NEW NUCLEAR PROGRAMS IN LONG TERM SCENARIOS: UPDATING THE REACTOR DESIGNS AND POLICIES IN THE INTEGRATED ASSESSEMENT MODEL POLES

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Overview

In the last decade, and following the Fukushima accident in 2011, the plans to build new nuclear reactors have considerably evolved. The nuclear industry has seen the emergence of Small Modular Reactors (SMRs). Advanced reactor startups offer a path to cheaper, faster alternatives to conventional reactors. A wider range of applications and locations is targeted. Furthermore, enhanced safety measures in new large reactors were developed, despite major delays for some projects. Robust reactor designs were applied in countries that had no nuclear programs. The global perception of nuclear energy has turned more positive in recent years. Those aspects, associated with the global goal to achieve global net-zero greenhouse gas emission, has led an alliance of countries to announce at the COP29 UN climate change conference a plan whose goal is to triple the global nuclear energy capacity by 2050.
What development for nuclear technologies can be expected from a modelling point of view, including the competition between conventional and advanced reactor? What would be the impact of such a growth on natural uranium resources, not only in 2050 but up to 2100? And how the nuclear technologies would adapt to the need for dispatchable power in a context of growing shares of Variable Renewable Energies ? To answer those questions we updated and improved the modeling of nuclear energy technologies in the Integrated Assesment model (IAM) POLES-Enerdata (Prospective Outlook on Long-Term Energy Systems).
This study will present a comprehensive analysis of the transition from current generation nuclear reactors to future generation reactors and the interaction with an increasing renewable energy development. Using the model, we simulate transition scenarios up to 2100, providing insights into the dynamics of GEN III and GEN IV reactor deployments. A new nuclear fuel management model is implemented, examining the combined effects of economic, geological, and physical parameters on nuclear technology evolution.

Methods

The POLES-Enerdata model simulates long-term energy demand and supply, covering 54 countries and 12 regions up to 2100. It integrates various technologies, simulating the energy mix based on physical, economic and non-economic parameters. The diversity of nuclear reactors designs is simplified into two "generations" of nuclear reactors. The reactors of current generation that need natural uranium for their operation and "new designs", advanced reactors who use recycled materials from the previous ones as start-up cores and will not consume natural uranium in their operating life. For this paper, the model was improved and updated to take into account the lattest data in the volume and prices of natural uranium, the demonstrated capacity of nuclear reactors to do load-following and the changes of policies toward nuclear energy in many countries.

Results

The model shows a high diversity of available resources and development paths, in terms of development of nuclear technologies ans power mix. In the most ambitious scenarios of nuclear development, the cheapest and proven natural uranium resources would be depleted in the second half of this century. We will discuss the impacts of the limited availability of this material on the growth of the two technologies of nuclear reactors and on the market of fuel reprocessing. We will also show how the contribution of nuclear reactors may adapt to the changes in consumption and production of solar and wind resources.

Conclusions

A faster development of nuclear energy relies on many aspects that are often seen separately, such as the market of nuclear uranium, but can be factored in thanks to the use of an Integrated Assessment Model. Following recent nuclear power trends of new designs and the announcement by many countries of a major shift in their nuclear policy, we made a major update in the modelling of nuclear energy in POLES-Enerdata. The results suggest that, at least in some countries, nuclear power can play a crucial role in the future energy mix, provided it can adapt to the variability of renewable production and maintain its economic viability.

References