Summary

The sharply increasing trend of global GHG emissions in the last forty years has urged countries to set increasingly demanding decarbonization targets and place sustainability on top of their 2030 and 2040 agendas. Transitioning towards a decarbonized energy system does not only imply a technological overhaul – with carbon-intensive energy sources that should be replaced by more sustainable alternatives – but also to adequately balance sustainability with energy security and affordability, three attributes better known as the Energy Trilemma.

Simultaneously and effectively accomplishing these attributes is extremely challenging as the paths leading to their improvement are usually diverging and conflicting. Furthermore, energy systems are frequently influenced by external events that may change the prioritization of the attributes.

The Russo-Ukrainian conflict renewed the competition between energy security and sustainability and exhorted European countries to re-think their oil and gas supply systems while struggling to protect final consumers from the price volatility that affected energy supplies and simultaneously work to achieve their decarbonization targets.

Indeed, the decarbonization pathway will be likely pulled by electricity, thanks to the possibility of producing it from renewable energy sources. At the same time, given the unfeasibility of electrifying all the final energy uses, the present energy system is expected to transition towards a multi-commodity framework where electricity will be supported by alternative commodities such as green hydrogen, biofuels and synthetic fuels. From a broader perspective, the concepts of Energy Trilemma and multi-commodity are reciprocally intertwined, because the selection of specific commodities at the policy decision-making level inevitably affects the security, sustainability and affordability of the energy system they are part of.

In this framework, this thesis joins together the concepts of Energy Trilemma and multi-commodity energy systems presenting an optimization framework where

several energy mixes are reciprocally compared with reference to the three Trilemma attributes. More specifically, the work consists in four sections: the first presents the framework of the Energy Trilemma and investigates the tight link between geopolitics, i.e., the study of how geography and socioeconomics influence the processes of policy decision-making, and energy systems, analyzing the impacts of the Russo-Ukrainian and Israeli-Palestinian crises on energy supplies. Then, the reasons behind development of a multi-commodity energy system are introduced and discussed and joined to the idea of Commodity Energy Chains, developed to compare energy commodities in relation to the final energy consuming uses they match and the technologies they are supplied by. The third section analyzes the energy transition in the Mediterranean Basin and its countries: the area, historically characterized by the simultaneous presence of countries with a high dependence on energy imports and oil&gas producers and net exporters, represents the perfect candidate to assess the levers and the bottlenecks of a demographically and socioeconomically tessellated context along its journey towards decarbonization.

In conclusion, the last section illustrates the narrative, the reference system and the main features of the aforementioned energy optimization model. The proposed approach stands out as it effectively integrates the concepts of Energy Trilemma and multi-commodity energy system in a single optimization framework and easily helps to infer what energy commodity mixes are preferable, depending on which is given more relevance among security, sustainability and affordability. Results suggest and confirm that electricity is the energy commodity that will presumably pull the transition thanks to the possibility of exploiting endogenous renewable generation, thus producing carbon-free energy at almost zero cost while improving energy independency and, consequently, security.