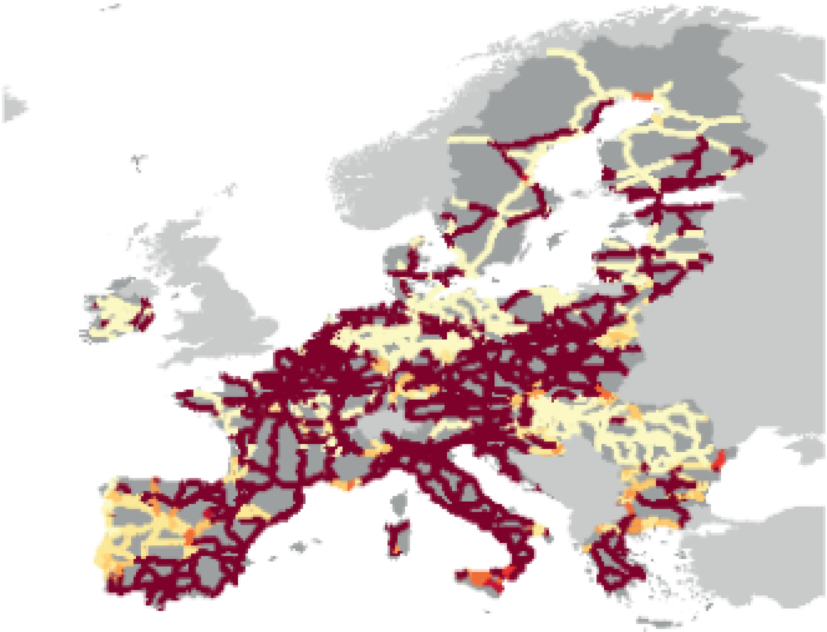
Future TEN-T exposure to climate extremes: droughts/railways

Droughts, RCP6.0,mid-century

Railways

Droughts, RCP6.0 end-of-century





(source: VUB, Lange et al., 2020 Earth's F
Thiery et al., 2021 Science)

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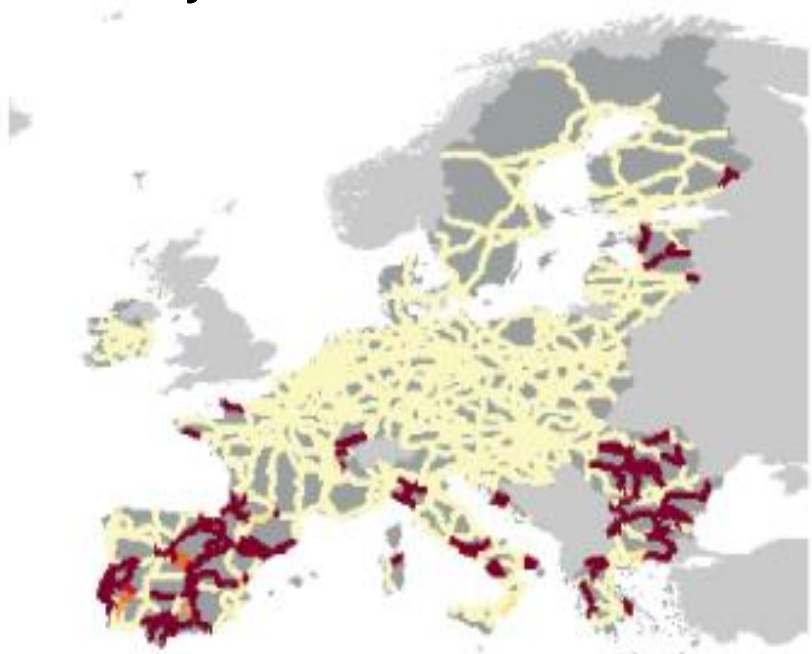
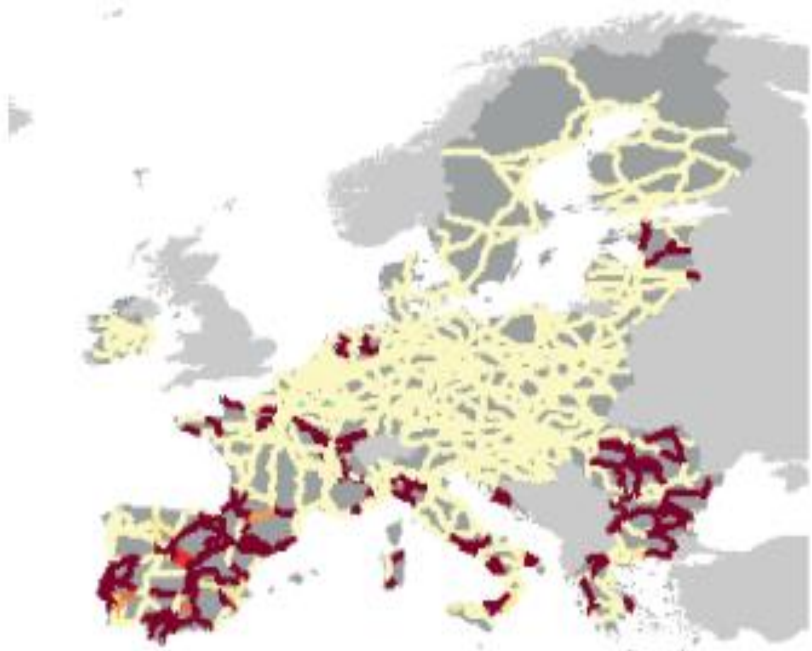
Future TEN-T exposure to climate extremes: wildfires/railways

