Europe's transport in a changing climate

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Damage costs of extreme events

Present

Transport

The most affected transport mode in Europe is road transport, which bears ca. 80% of total costs, followed by air (16%) and rail transport (3%).

Roads
Rail
Aviation
Inland navigation
Maritime shipping

1998 – 2010: total annual weather-inflicted damage costs across all transport modes, weather categories and European regions were estimated to be €2.5 billion. These costs refer to very extreme events only; damage estimates might be 10 times higher when all adverse weather conditions are considered.

Severe winters and floods have the largest impact on the transport system, with winters accounting for 43% of the costs and floods 39%.

The indirect costs, such as production losses due to delayed or cancelled deliveries or business trips or damages of cargo, have been estimated to amount an additional 20%.

Damage costs of extreme events

Transport

2050

Roads
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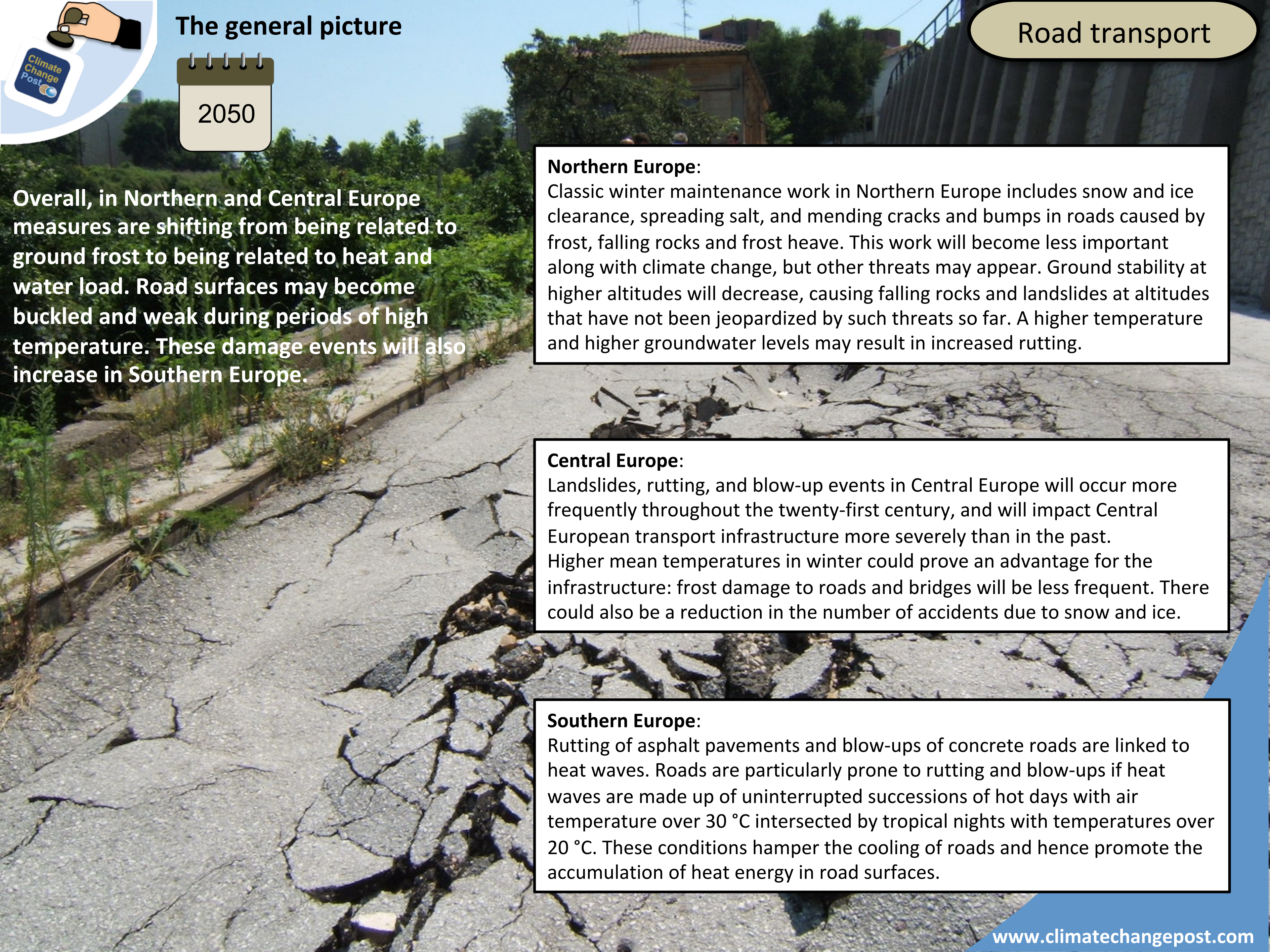
2040 – 2050: 20 % increase of current costs is estimated.

Projections: Average road transport costs will only rise by 7% due to milder winters, rail traffic costs may increase by up to 80% due to more floods and less predictable winter periods.

