Setting the Bar for 2035: Energy Foresight Scenarios for Estonia

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This research explores scenarios of global energy futures and their implications for Estonia, providing further insights into how the outlook might need to be adjusted as a result of the coronavirus pandemic. The paper makes several contributions. After summarizing energy trends and uncertainties, the author uses scenario planning to develop energy foresight for the year 2035 and beyond. This narrative-based approach allows consideration of alternative future trajectories rather than relying on extrapolation of current trends. The paper is informed by over 60 different energy scenarios that have been developed by consultancies (e.g. BloombergNEF), energy companies (e.g. Shell) and international organizations (e.g. EIA). Importantly, the paper integrates views on energy futures that are suggested by non-Western think thanks (e.g. Skolkovo in Russia, KAPSARC in Saudi Arabia) and NGOs (e.g. WWF Japan), providing one of the most comprehensive overviews of the issue that is currently available. Based on the reviewed scenarios, the author suggests four meta-scenarios that depend on the policy and economic environment as well as the rate of technological progress. To explore the limit of the current 'scenario cone', the paper considers a wild card scenario that introduces a disruptive technology that changes the energy system as we know it. In the final step, the paper discusses implications of different meta-scenarios for Estonia.

Keywords: scenario planning, energy transition, energy outlook, general purpose technology, artificial intelligence, COVID-19

1. Introduction

Energy issues are characterized by a high degree of uncertainty and high complexity. In order to capture the interrelation of different factors, highly sophisticated models are often employed by think tanks, international organizations, consultancies, and industrial companies. Rather than focusing on predicting the future with the utmost mathematical accuracy, scenario planning explores and describes plausible futures. Thus, it presents a compromise between a 'highly formal model and informal conjecture' (Huss, 1988[1], cited in Schoemaker, 2004[2]). While considering multiple plausible futures, scenario planning instills the necessary structure to guide one's thinking, providing solid frameworks for strategic decision-making. Scenario analysis has gained popularity in the recent years among the international policymakers. Since 2018, the governments of 11 countries and seven research institutions have participated in the Long-term Energy Scenarios for the Clean Energy Transition campaign (LTES campaign), disseminating best practices of long-term scenario-building under the auspices of the International Renewable Energy Agency (IRENA, 2019[3]). This campaign will last for 2 more years, showcasing the advantages of the LTES as a planning method.

Building long-term energy strategy is important for Estonia, a country that is a signatory to Paris Agreement (UN, 2016[4]) and has recently announced its support for achieving net-zero emissions in the European Union by 2050 (Bloomberg News, 2019[5]). Estonia has met its 2020 targets for renewable energy and energy efficiency, despite having the highest carbon intensity of all IEA countries in 2017 (IEA, 2019[6]). On per-capita terms, Estonia's C02 emissions in 2017 were comparable to those in the US, Canada, Australia, Saudi Arabia, and Kazakhstan, reaching 15.13 tonnes (Ritchie and Roser, 2019[7]). The two main issues are the integration of renewable energy (RE) into the transportation sector and the country's reliance on domestic oil shale, a carbon-rich fossil fuel (European Commission, 2020[8]).

In the last two years, the country has experienced a remarkable drop in carbon emissions. According the EU Emissions Trading Scheme, the energy- and industrial sector emissions dropped to 8.5 million tonnes

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[1] Huss, W.R. 1988. A move toward scenarios. International Journal of Forecasting, 4, 377-388.