Wildfires, RCP6.0,mid-century

Railways

Wildfires, RCP6.0 end-of-century





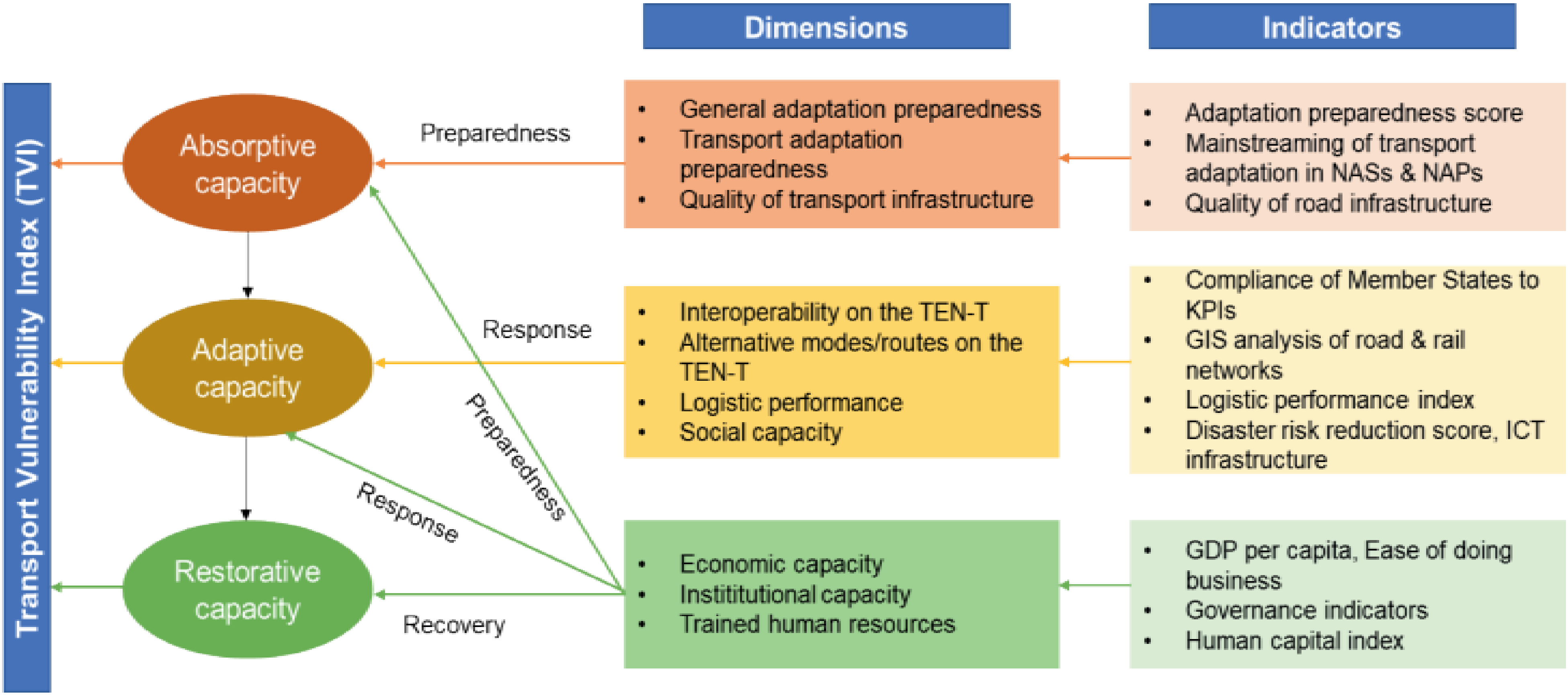
(source: VUB, Lange et al., 2020 Earth's F
Thiery et al., 2021 Science)