The impact of climate change on road and rail transport in 2050 in terms of welfare loss as a percentage of GDP is negligible (below 0.1 %), and much lower than the impacts on other sectors, such as water or health.



The general picture

2050

Overall, in Northern and Central Europe measures are shifting from being related to ground frost to being related to heat and water load. Road surfaces may become buckled and weak during periods of high temperature. These damage events will also increase in Southern Europe.

Northern Europe:
Classic winter maintenance work in Northern Europe includes snow and ice clearance, spreading salt, and mending cracks and bumps in roads caused by frost, falling rocks and frost heave. This work will become less important along with climate change, but other threats may appear. Ground stability at higher altitudes will decrease, causing falling rocks and landslides at altitudes that have not been jeopardized by such threats so far. A higher temperature and higher groundwater levels may result in increased rutting.

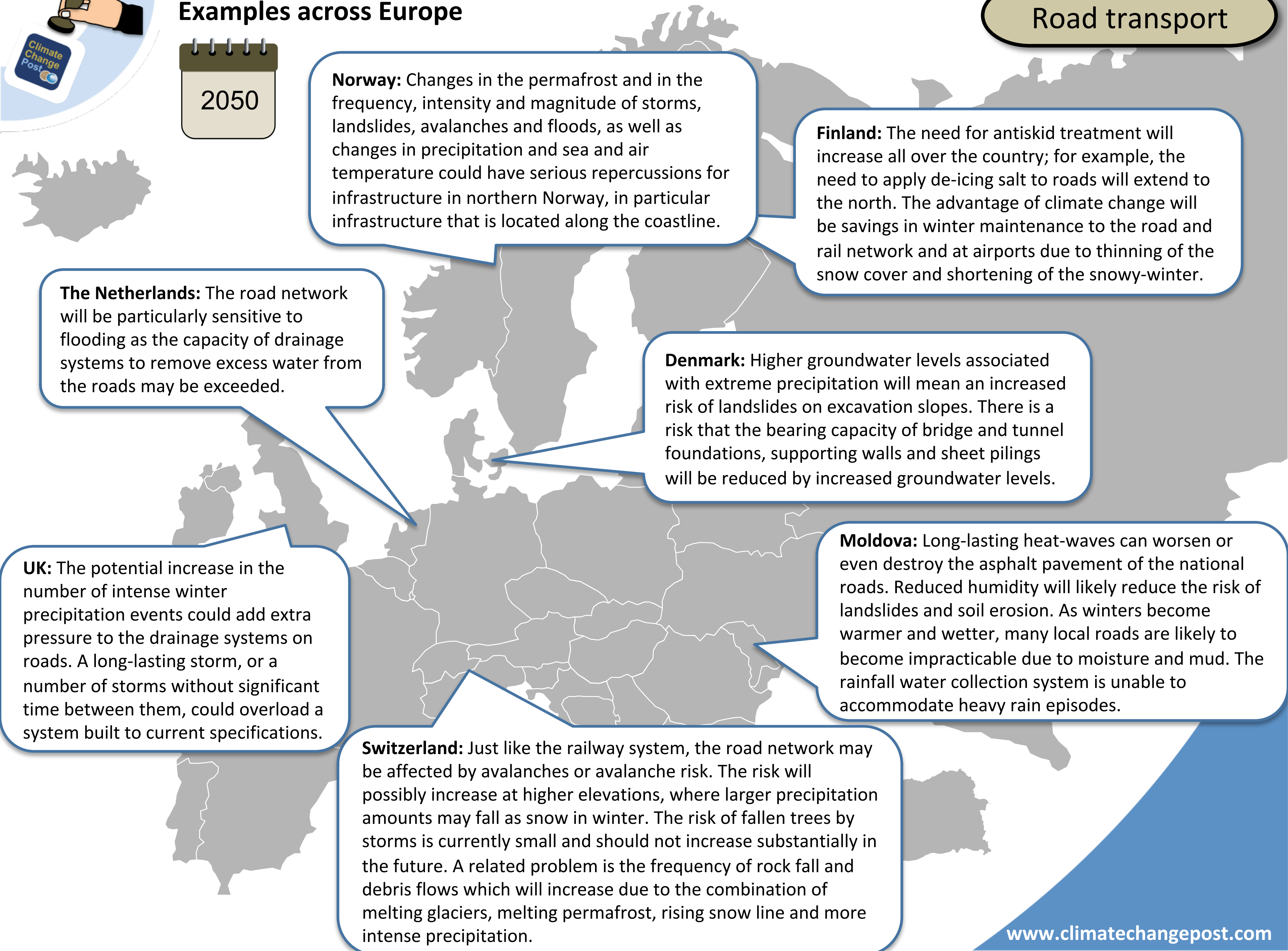
Central Europe:
Landslides, rutting, and blow-up events in Central Europe will occur more frequently throughout the twenty-first century, and will impact Central European transport infrastructure more severely than in the past.
Higher mean temperatures in winter could prove an advantage for the infrastructure: frost damage to roads and bridges will be less frequent. There could also be a reduction in the number of accidents due to snow and ice.

