Executive summary

The European Commission, together with the member states, has defined clear targets for the decarbonisation of the European economy from 2020 up to the mid of the twenty first century (2050). Today, one main binding target prevails for 2030: a domestic greenhouse gas reduction target of at least 40% compared to 1990, together with the other main building blocks of the 2030 policy framework for climate and energy. The further reduction of greenhouse gas emissions, which leads to a reduction of 80-95% below the 1990 levels, remains the long-term orientation by 2050.

These low carbon trends for the European economy have a direct impact on the design and upgrade of all the European energy infrastructures, with a specific attention paid with the electricity transmission networks critical role for the pan-European power system. The European Network of Transmission System Operators for Electricity (ENTSO-E) has already addressed the developments of the pan-European electricity transmission network until 2030 in the Ten-Year Network Development Plan (TYNDP) 2014. Starting with the same network configuration envisaged by ENTSO-E in 2030, the e-Highway2050 research and innovation project goes beyond 2030: it deals with the transition paths for the whole power system, with a focus on the transmission network, to support the European Union in reaching the low carbon economy envisioned by 2050.

A novel top down network planning methodology has therefore been developed to address such long-term horizons, and used extensively to analyse the network development issues coming from the above long term low carbon overarching goal: this analysis involves five very contrasted energy scenarios which are supposed to provide an envelope of all the possible future evolutions of the European power system while meeting the 2050 low carbon economy orientation.

This methodology relies next on extensive numerical simulations of a model of the pan-European transmission network (made of approximately 100 regional and interconnected clusters): these simulations support an estimation of the benefits of grid expansion, thanks to a modelling of both generation and grid constraints. The robustness is guaranteed by a Monte-Carlo approach covering probabilistically 99 possible years.

The simulations show that the 2030 network is not sufficient to face the 2050 energy scenarios. Indeed, during significant periods, some available generation cannot reach the load. Especially, huge volumes of RES curtailment occur which are compensated by expensive thermal generation emitting CO2.

To tackle these issues, different transmission grid architectures (the starting grid with modifications) have been compared to assess their techno-economic efficiency. The results of the studies exhibit the following trends:

- **An invariant set of new lines and reinforcements has been found**: major “North – South” corridors appear: all scenarios have several reinforcements that connect the North of the pan-European electricity system (North Sea, Scandinavia, UK, Ireland), and southern countries (like Spain and Italy), to the continental synchronous area (northern Germany, Poland, Netherlands, Belgium and France);
- **The network extension rate is driven by the increase of generation capacities, especially renewable sources;**
- The proposed architectures could be **integrated in the present grid**, without introducing a separated ‘layer’ of transmission grid.

The costs of investment in grid expansion depend on the scenarios. They lie between 100 and 400 billion €. However, the study demonstrates that the benefit for the European economy, resulting from an optimal use of energy sources, would largely exceed these costs in all cases. Indeed, up to 500 TWh of RES curtailment and 200 mega tons of CO2 emissions would be avoided annually.

To successfully realize and operate those future transmission grids, key challenges have to be overcome. The project has highlighted some of them in the fields of technology, operation and governance.

Key findings at a glance

A new methodology for the development of the European transmission grid has been developed, able to:

- **Address long term horizons,**
- **Cover the whole Europe,**
- **Cope with the European low carbon objectives, translated at national, and local levels, while building global grid architectures**

An invariant set of transmission requirements has been identified in consistency, and in continuity with the Ten-Year Network Development Plan conducted by ENTSO-E. Their benefits for the European system, resulting from the optimal use of energy sources, largely exceed their costs.

The proposed architectures integrate the present pan-European transmission grid, without needing a new separate 'layer' within this existing transmission network.