Summary TEN-T exposure to climate extremes: RCP6.0

- **By mid-century**, all transport modes on the TEN-T will on average experience :
  - ✓ 17.6 - 20.0 times more extreme heatwaves.
  - ✓ 9.8 - 17.6 times more droughts
  - ✓ 10% to 50% more river floods.
  - ✓ 10% to 50% more wildfires

- **By end-century**, all transport modes on the TEN-T will on average experience:
  - ✓ 28.8 – 34.4 times more extreme heatwaves
  - ✓ 20.0 – 36.4 times more droughts
  - ✓ 20% – 80% more river floods
  - ✓ 20% – 230% more wildfires

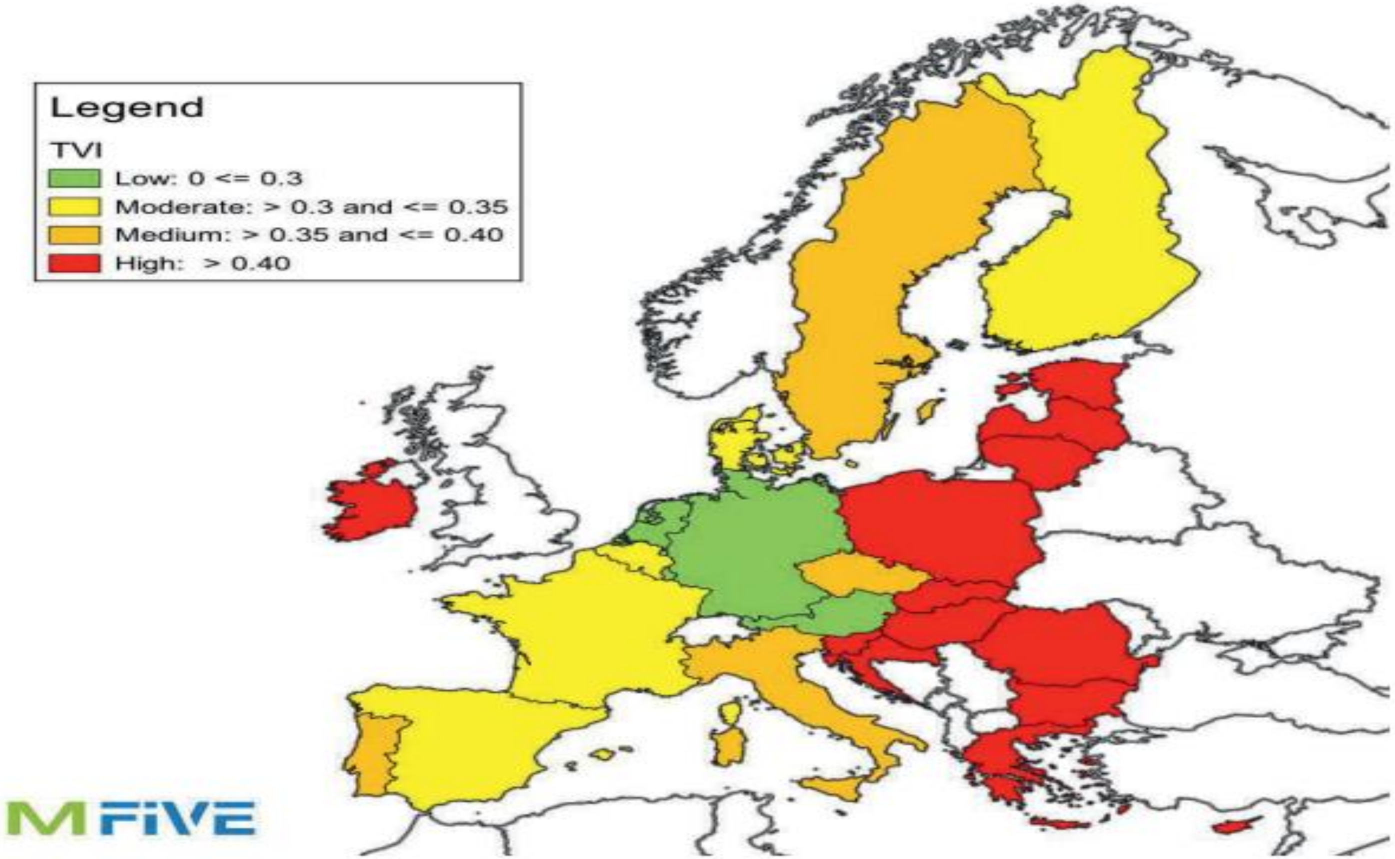
Transport Vulnerability Index (TVI): composite indicators