Southern Europe:
Rutting of asphalt pavements and blow-ups of concrete roads are linked to heat waves. Roads are particularly prone to rutting and blow-ups if heat waves are made up of uninterrupted successions of hot days with air temperature over 30 °C intersected by tropical nights with temperatures over 20 °C. These conditions hamper the cooling of roads and hence promote the accumulation of heat energy in road surfaces.

Examples across Europe

Road transport

2050



Norway: Changes in the permafrost and in the frequency, intensity and magnitude of storms, landslides, avalanches and floods, as well as changes in precipitation and sea and air temperature could have serious repercussions for infrastructure in northern Norway, in particular infrastructure that is located along the coastline.

Finland: The need for antiskid treatment will increase all over the country; for example, the need to apply de-icing salt to roads will extend to the north. The advantage of climate change will be savings in winter maintenance to the road and rail network and at airports due to thinning of the snow cover and shortening of the snowy-winter.

The Netherlands: The road network will be particularly sensitive to flooding as the capacity of drainage systems to remove excess water from the roads may be exceeded.

Denmark: Higher groundwater levels associated with extreme precipitation will mean an increased risk of landslides on excavation slopes. There is a risk that the bearing capacity of bridge and tunnel foundations, supporting walls and sheet pilings will be reduced by increased groundwater levels.

UK: The potential increase in the number of intense winter precipitation events could add extra pressure to the drainage systems on roads. A long-lasting storm, or a number of storms without significant time between them, could overload a system built to current specifications.

Moldova: Long-lasting heat-waves can worsen or even destroy the asphalt pavement of the national roads. Reduced humidity will likely reduce the risk of landslides and soil erosion. As winters become warmer and wetter, many local roads are likely to become impracticable due to moisture and mud. The rainfall water collection system is unable to accommodate heavy rain episodes.

Switzerland: Just like the railway system, the road network may be affected by avalanches or avalanche risk. The risk will possibly increase at higher elevations, where larger precipitation amounts may fall as snow in winter. The risk of fallen trees by storms is currently small and should not increase substantially in the future. A related problem is the frequency of rock fall and debris flows which will increase due to the combination of melting glaciers, melting permafrost, rising snow line and more intense precipitation.

The general picture

2050

In Austria, current annual weather-induced costs are two to three times larger in the road sector than in the rail sector. When put into perspective by network length, however, damages are about 300 €/km in the road transport sector and 3300 €/km in the rail sector. Thus, damage events concerning infrastructure are eleven times costlier in the rail sector than in the road sector.

When only direct effects are captured, adaptation measures do not seem beneficial. When indirect effects are also included, adaptation measures in both road and rail sectors clearly pay off.

Floods:
European rail transport damage costs are dominated by floods and their consequences, including landslides, mudflows and avalanches. Floods and mass movements have a high potential for damaging infrastructures with several months of entailed repair and detouring traffic.

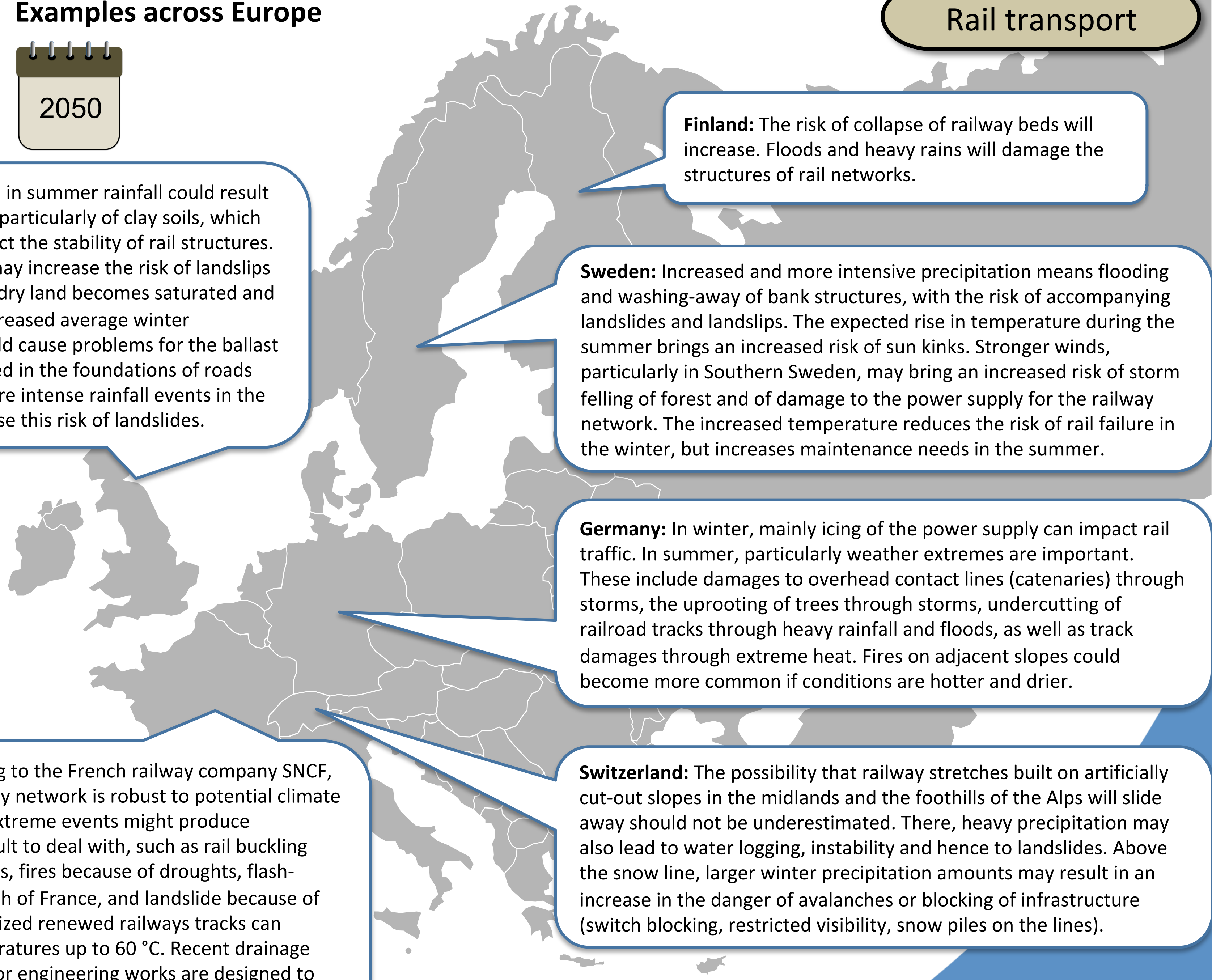
Heat:
The increase in summer temperatures affects the railway system. High temperatures lasting for days can result in lateral displacement of the tracks. This happens because expansion of the tracks due to the heat is blocked by the seamless welding.

