Roadmap to 2050: Key Messages from Engineers for COP25

Recognising the urgency for identifying viable technology pathways for decarbonization in the pursuit of meeting the 1.5 C limit to anthropogenic warming set by the UNFCCC, Fondazione Eni Enrico Mattei and the Sustainable Development Solutions Network partnered in a joint effort to investigate technology roadmaps for the transition to zero emissions of four key sectors, notably power, industry, transport, and buildings.

The result of this effort, developed by the two institutions and enriched by technical contributions from more than 70 experts worldwide, is the **Roadmap to 2050: A Manual for Nations to Decarbonize by Mid-Century.**

The Roadmap to 2050 is based on a "systems approach" that aims to address multiple objectives simultaneously and that promotes policy instruments and technological solutions that can be used across many sectors. The multiple objectives span decarbonization and environmental sustainability, economic prosperity (including poverty reduction), and social inclusion. Policy instruments include public investments, the phaseout of subsidies to fossil fuels, market mechanisms, regulatory frameworks on energy and land use, and targeted R&D. Technological solutions include a wide range of existing and emerging technologies, such as 5G-enabled and AI-empowered smart power grids to synthetic fuels produced with renewable energy.

The systems approach identifies several key complementarities for managing the complexity of the energy system. The approach identifies six main pillars for decarbonization:

SIX MAIN PILLARS FOR DECARBONIZATION

ZERO-CARBON ELECTRICITY:
A shift towards zero-carbon electricity mix.

SMART POWER GRIDS:
Systems able to shift among multiple sources of power generation and various end uses to provide efficient, reliable and low-cost systems operations, despite the variability of renewable energy.

ELECTRIFICATION OF END USES:
The penetration of electricity, built on existing technologies, can enable a green conversion for the sectors currently using fossil-fuel energy.

MATERIALS EFFICIENCY:
Improved material choices and material flows, such as reduce, reuse, and recycle to significantly improve materials efficiency.

GREEN SYNTHETIC FUELS:
Deployment of a wide range of potential synthetic fuels, including hydrogen, synthetic methane, synthetic methanol, and synthetic liquid hydrocarbons applicable for harder to abate sectors.

SUSTAINABLE LAND-USE:
Mainly involving the agriculture sector, as it contributes up to a quarter of all greenhouse gas emissions from deforestation, industrial fertilizers, livestock, and direct and indirect fossil fuel uses.

POWER

Power production and distribution is already in the midst of an ongoing decarbonization process in many parts of the world, underpinned by the shift from fossil fuels to renewable energy and other zero-carbon primary energy sources. Current technologies supporting the power sector transition include renewable energy, short-term and long-term storage technologies (e.g. batteries, pumped hydro, and others), geographically distributed networks, sector coupling, dispatchable zero-carbon power (hydro reservoirs, bioenergy), demand-side management (DSM), and various carbon-management technologies, including carbon capture and storage (CCS), carbon capture and use (CCU).

INDUSTRY

The Roadmap examines three energy-intensive sectors: cement, iron and steel, and petrochemicals, each of which contributes to emissions in distinct ways (direct thermal; direct chemical; and indirect). Decarbonization technologies for energy-intensive industry can be categorized in four supply-side decarbonization routes based on electrification, biomass, hydrogen and synthetic fuels, and carbon capture technology. Barriers to the deployment of these four technological routes are mainly economic and not technological per se. Fully decarbonizing such complicated and integrated industrial environments will require a multidimensional, multi-technology approach.

TRANSPORT

The Roadmap considers several transportation sectors—roadways, railways, aviation, and shipping—and each requires its own distinctive technological approaches. Effective decarbonization pathways for transport rely mostly on technological solutions, including electrification and new sustainable fuels (such as hydrogen), complemented by demand-side efficiencies and modal shift strategies. Regulatory frameworks will need to create a fertile environment for innovation, unleashing the potential of the research while fostering virtuous behaviours of all transport modes. Research and innovation need to investigate life-cycle analysis (LCA) and indirect land-use change (ILUC) impacts of the alternative transport technologies to confirm their sustainability, avoiding solution lock-in and stranded assets.

BUILDINGS

The goal of total decarbonization in the buildings sector will be met through the construction of new buildings and districts with zero or nearly zero energy consumption from fossil fuels, and the large-scale retrofitting of existing buildings with net-zero carbon technologies such as heat pumps. Using a combination of readily available technologies and approaches, and performance-based design metrics, net zero carbon buildings and districts can be achieved today through the implementation of key actions such as maximizing energy efficiency through passive and low embodied-carbon solutions; adopting high-efficiency technical systems and advanced control/management strategies; and maximizing on-site or nearby renewable energy production and own-consumption while electrifying the buildings sector.

Roadmap to 2050: A Manual for Nations to Decarbonize by Mid-Century is conceived as a technical toolkit for policymakers for the adoption and implementation of effective decarbonization pathways at all scales: local, national, and regional. The roadmap examines technologies, regulatory policies, and economic measures to implement the pathways.

COST-COMPETITIVENESS OF TECHNOLOGIES

While many of the analysed technologies are already cost-competitive and are likely to offer even lower costs in the future, others (e.g. electricity storage and carbon capture) will require future technological developments and/or increased economies of scale to support their effective deployment at the levels needed to achieve a full decarbonization of the power sector.

FAIR COMPETITION

Competition applies across all four sectors. Regulations and incentives should aim to promote least-cost and most robust solutions, with transfer payments and other instruments ensuring social inclusion and social justice in the transition process.

POWER SECTOR DECARBONIZATION

Decarbonizing the power sector is the main precondition to reaching full decarbonization of other segments due to the strong cross-sectoral interactions between power generation and other technologies.

EQUALITY VS EQUITY

Ample attention must be given to low-income countries and developing regions where decarbonization must occur without impeding economic development or increasing inequities with the high-income countries. And within every country, policies must be directed to ensuring that vulnerable groups and regions are treated equitably during the energy transition.