Source: M-Five, own elaboration

Figure 4.21 Dimensions and indicators of the TVI

Transport Vulnerability Index: application



Source: M-Five, own elaboration

Figure 4.23 Vulnerability across the EU Member States

TEN-T infrastructure at risk of river flooding at present

Table 4.8 Infrastructure affected by a present river flooding event of a one-in-50-year magnitude

	Airports[24] [cases]	Railways [km]	Roads [km]	Ports Maritime[25] [cases]	Ports IWW[25] [cases]
AT	2	578	305	4	4
BE	0	265	158	7	7
BG	0	229	146	6	6
CH	1	177	112	0	1
CZ	0	400	57	9	9
DE	3	2471	958	60	66
ES	3	1158	362	0	1
FI	3	673	907	2	2
FR	0	2442	997	14	16
HR	1	383	304	0	0
HU	0	888	679	7	7
IE	0	30	28	0	0
IT	3	922	790	3	4
LT	0	52	66	2	2
LU	0	5	1	0	0
LV	1	169	248	0	0
NL	2	1097	1169	0	0
NO	1	515	330	0	0
PL	0	466	346	0	2
PT	0	211	82	0	0
RO	1	798	432	0	0
SE	6	756	934	0	0
SI	1	115	65	0	0
SK	1	600	312	0	0

Source: M-Five, own elaboration and JRC river flooding data

TEN-T railways at future risk and in need of adaptation

Medium-high emissions scenario RCP6.0, mid-century time horizon (2024-2075)

Table 4.13: The TEN-T railway network at risk by hazards and Member States in kilometres (core and comprehensive)

Member States	Total length on the TEN-T network	Wildfires	River floods	Heatwaves	Coastal floods	TVI
AT	3,059	0	651	796	0	Low
BE	2,387	0	254	0	0	Moderate
BG	2,372	1,316	0	322	10	High
CZ	3,179	0	0	409	0	Medium
DE	15,141	0	723	1,067	366	Low
DK	1,083	0	37	51	95	Low
EE	1,158	301	27	0	0	High
EL	3,046	2,459	0	1,134	46	High
ES	14,622	11,254	0	2,429	118	Moderate
FI	3,958	127	176	0	0	Moderate
FR	17,553	4,618	2,195	291	138	Moderate
HR	2,027	95	229	432	63	High
HU	3,667	0	620	2,434	0	High
IE	1,685	1,351	276	0	204	Medium
IT	11,273	1,374	398	1,768	131	Medium
LT	1,986	0	0	0	0	High
LU	216	0	0	0	0	Low
LV	1,622	53	0	0	0	High
NL	2,480	149	1,714	0	88	Low
PL	10,112	0	871	1,931	76	High
PT	3,205	2,123	0	322	224	Medium
RO	5,739	1,725	23	0	0	High
SE	5,225	0	459	165	173	Medium
SI	987	0	0	281	0	Medium
SK	1,578	0	65	961	0	High
EU27	**119,356**	**26,946**	**8,718**	**14,794**	**1,733**	