High temperatures affect slope stability. In the course of the hot summer of 2003, a great number of rockfalls and rock avalanches were observed in the entire alpine region, in particular at higher elevations and on north facing slopes. As areas with permafrost are very often located outside of settlement and infrastructure areas, the future risk is limited.

Rail transport

Examples across Europe

2050



UK: The decrease in summer rainfall could result in soil shrinkage, particularly of clay soils, which could in turn affect the stability of rail structures. Wetter winters may increase the risk of landslips when previously dry land becomes saturated and unstable. The increased average winter precipitation could cause problems for the ballast and subgrade used in the foundations of roads and railways. More intense rainfall events in the future will increase this risk of landslides.

Finland: The risk of collapse of railway beds will increase. Floods and heavy rains will damage the structures of rail networks.

Sweden: Increased and more intensive precipitation means flooding and washing-away of bank structures, with the risk of accompanying landslides and landslips. The expected rise in temperature during the summer brings an increased risk of sun kinks. Stronger winds, particularly in Southern Sweden, may bring an increased risk of storm felling of forest and of damage to the power supply for the railway network. The increased temperature reduces the risk of rail failure in the winter, but increases maintenance needs in the summer.

Germany: In winter, mainly icing of the power supply can impact rail traffic. In summer, particularly weather extremes are important. These include damages to overhead contact lines (catenaries) through storms, the uprooting of trees through storms, undercutting of railroad tracks through heavy rainfall and floods, as well as track damages through extreme heat. Fires on adjacent slopes could become more common if conditions are hotter and drier.

France: According to the French railway company SNCF, the French railway network is robust to potential climate changes. Some extreme events might produce disruptions difficult to deal with, such as rail buckling during heat waves, fires because of droughts, flash-floods in the south of France, and landslide because of heavy rain. Stabilized renewed railways tracks can withstand temperatures up to 60 °C. Recent drainage systems and major engineering works are designed to cope with at least a 1:100-year flood event.

Switzerland: The possibility that railway stretches built on artificially cut-out slopes in the midlands and the foothills of the Alps will slide away should not be underestimated. There, heavy precipitation may also lead to water logging, instability and hence to landslides. Above the snow line, larger winter precipitation amounts may result in an increase in the danger of avalanches or blocking of infrastructure (switch blocking, restricted visibility, snow piles on the lines).

Examples across Europe

2050

Rail transport

UK:

The London Underground may be affected by longer periods of excessive heat, and more frequent heavy rainfall and flooding.