[2] Shoemaker, P.J.2004. Forecasting and Scenario Planning: The Challenges of Uncertainty and Complexity. In D.J. Koehler and N. Harvey eds. Blackwell Handbook of Judgement and Decision Making. pp.274-296. Oxford: Blackwell Publishing

[3] IRENA. 2019. Long-term Energy Scenarios for the Clean Energy Transition, first-year campaign findings. Report. May 2019

[4] United Nations, 2016. List of Parties that Signed Paris Agreement on 22 April. Available online at: https://www.un.org/sustainabledevelopment/blog/2016/04/parisagreementsingatures/

[5] Bloomberg News. 2019. Net-Zero Carbon Emissions Goal Comes a Step Closer in Europe. Ewa Krukowska. October 3, 2019. Available online at: https://www.bloomberg.com/news/articles/2019-10-03/net-zero-carbon-emissions-target-comes-a-step-closer-for-europe

[6] IEA. 2019. Energy Policies of IEA Countries: Estonia 2019 Review, IEA, Paris https://www.iea.org/reports/energy-policies-of-iea-countries-estonia-2019-review

[7] Ritchie, H., and Roser, M. 2019. CO2 and Greenhouse Gas Emissions. December 2019. Our World in Data. Available Online at: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

[8] European Commission. 2020. Commission Staff Working Document. Country Report Estonia 2020. Brussels, February 26, 2020. SWD(2020) 505 final.

of CO2 in 2019, down from 14.7 million tonnes of CO2 in 2017, with further declines expected in 2020 (Ministry of the Environment of Estonia, 2019)[9].

Decreasing the importance of domestic shale oil is a not a quick process and its phase-out has been carried out stepwise, with its horizon recently extended to 2030 (ERR news, 2020[10]). In 2018, country's generation mix has been dominated by coal (10,093 GWh), followed by smaller shares of biofuels (1,255 GWh) and wind power (636 GWh) (IEA, 2019[11]). The Estonia's national grid system is among the most interconnected in the world, being part of the BRELL system that connects Estonia to Latvia and Russia, all the way to Lithuania and Belarus (Elering, 2020[12]). Additional interconnections to Finland, Sweden, and Denmark, allow Estonia to be part of a single regional electricity market. In the coming years, it is envisaged that Estonia will leave the BRELL system, to participate in the electric grid of the continental Europe (ibid.) Moreover, Estonia has been one of the pioneering countries that embraced electric vehicle (EV) charging back in 2013, covering the country with a network of 165 fast-charging stations (Forbes, 2013[13]). The growth of the electric vehicle market has not been as fast as expected, with about 1,000 electric vehicles on the road in Estonia in 2019, but further integration of the grid with the EV sector is underway (Eesti Energia, 2019[14]). The country has adopted other numerous digital innovations, such as smart meters, which allowed importing to the internet all consumers' annual energy data via blockchain, serving as an early experiment in digital energy trading via Ethereum (Digigeenius, 2018[15]).

By the end of 2019, Estonia has developed an ambitious energy and climate plan, with 11 energy-related targets for 2030, which range from carbon reduction and energy demand, to renewable energy share in production of heat and power, as well as in transportation sector (Ministry of the Environment of Estonia[16]). Despite this progress, the outlook for 2030 is unclear, as Estonia's predicted greenhouse gas (GHG) emissions are much higher than target emissions (European Commission, 2020[4]). Moreover, Estonia's carbon pricing initiative prices carbon among the lowest in the world, well below the social cost of carbon of $51/ton suggested by the Interagency Working Group (Brookings Institution, 2019[17]).

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[9] Ministry of the Environment of Estonia. 2020. Energia- ja tööstussektori CO2 heitkogused vähenesid aastaga peaaegu 40%. 30 March, 2020. Available online at: https://www.envir.ee/et/uudised/energia-ja-toostussektori-co2-heitkogused-vahenesid-aastaga-peaaegu-40

[10] ERR News. 2020. Jaak Aab in Kohtla-Järve: there won't be quick end to oil shale industry. February 21, 2020. Available online at: https://news.err.ee/1055447/jaak-aab-in-kohtla-jarve-there-won-t-be-quick-end-to-oil-shale-industry

[11] IEA, 2019. Electricity Information by country. Available online at: https://www.iea.org/data-and-statistics?country=ESTONIA&fuel=Energy%20supply&indicator=Electricity%20generation%20by%20source

