Projecting Energy and Climate for the 21st Century

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Executive summary

1. Motivations underlying the research

The growing evidence of severe climate change impacts on human life and the global economy has created the increasing need for an assessment of low-carbon pathways. Energy and climate scenarios have an important role to play in assessing the energy system transition required to mitigate climate challenges. Energy and industrial companies, governments, civil society and other stakeholders need to align their strategies with the science-based targets while continuing economic growth and development including providing reliable and affordable energy. Numerous expert groups and individual researchers produce energy scenarios and analyze their implications for climate.

While the ultimate goal of zero- or near-zero global emissions is clear, the timing and trajectory to achieve low-carbon economic system are subject to substantial uncertainty driven by policy structures, technological progress, and societal pressures. As a result, most of the scenarios that do not force a particular outcome (like net-zero emissions or certain percentage of renewable energy) diverge substantially from the scenarios that define a set of particular desired outcomes and explore the ways to achieve those outcomes.

For the Paris Agreement process, countries have submitted their plans to reduce greenhouse gas (GHG) emissions. Numerous studies have shown that the current pledges, formulated as Nationally Determined Contributions (NDC), are inadequate to bridge the gap between the resulting emissions in the next decade and the least-cost pathways to stay below 1.5°C or 2°C. The current emission pathways imply the global warming by around 3°C by 2100 with a continuing increase in temperature afterwards. Despite the efforts to accelerate the energy transition, the progress has been rather slow. The motivation for this paper is to explore the major dimensions of the major long-term energy and climate forecasts and to compare their similarities and reasons for their diversity. We search for some robust findings for the energy system mix developmet and the required efforts for de-carbonization. Cinsidering both medium-term and longer-term trajectories, we look at the dynamics of technology mix evolution required to achieve deep de-carbonization goals to assess if dominant technologies are performing differently in different emission mitigation regimes.

2. A short account of the research performed

Focusing on the most-established periodically-updated outlooks, we compare their forecasts with the integrated approach from the MIT Joint Program Outlook that can be used for a quantitative analysis of decision-making risks associated with different energy pathways. We start with a short

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description of historic trajectories for global primary energy use and related CO_2 emissions. Then we contrast the historic trends with projections of global energy in the next couple decades, up to 2040.

We distinguish between the descriptive or "the best guess" scenarios and prescriptive scenarios. Descriptive scenarios are constructed to provide the "most likely" outcomes under the current policies. Prescriptive scenarios are constructed to explore the required energy trajectories to reach a particular target (e.g., achieving certain percentage of renewables, the 2°C target, or net-zero emissions by a certain date).

For an analysis of the descriptive scenarios, we explore the Stated Policies Scenario from the 2019 IEA World Energy Outlook, the 2019 BP Evolving Transition Scenario, the 2019 ExxonMobil Outlook Scenario, and the Paris Scenario from the 2018 MIT Joint Program Outlook. For prescriptive scenarios, we focus on the Sustainable Development Scenario from the 2019 IEA World Energy Outlook, the 2019 BP Rapid Transition Scenario, the 2018 Shell Sky Scenario, and the 2°C Scenario from the 2018 MIT Joint Program Outlook. We compare their views on the roles of fossil fuels (natural gas, oil, coal) and renewables in their contribution to the global primary energy. To provide an example of an integrated approach that combines the long-term projections for energy, emissions, and the resulting climate variables such as temperature, precipitation, sea level rise, and ocean acidity, we discuss the MIT Joint Program Outlook that assesses several 2°C and 1.5°C scenarios.

3. Main conclusions and policy implications of the work

We find that projecting energy and climate is getting more challenging because of a clear divergence between descriptive (i.e., those that track the stated policies) and prescriptive (i.e., those that show a path to a particular target) scenarios. It is also getting more difficult to assess the credibility of numerous declarations related to the de-carbonization goals, such as aspirations to achieve full energy access in a few years, to reform energy prices, and/or to reach the net zero emissions in some countries and/or sectors.

Exploring the major energy outlooks for the shares of energy types in the global primary energy use, we find that under the current policy (descriptive scenarios), the fossil fuel share is projected to be reduced from the current (2018) contribution of about 80% to around 73-76% in 2040. In the scenarios consistent with the 2°C goal (prescriptive scenarios), the fossil fuel share is further reduced to about 56-61%. On the other hand, the share of wind and solar (which is the majority in the "other renewables" category) is increasing to 6-13% in the descriptive scenarios and to 17-26% in the prescriptive scenarios. While the shares of renewables differ between the outlooks, none of the scenarios envisions the complete de-carbonization of energy in the next 20 years.

Looking at the projections up to 2100, we show that the seemingly winning in the medium-term technologies may not be the dominant long-term solution for de-carbonization. We conclude that the pathway for a particular technology depends on many economic and political variables, and rather than been informed by a single or several scenarios, a range of projections that encompass plausible futures provides a good guidance for a strong decision-making.