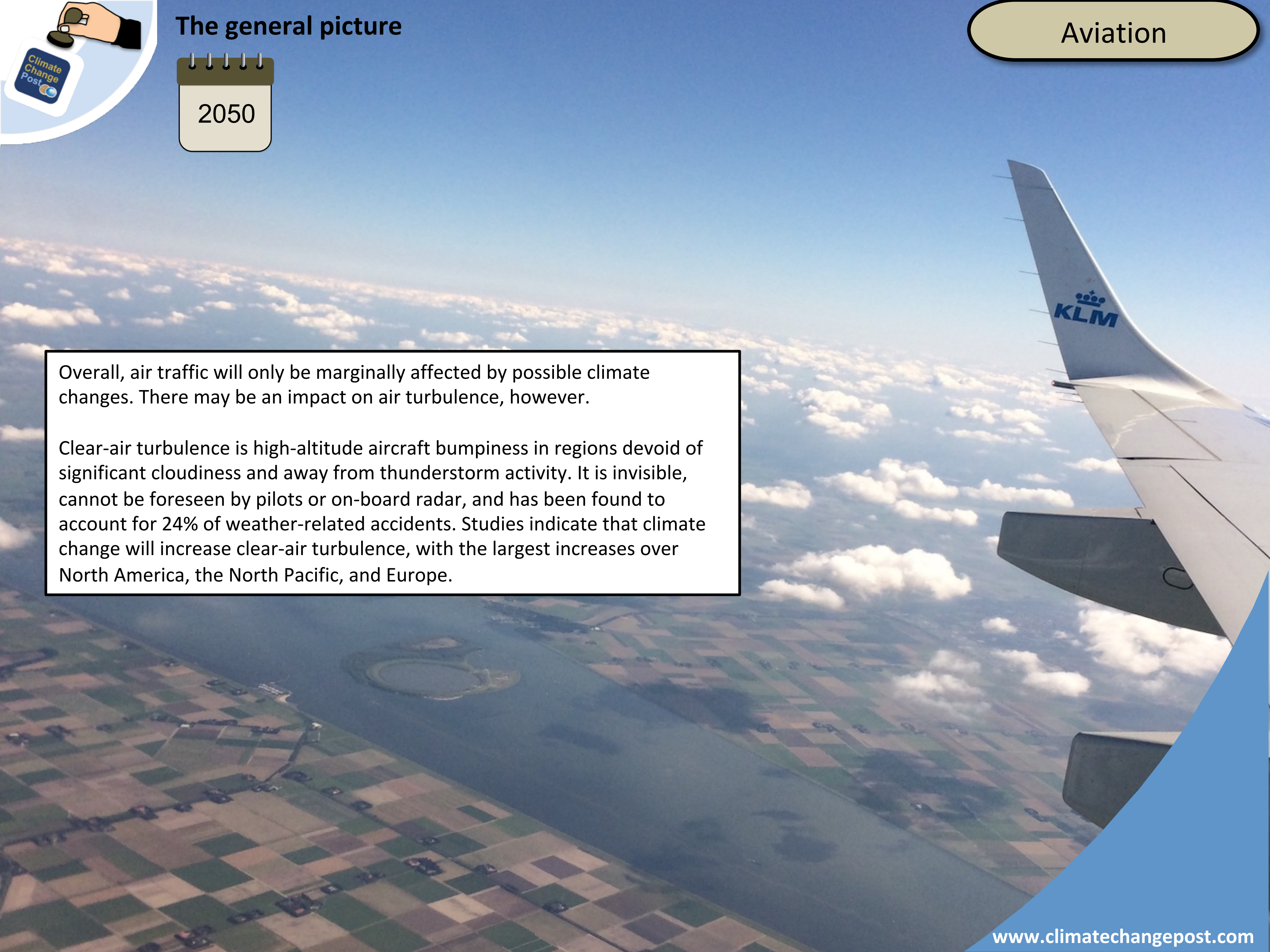
The risk of flooding in the London Underground Rail System, either from groundwater seepage or flooding from the surface, is a major and urgent one. On 7th August 2002, intensive rainfall led to flooding of a number of tunnels and closure of stations and parts of the network. There are well-established procedures in place to deal with pumping water from tunnels, including a combined water pumping strategy, in which groundwater surrounding the tunnels is pumped via boreholes to local water courses, preventing water from entering the tunnels at all. Such pumping does raise the risk of the pumped water being replaced by saline water intrusion. Many lines have flood gates to prevent water entering stations.

Installing air conditioning in the London Underground to deal with excessive heat is not an option. There is not enough space within the tunnels for additional AC units to be attached to carriages.

The general picture

2050

Aviation



Overall, air traffic will only be marginally affected by possible climate changes. There may be an impact on air turbulence, however.

Clear-air turbulence is high-altitude aircraft bumpiness in regions devoid of significant cloudiness and away from thunderstorm activity. It is invisible, cannot be foreseen by pilots or on-board radar, and has been found to account for 24% of weather-related accidents. Studies indicate that climate change will increase clear-air turbulence, with the largest increases over North America, the North Pacific, and Europe.

The general picture

2050

In Europe, the highest amount of cargo by means of inland waterways is transported in the Rhine–Main–Danube corridor. In this corridor, no decrease in the performance of inland waterway transport due to extreme weather events is expected till 2050. Extreme weather events relevant to inland waterway transport are low-water events (drought), high-water events (floods) and ice occurrence. Of less importance are wind gusts and reduced visibility.