[12] Elering, 2020. Electricity System. Available online at: https://elering.ee/en/electricity-system

[13] Forbes. 2013. Estonia Launches Nationwide Electric Vehicle Fast-Charging Network. Written by Justin Gerdes. Available online at: https://www.forbes.com/sites/justingerdes/2013/02/26/estonia-launches-nationwide-electric-vehicle-fast-charging-network/#486b81de2610

[14] Eesti Energia. 2019. Eesti Energia hakkab pakkuma elektriautode laadimisvõimalusi. 08 May, 2019. Available online at: https://www.energia.ee/uudised/avaleht/-/newsv2/2019/05/08/eesti-energia-hakkab-pakkuma-elektriautode-laadimisvoimalusi

[15] Digigeenius. 2018. Kogu Eesti elektritarbinise andmed kanti plohiahelasse. Written by Hans Lougas. 29 October 2018. Available online at: https://digi.geenius.ee/rubriik/uudis/kogu-eesti-elektritarbimise-andmed-kanti-plokiahelasse/

[16] Ministry of the Environment of Estonia. 2019. Eesti riiklik energia- ja kliimakava aastani 2030 (REKK 2030). 19 December 2019. Available online at: https://www.mkm.ee/sites/default/files/teatis_eesti_riiklik_energia-_ja_kliimakava_aastani_2030.pdf

[17] Brookings Institution, 2019. Ten Facts about the Economics of Climate Change and Climate Policy. Report by the Hamilton Project. Authors: Nunn, R., O'Donnell, J., Shambaugh, J., Goulder, L., Kolstad, C.D., Long, X. October 2019.

The price for carbon has fluctuated between 24.7 Euros per tonne C02 in 2019, to 16 Euros per tonne in March 2020, during the pandemic[9]. Taking into account these diverse factors, the IEA suggests that 'Estonia is on the brink of a major energy transition' and recommends that the country carefully balances economic, social, environmental, and geo-political considerations (IEA, 2019[6]). Strategic scenario planning is well-suited to provide such support to the country's decision-makers.

This research provides several important insights into alternative energy futures for Estonia. First, it covers a wide range of scenarios developed by international organizations, think tanks, energy companies, and NGOs. In order to address the potential status quo bias potentially present in the 'Western' scenario development (Braunger and Hauenstein, 2020[18]), the author reviewed scenarios from non-Western sources (e.g. Skolkovo in Russia, KAPSARC in Saudi Arabia). The differences and similarities among the scenarios are discussed and illustrated. The author developed four meta-scenarios, which assume that the energy future is likely to be driven by global economic situation, policies and technological innovation. The *Innovation Unleashed* scenario gives the most prominent role to entrepreneurship, with the government acting as a supporter and an enabler for entrepreneurial infrastructure. *Bad Economy, Hotter World* scenario considers the future when economic calamity crowded out climate action for at least a decade, making it difficult to catch up afterwards to stop considerable warming. The *Big Government Solutions* scenario, which might become more likely due to COVID-19 impacts, highlights the possibility of government-led climate action, including revival of international climate collaboration, but also warns against potential adverse impacts on personal liberties. Finally, the fourth scenario, *Dark Horse*, looks beyond the most plausible futures, venturing towards the edges of the 'scenario cone' (Amer et al., 2013[19]). The *Dark Horse* scenario centers around large-scale deployment of a general-purpose technology (GPT) that will re-shape the energy system as we know it. In the post-coronavirus world, consideration of not-so-likely events can find new relevance. The author suggests that artificial intelligence might be the next GPT (view aligned with Trajtenberg, 2019[20]) with a wide range of applications in energy and beyond (OECD, 2018[21]). The likelihood of the meta-scenarios is subsequently evaluated through the lens of predicted impacts from the COVID-19 pandemic. Finally, the findings are presented in the Estonian context, outlining the implications from the scenarios for different parts of the Estonian society. Thus, the aim of the article is to examine, which global and European uncertainties and trends have relevance for Estonia. The suggested meta-scenarios, while global in nature, should be potentially feasible for the Estonian context.