Source: M-Five, own elaboration, for wildfire and river flooding based on the EMF

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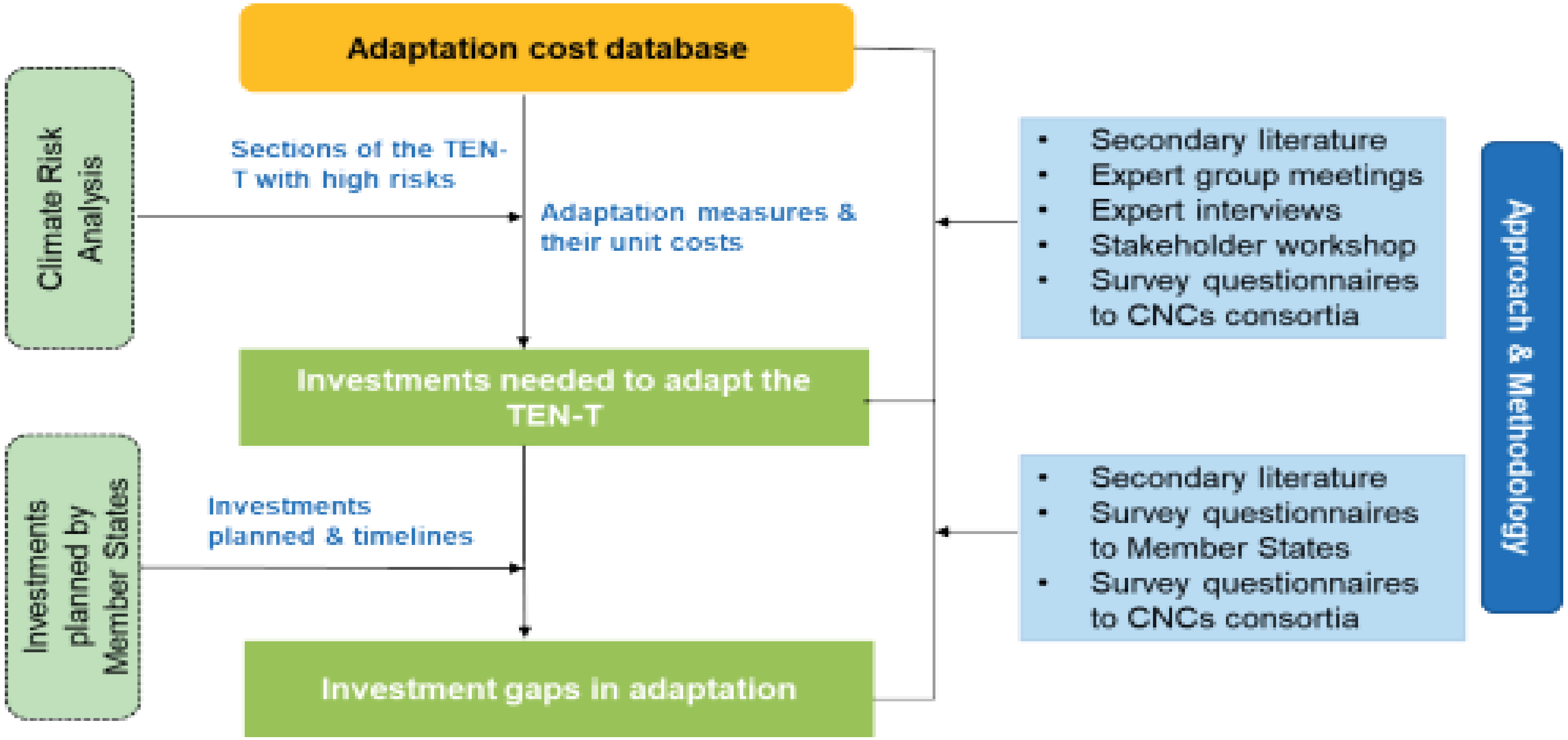
Adaptation measures and cost database