The Netherlands: Under a high-end scenario of climate change, transportation costs by inland shipping may increase by 9% to 23%. This is due to increased occurrences of extreme high and low water levels. In the worst case scenario, a 10-day period with the lowest water level, the decrease in transport capacity is up to 28% in all inland navigation to and from the Netherlands.

High-water events

At high water levels, navigation may be restricted in terms of speed limits, the concentration of traffic in the centre of the fairway (to reduce wave stress on the lateral infrastructure) and (at the highest threshold) a general stoppage of navigation. For both the Rhine and the Danube, no change in the frequency of these events has been observed so far.

Future projections:
For the near future (up to 2021-2050), most of the projections for the Rhine point towards a higher number of days than at present when navigation is restricted due to floods. Most projections are clustered in a range between 11 and 20 days per year. For the distant future (2071-2100), the span of results is much wider, ranging between 8 and more than 30 days per year. For the Upper Danube no clear picture can be given yet of the future development in the number of days with restricted navigation due to high flow.

Current trends:
For both the Rhine and the Danube, no change in the frequency of these events has been observed so far.

Low-water events

The Rhine corridor is by far the most important inland waterway in Europe in terms of volume transported, connecting the seaports of Rotterdam, Amsterdam and Antwerp with large industrial areas in Germany.

At extremely low water levels, the price per tonne for inland waterway transport in the river Rhine area will almost double. For the dry summer of 2003, the losses for North West Europe have been estimated to sum up to around €480 million. Shipping may benefit from the low water periods because the temporary reduction in capacity may have a further upward pressure on prices.

Future projections:

There is no convincing evidence that low-water events will become significantly severer on the Rhine as well as the Upper Danube in the near future. However, on the Lower Danube, some impact of drought in association with increased summer heat might appear. Severe low-water situations seem to become more important in the period 2071 - 2100.

Current trends:

For the Rhine, low flow situations with water-levels below a certain threshold for navigation have occurred throughout the 20th century. A clear trend is not discernible in the data, however, neither in the duration nor in the frequency of low flow situations.

Ice, wind and reduced visibility

With respect to the Rhine-Main-Danube corridor, ice is mainly an issue for the River Main, the RMD canal and the River Danube. Since 1950 the number of days with stoppage of navigation due to river ice has decreased.

A distinct reduction of the number of days per year with low visibility on the Rhine-Main-Danube corridor has been observed at all stations in the 1970s. This may be the result of a strong decline of aerosol emissions over Europe.

Opportunities for Trans-Arctic shipping

2100

Due to the reduction in summer Arctic sea ice, the Arctic Ocean can be used as a shortcut between Pacific and Atlantic ports for increasing (summer) periods in future decades.

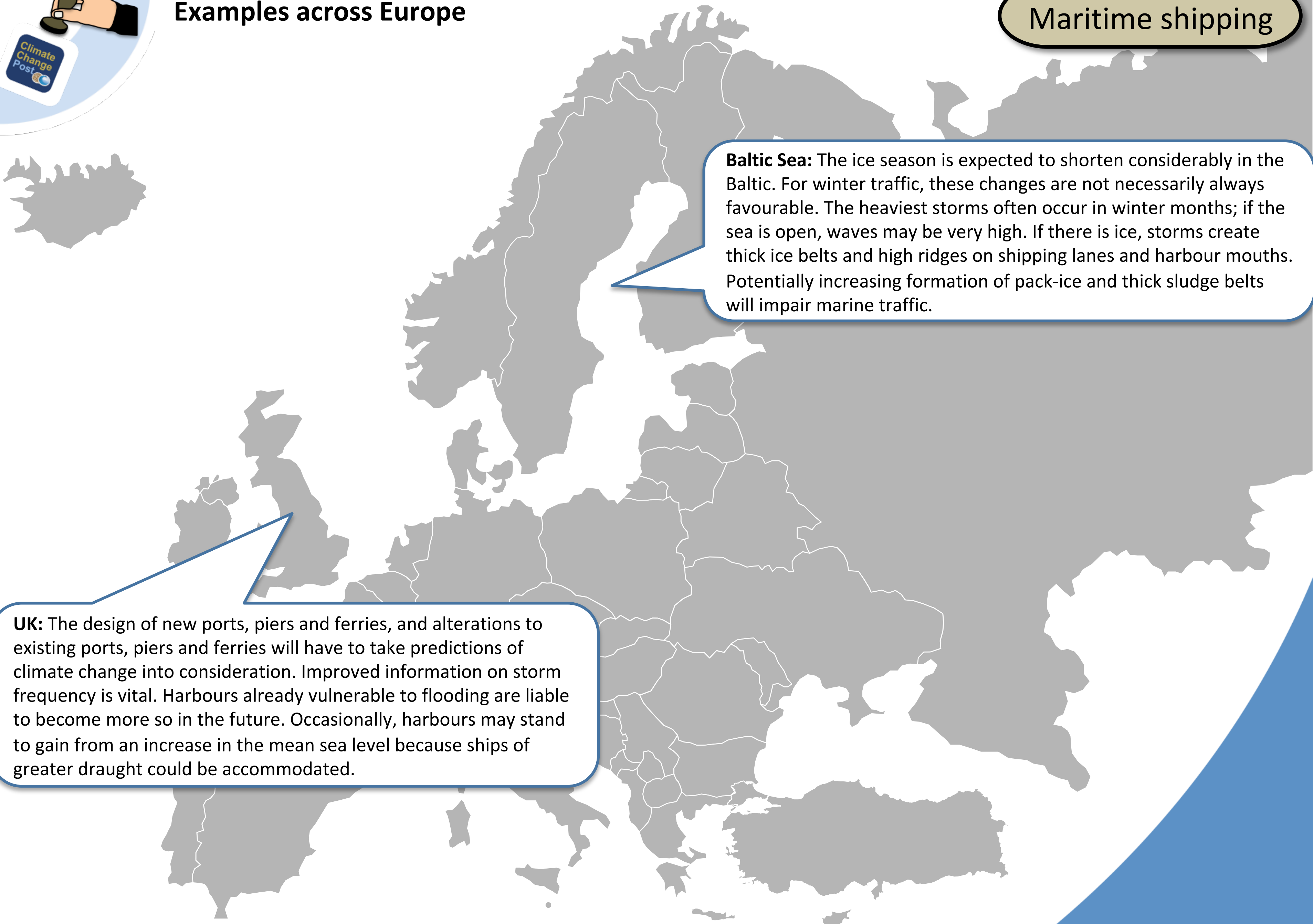
The average journey time between Europe/North America and Asia currently is still dominated by the Suez and Panama Canal routes, but this will switch gradually towards the trans-Arctic routes. As a result, the average minimum journey time for all European (Arctic + Suez) voyages using open water vessels will decrease from 26 days in 2015-2029 to 20-23 days by mid-century and 17-22 days in 2075-2089.