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[18] Braunger, Isabell, and Christian Hauenstein. 2020. How Incumbent Cultural and Cognitive Path Dependencies Constrain the "Scenario Cone": Reliance on Carbon Dioxide Removal Due to Techno-Bias. *Economics of Energy & Environmental Policy* 9 (1). https://doi.org/10.5547/2160-5890.9.1.ibra.

[19] Amer, M, Daim, T.U., and Jetter, A. 2013. A review of scenario planning. Futures 46: 23–40. https://doi.org/10.1016/j.futures.2012.10.003.

[20] Trajtenberg, M. 2019. Artificial Intelligence as the Next GPT: A Political Economy Perspective. The Economics of Artificial Intelligence: An Agenda. Eds: Agrawal, A., Gans, J., Goldfarb, A. pp. 175-186.

[21] OECD, 2018. AI: Intelligent machines, smart policies: Conference summary, OECD Digital Economy Papers, No. 270, OECD Publishing, Paris, https://doi.org/10.1787/f1a650d9-en.

2. Trend and Uncertainties

In order to engage in scenario planning, it is important to accurately represent both trends and uncertainties of the energy landscape. In broad terms, main trends are demographic, social, environmental, including geopolitical and governance transformations, climate change, and a new model of economic growth (Proskuryakova, 2019[22]). Ernst and Young (2018[23]) define three mega-trends that will change our society in the long-term (beyond 10 years). These include new social contracts between populations, governments and companies, a rebalanced global system that is characterized by the increased role of China, and superfluid markets with minimal market friction. These trends exist in the context of economic growth, population growth (particularly in African urban centers) (IEA, 2019[24]), as well as deep integration of economies (EADP, 2019[25]).

Proskuryakova (2019[22]) and Skolkovo (2020[26]) provide a list of trends in energy and environmental domains:

- Environmental: increased climate risks, environmental changes in precipitation, hydrological regimes;
- Social: limited energy access for some segments of population, increased social protests, conflicts in countries that are hydrocarbon exporters, new geopolitical situations and global governance systems, new competence and skill requirements for employees in the energy industry, recognition of circular economy and water-food-energy nexus paradigm, rise in climate-friendly social attitudes, consumers become prosumers;
- Economic: decreasing energy intensity per unit of GDP, decoupling of economic growth and GDP;
- Energy markets: electrification, increase in global energy use due to population growth, distributed power generation, change in energy mix, increase in volume of processed nuclear fuel, changes in supply chains, increased competition in energy sector, change in business models, need for new frameworks to correctly price novel energy services, integrated electricity and gas markets;
- Technology: digitalization, decentralized energy system, decreased cost (esp. for energy storage, hydrogen technologies, and RE), wide application of smart energy systems, including cloud computing, big data, Internet of Things and Internet of Energy, blockchain technology, microgrids, predictive analytics, smart homes, electric vehicles (EVs), and smart meters.

World Energy Outlook (WEO) 2019 points out several threats, including world oil supply reliance on the Middle East, threats range from cybersecurity to extreme weather, noting that electrification with

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[22] Proskuryakova, L., 2019. Foresight for the ‘energy’ priority of the Russian Science and Technology Strategy. Energy Strategy Reviews, 26, p.100378.
[23] Ernst and Young. 2018. What’s after what’s next? The Upside of Disruption. Megatrends shaping 2018 and beyond. Report.
[24] IEA, 2019. World Energy Outlook 2019. Report by International Energy Agency. November 2019.
[25] EADP. 2019. Global Futures of Energy, Climate, and Policy: Qualitative and Quantitative Foresight Towards 2055, by Ansari, D., Holz, F., Tosun, H.B. Discussion Paper 01/2019.
[26] Skolkovo. 2019. Prognosis of development of the energy sector in the world and in Russia [in Russian]. Report prepared by Skolkovo Institute of Science and Technology. Moscow.

domestic energy resources alleviates some tensions (IEA, 2019[17]). WEO 2019 also predicts a slow-down in energy efficiency improvements and a rapid growth of solar PV (ibid.). In addition to geopolitical tensions, the researchers recognize uncertainties with respect to climate investment flows, dynamics of oil prices, shifts in energy demand, as well as water stress (EADP, 2019[19]).