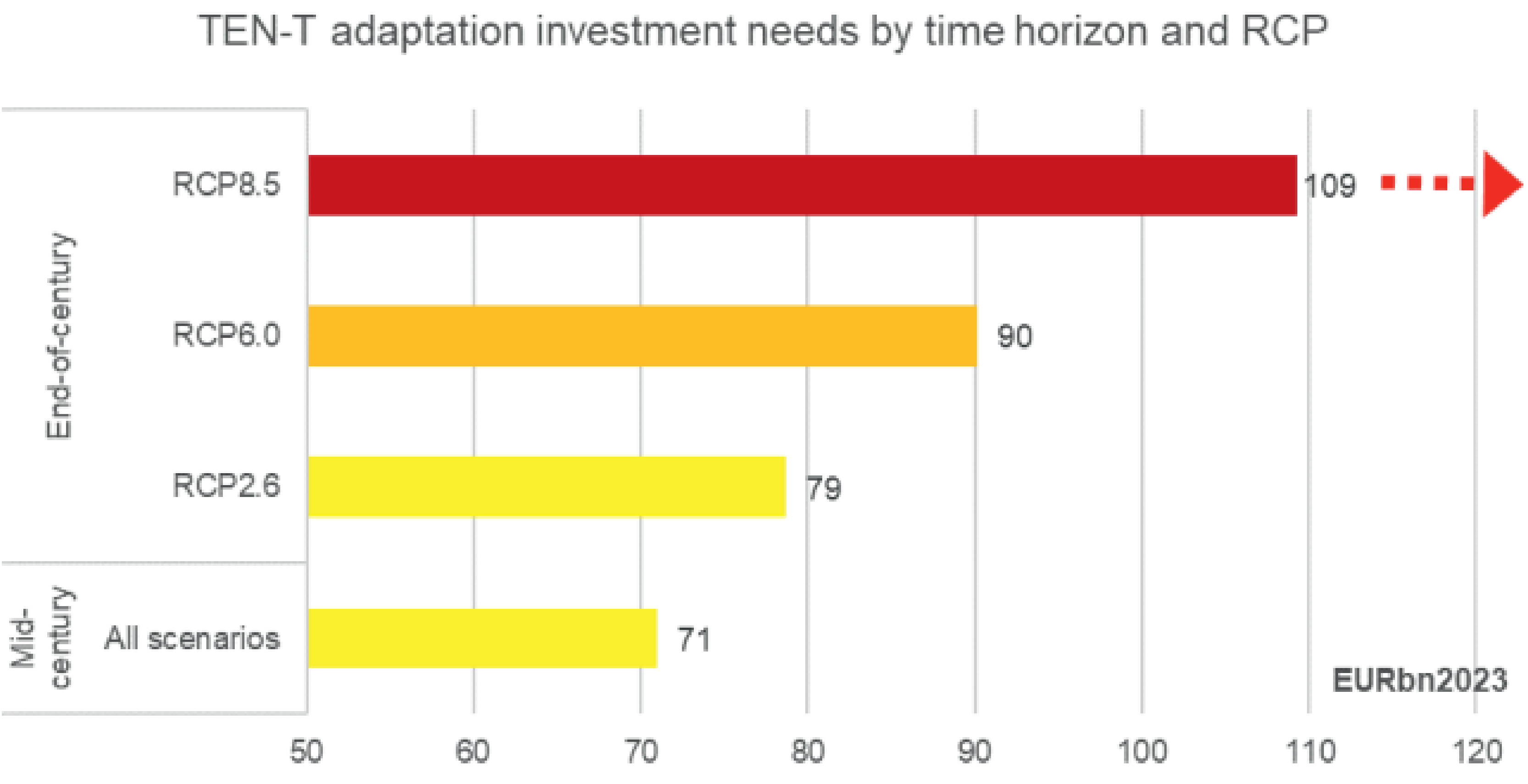
Source: M-Five, own elaboration

Figure 4.30 Approach for assessment of climate adaptation cost of the TEN-T

Adaptation measures: focus on railways

Railways	Heat waves	• Heat protection of urban transport systems (e.g., tram shading, metro cooling) • **Continuous welded rail lines**
	Coastal flooding	• Elevation of streets, bridges, and rail lines • Addition of drainage canals near coastal rail-roads • Elevation and protection of bridge, tunnel, and transit entrances • Additional pumping capacity for tunnels • Nature-Based solutions for coastal railways resilience (e.g. marshes and seawalls) • **Levees, seawalls, and dikes**
	Flooding	• Upgrading of drainage systems • Protection of bridge piers and abutments with riprap • Increases in culvert capacity • Increases in pumping capacity for tunnels • Addition of slope retention structures and retaining facilities for landslides
	Tropical cyclones	• Changes in bridge design to tie decks more securely to substructure and strengthen foundations • Increases in drainage capacity for new transportation infrastructure or major rehabilitation projects (e.g., assuming more frequent return periods) • Removal of traffic bottlenecks on critical evacuation routes and building of more system redundancy • Adoption of modular construction techniques where infrastructure is in danger of failure including modular traffic features and road sign systems for easier replacement
	Wildfires	• Nature-based solutions (e.g. landscaping)

Future adaptation investment needs under the 3 examined scenarios



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Source: M-Five

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Adaptation costs per MS and hazard for railways

Table 4.22 Adaptation Costs in EUR millions per Member State and hazards for railways, in mid-century, RCP6.0

Member State	Wildfires	River floods	Heatwaves	Coastal floods	Total
AT	-	302	1,063	-	1,365
BE	-	120	-	-	120
BG	146	-	205	13	364
CZ	-	-	369	-	369
DE	-	317	1,346	963	2,627
DK	-	22	87	334	443
EE	56	10	-	-	66
EL	417	-	1,105	94	1,615
ES	2,095	-	2,600	264	4,960
FI	32	90	-	-	123
FR	989	940	359	355	2,643
HR	12	58	312	95	477
HU	-	156	1,758	-	1,914
IE	392	160	-	711	1,264
IT	278	161	2,057	318	2,814
LT	-	-	-	-	-
LU	-	-	-	-	-
LV	9	-	-	-	9
NL	36	828	-	256	1,120
PL	-	202	1,288	106	1,596
PT	367	-	320	465	1,152
RO	182	5	-	-	187
SE	-	237	245	537	1,020
SI	-	-	287	-	287
SK	-	21	887	-	907
EU27	**5,011**	**3,630**	**14,288**	**4,512**	**27,440**

Source: M-Five, own elaboration