Along with a reduction of average journey time, the season for trans-Arctic shipping will become longer. By the end of the century the majority of the Arctic Ocean is expected to be open water for half the year. For a high-end scenario of climate change, by late century trans-Arctic shipping may be potentially commonplace, with a season ranging from 4 to 8 months. For the low-end scenario, with global mean temperature stabilization of less than 2°C above preindustrial, the frequency of open water vessel transits still has the potential to double by mid-century with a season ranging from 2 to 4 months.

Trans-Arctic navigation is likely to remain a summertime phenomenon. The Arctic marine environment is likely to be fully or partially ice-covered 6–8 months each year for the first half of the century. An ice-free Arctic in winter by 2100 is highly unlikely.

Examples across Europe

Maritime shipping



Baltic Sea: The ice season is expected to shorten considerably in the Baltic. For winter traffic, these changes are not necessarily always favourable. The heaviest storms often occur in winter months; if the sea is open, waves may be very high. If there is ice, storms create thick ice belts and high ridges on shipping lanes and harbour mouths. Potentially increasing formation of pack-ice and thick sludge belts will impair marine traffic.

UK: The design of new ports, piers and ferries, and alterations to existing ports, piers and ferries will have to take predictions of climate change into consideration. Improved information on storm frequency is vital. Harbours already vulnerable to flooding are liable to become more so in the future. Occasionally, harbours may stand to gain from an increase in the mean sea level because ships of greater draught could be accommodated.

Adaptation: Roads and rail transport

Adaptation of rail networks to an increasing number of hydrological events is needed, particularly in the Alpine area. Investments in advanced protection systems (tunnels, protection walls and enlarged drainage) need to be considered.

There seems to be a larger adaptation potential in road transport than in rail. Car-to-car and car-to-infrastructure communication technologies are expected to enter the market in the coming decades and will be connected to weather information systems.
Possible technological adaptations to climate change are using new heat-resistant materials in transport infrastructure (e.g. new pavements), measures against extreme events (e.g. protection against mudflows and relocation of routes (in potential flood areas)), providing roads with larger-capacity drainage systems to cope with intense rainfall.

Adaptation: Inland navigation

Fleet management:

- The most promising measures to adapt to more frequent low-flow conditions in the future involve weight-reducing technologies, flat hulls (for push boat technology), and the use of coupling convoys.
- Adjustment to smaller ship size is unlikely; the advantages of large ships are so large that the current trend of increasing ship sizes may be expected to continue even when low water intervals become more frequent.

River management:

- Improved water management (including dredging) and the construction of structures such as groynes, fixed bed layers, bottom vanes, bendway weirs and dams can counteract fluctuating water levels in rivers. However, such large-scale technological intervention measures are costly, and can conflict with other objectives, in particular goals in nature conservation.