The COVID-19 pandemic has created a new uncertainty, as the medium- to long-term impact are still unknown. Currently, most predictions are focusing on short-term recovery from the pandemic, as the uncertainty is too large to consider long-term future impacts. For example, Wood Mackenzie (2020)[27] released scenarios for GPD impacts in 2020, ranging from a 0.8% drop in global GDP in case of a quick containment to a dramatic decrease of 2%. Coronavirus decreases energy demand and reduces profit margins, which leads to concern that this downturn will create potential for a global recession. Another estimate considers 7 different scenarios for the economic cost and the loss of life in the pandemic, calculating a range of GDP loss between -0.2% to -8.4% in the Eurozone in 2020, with the average loss of -2.6% across the scenarios (McKibbin and Fernando, 2020[28]).

There are several scenarios for recovery. These are the rapid V-shaped recovery that will strengthen the US, the Nike-Swoosh recovery lead by China and is beneficial to both China and the US, the U-shaped recovery that would break the Eurozone, and the an L shaped recovery that would result in low growth and a prolonged economic depression (Nordic West Office, 2020[29]). A recent opinion poll among global CEOs suggested that U-shaped (60% of respondents) or W-shaped (22% of respondents) recovery might be likely (World Economic Forum, 2020[30]).

The COVID-19 pandemic has likely accelerated long-term trends, propelling the world closer to (or perhaps even past) the peak oil (The Economist, 2020[31]), which happened not due to technological extraction constraints, but rather due to a demand shock. IEA calls the pandemic 'a once in century event', showing that the energy demand has dropped more in 2020 (percentagewise) than during the first and second oil shocks, or the financial crisis (IEA, 2020[32]). In 2020, coal is predicted to see the largest decline since World War II, with considerable negative impacts on demand of oil and gas (ibid.).

Not all crises result in long-lasting societal changes (e.g. Great Depression vs. 2008 financial crisis), but COVID-19 might have a disruptive effect on society at large (Demos Helsinki, 2020[33]). As a result, Demos Helsinki (2020) predict that the social contract will be re-negotiated in the coming 2-3 years. In addition, COVID-19 might result in redesign of global value chains, slowing down of global trade, changed consumption patterns (shrinking of markets for luxury goods, travel, clothes, food, cars, property), and

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27 Wood Mackenzie. 2020. Coronavirus Impact Update: Week of March 23. Report summary.

28 McKibbin, W. and Fernando, R. 2020. The Global Macroeconomic Impacts of COVID-19: Seven Scenarios. Brookings Institution. Available online at: https://www.brookings.edu/wp-content/uploads/2020/03/20200302_COVID19.pdf

29 Nordic West Office. 2020. Alternative Futures for the Global Balance of Power. 28 April 2020. Webinar by Foresight Center at the Estonian Parliament. Presenter Risto Penttilä.

30 World Economic Forum. 2020. This is what the coronavirus recession could look like, according to global CEOs. Available online at:
https://www.weforum.org/agenda/2020/04/global-ceos-coronavirus-covid19-recession-economics-recovery-crisis

31 Economist, 2020. Can covid help flatten the climate curve? 21 May, 2020
https://www.economist.com/briefing/2020/05/21/can-covid-help-flatten-the-climate-curve