Methodological caveats and need of future research

- Large spatial resolution of the input data on hazards from the climate models: a trade-off between the level of granularity/ resolution and comparability of input data
- Multi-hazard analysis does not include pluvial floods, landslides, hydrological droughts, windstorms, glacial lake outburst floods due to lack of harmonisation of impact models representing these hazards: lower bound estimation of risk and adaptation cost
- RRTs and urban nodes not in scope: urban climate risk assessments to capture specific and local risk factors
- Developing network/local level indicators (e.g., for the age/quality of the infrastructure) would enable a closer understanding of the vulnerability of the network
- Focus on the “preparedness” dimension of climate resilience: “response” and “recovery” dimensions could showcase the trade-offs between adapting to climate change vs. bearing certain risks
- Challenging to obtain accurate cost data for climate adaptation measures

Conclusions and recommendations of the study

- Streamline resilience in TEN-T implementation via new governance mechanisms in the TEN-T Regulation

- The Member States are at different levels of TEN-T adaptation preparedness: identified investment gap of ~ EUR 70 billion until 2035 for the hazards examined by the study

- EU co-funding for works should be made available for and take into account climate adaptation

- Adaptation to cope with the present (baseline) should come upfront. For future adaptation needs, prioritization is useful based on e.g TVI, criticality of the infrastructure in terms of traffic, infrastructure age

- Balance to be found between investing in adaptation, damage repair, and mitigation

- MSs and the Commission should keep track of investments made for adapting the TEN-T (e.g. via NAPs reporting)

- Commission to facilitate exchange of best practices on adaptation and urban climate risk assessments (e.g. in context of Sustainable Urban Mobility Plans)

- Future analysis to address existing caveats

Thank you

Support study on the climate adaptation and cross-border investment needs to realise the TEN-T network: https://op.europa.eu/en/publication-detail/-/publication/26731a63-b904-11ef-91ed-01aa75ed71a1/language-en

European Climate Risk Assessment (EUCRA): https://www.eea.europa.eu/en/analysis/publications/european-climate-risk-assessment

Communication on managing climate risks: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52024DC0091

European Commission