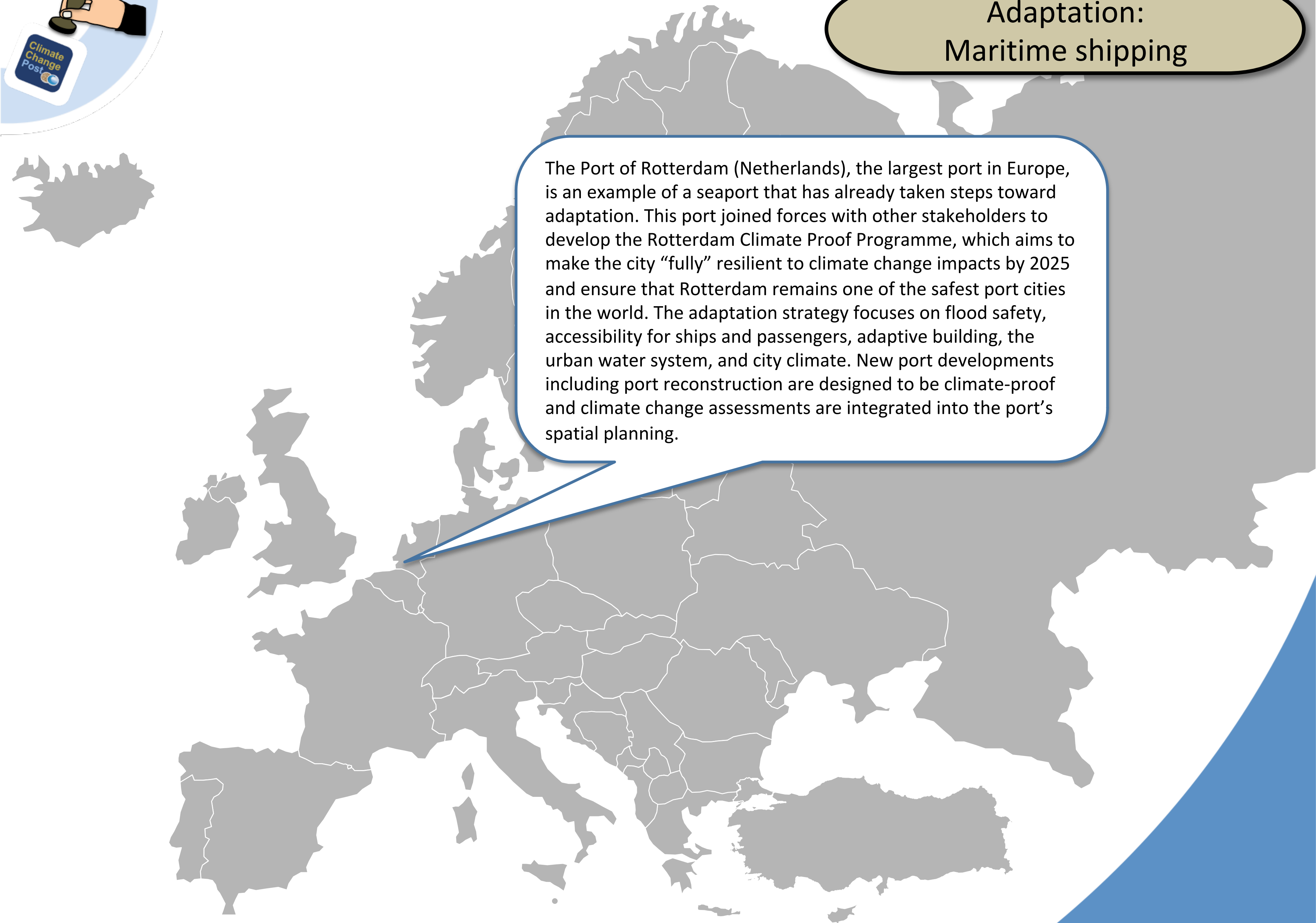
Logistic management:

- In the short run, adaptation to low water periods can take place via modal shift to road and rail transport to avoid the high prices in water transport. Studies indicate that this shift will be modest because even with low water, barges remain relatively cheap.
- 24 h operation, reserve of tonnage, increased storage capacity, cooperation with other modes of transport, alternative routes, other transport modalities, extra cargo handling facilities in ports and terminals enhance flexibility.
- Bulk cargo companies may reduce their vulnerability to low water on the river, and thus ensure continuity of business processes, by increasing their storage capacity for mass cargo. According to projections for the River Rhine, in 2021 - 2050 2.5% and in 2071 - 2100 25% extra storage capacity is needed to compensate the impact of lower water-levels in autumn.

Information management:

- The use of ICT systems for inland shipping can lead to a better exchange of traffic and cargo information. Navigability can be improved by providing up-to-date on-line information on current and expected water depths in the shipping route, expected bed topography, as well as real-time draught and trim of the vessel.

Adaptation: Maritime shipping



The Port of Rotterdam (Netherlands), the largest port in Europe, is an example of a seaport that has already taken steps toward adaptation. This port joined forces with other stakeholders to develop the Rotterdam Climate Proof Programme, which aims to make the city “fully” resilient to climate change impacts by 2025 and ensure that Rotterdam remains one of the safest port cities in the world. The adaptation strategy focuses on flood safety, accessibility for ships and passengers, adaptive building, the urban water system, and city climate. New port developments including port reconstruction are designed to be climate-proof and climate change assessments are integrated into the port’s spatial planning.