32 IEA. 2020. Global Energy Review. 30 April 2020.

33 Demos Helsinki. Webinar summary, 14 April 2020. Available online: https://www.demoshelsinki.fi/en/2020/04/14/webinar-emerging-changes-in-the-post-pandemic-world-2/

increasing prevalence of value-based hyper-local consumption (ibid.). In the same vein, COVID-19 might have changed the nature of work, making the remote work a new normal (EY, 2020[34]), which would allow migration away from metropolitan urban centers and considerable reduction in the number of miles driven for commuters. Some believe that the coming decades will result in bigger governments across the board, less individualism and freedom, potential social unrest. However, many often say that it will also be a boon to virtual reality and digital tools, will bring about revived trust in governments and institution, move leadership from the federal to more local levels, encourage conscious consumption, and strengthen national supply chains (Politico, 2020[35]). The pandemic might result in higher taxes (perhaps even a carbon tax) to offset increased public spending, increased public debt, as well as increased structural unemployment. In general, a survey of over 28,000 adults in 14 countries has shown that climate change is perceived by 71% of respondents as a long-term threat, as 'serious a crisis as COVID-19' (Ipsos, 2020[36]).

At the same time, it must be clear that the disruptive effect of COVID-19 pandemic is only one of many future paths and that there are opposing views, which predict a relatively rapid return to pre-crisis business-as-usual, with a significant recovery in energy prices and energy demand in the coming year (EIA, 2020[37]). With respect to renewables, they are likely to recover to pre-pandemic levels in the short- to medium-term, absent multiple virus waves, a prolonged depression or significant changes in policy or financing. For example, after a disappointing growth in 2020, the solar PV markets are projected to rebound in 2021 and 2022 (BloombergNEF, 2020[38]).

3. Summary of Energy Foresight

The aim of this section to introduce in broad terms the universe of energy scenarios. It must be noted that different scenarios, outlooks, and forecasts are employing varying approaches that can be placed into three categories (WEC, 2019a[39]). First category, where the current contribution falls, is a qualitative narrative-lead scenario planning exercise, which lists plausible alternative future options. This setup offers a structured decision framework for policymakers to understand different uncertainties (ibid.). The second type of foresight can be obtained from setting up increasingly complex energy models, with the focus of creating scenarios that predict the future with the best possible precision (ibid.). Both can be called 'positive' scenarios (describing what *might* happen), in contrast to 'normative' scenarios that are set up to achieve a certain future target (describing what *shall* happen) (Ansari, 2020[40]). Normative

[34] EY. 2020. Why remote working will be the new normal, even after COVID-19. Written by E. Verbeemen and S.B. D'Amico. 9 April 2020. Available online at: https://www.ey.com/en_be/covid-19/why-remote-working-will-be-the-new-normal-even-after-covid-19

[35] Politico. 2020. Coronavirus Will Change the World Permanently. Here's How. 19 March, 2020. Available online at: https://www.politico.com/news/magazine/2020/03/19/coronavirus-effect-economy-life-society-analysis-covid-135579

[36] Ipsos, 2020. How does the world view climate change and Covid-19? Available online at: https://www.ipsos.com/sites/default/files/ct/news/documents/2020-04/earth-day-2020-ipsos.pdf

[37] EIA, 2020. Short-term Energy Outlook. 12 May, 2020. Available online at: https://www.eia.gov/outlooks/steo/

[38] BloombergNEF, 2020. Global PV Market Outlook. 20 May, 2020.

[39] World Energy Council. 2019a. World Energy Insights Brief. Global Energy Scenarios Comparison Review. Technical Annex.

[40] Ansari, D., Holz, F., and al-Kuhlani, H. 2020. Energy Outlooks Compared: Different Methods, Different Futures. *Economics of Energy & Environmental Policy* 9 (1). https://doi.org/10.5547/2160-5890.9.1.dans.

scenarios in energy foresight are often back-calculating current action based on a certain future target, such as share of RE, degrees of global warming, nuclear or coal phase-out or others.

This paper reviews energy scenarios that suggested at least two plausible alternatives. These scenarios were developed by a variety of stakeholders, including consultancies (BloombergNEF (2019)[41], Nordic West Office (2018)[42]), international organizations (IRENA (2019[43]), World Energy Council (2019)[44], IEA's World Energy Outlook (2019[45])), think tanks (EADP (2019[46]), Our World in Data (2020[47])), and energy companies (Shell (2013 [48]and 2019[49]), Equinor (2019[50]), BP (2019[51])). In contrast, Exxon Mobil (2019[52]) and DNV GL (2019[53]) developed a single main scenario, so their projections were not considered in this paper. Not included in this review were also single scenarios dedicated to achieving 100% renewable energy globally (Deloitte (2019[54]), REN 21 (2017[55])) or Europe-wide (SPE/LUT University (2019[56]), Oei et al. (2020)[57]). We added several national scenarios developed for Saudi Arabia (KAPSARC, 2019 based on Saudi Vision 2030), India (Climate Policy Initiative, 2018), Russia (Proskuryakova, 2019), the US (America's Pledge, 2019[58]), and Japan (WWF Japan, 2017[59]).

There were several recent publications that compared a subset of these scenarios, including Ansari et al. (2020[28]), RFF (2019[60]), Dagnachew et al. (2019)[61] and WEC (2019a[27]). These publications offer a discussion of differences in assumptions and projections in the scenarios that would be too numerous to repeat. The aim of the next sections is to provide an overview of similarities and differences of plausible alternative scenarios. In the next step, the paper defines several meta-scenarios that share traits of reviewed scenarios, providing a meta-review of potential futures condensed from over 60 reviewed scenarios. In addition, the paper adds a Black Swan or a wild-card scenario that has not been considered

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[41] BloombergNEF. 2019. New Energy Outlook 2019.
[42] Nordic West Office. 2020. Global Scenarios 2021-2026.
[43] IRENA. 2019. A Roadmap to 2050. 2019 Edition.
[44] World Energy Council. 2019. World Energy Scenarios: Exploring Innovation Pathways to 2040.
[45] IEA. World Energy Outlook 2019.
[46] EADP. 2019. Global Futures of Energy, Climate, and Policy: Qualitative and Quantitative Foresight Towards 2055. Written by Ansari, D., Holz, F,. Tosun H.B. Discussion Paper. 2019/01.
[47] Our World in Data. 2020. Energy. Available online at: ourworldindata.org
[48] Shell. 2013. New Lens Scenarios: A Shift in Perspective for a World in Transition.
[49] Shell. 2019. Shell Scenarios: Sky. Meeting the Goals of the Paris Agreement.
[50] Equinor. 2019. Energy Perspectives 2019. Long-term macro and market outlook.
[51] BP. 2019. BP Energy Outlook: 2019 edition.
[52] Exxon Mobil. 2019. Outlook for Energy: A Perspective to 2040.
[53] DNV-GL. 2019. Energy Transition Outlook 2019. A Global and Regional Forecast to 2050.
[54] Deloitte. 2019. Moving Organizational Energy Use Toward 100 Percent Renewables – Aspiration or Destination.
[55] REN21. 2017. Renewables Global Futures Report. Great Debates Towards 100% Renewable Energy.
[56] Solar Power Europe & LUT University. 2019. 100% Renewable Europe. How to Make Europe's Energy System Climate-Neutral Before 2050.
[57] Oei, P.Y., Burandt, T., Hainsch, K., Löffler, K. and Kemfert, C., 2020. Lessons from Modeling 100% Renewable Scenarios Using GENeSYS-MOD. Economics of Energy & Environmental Policy 9 (1), 103-120. https://doi.org/10.5547/2160-5890.9.1.poei
[58] America's Pledge. 2019. Accelerating America's Pledge. Going All-In to Build a Prosperous, Low-Carbon Economy for the United States. Bloomberg Philanthropies.
[59] WWF Japan. Long-Term Scenarios for Decarbonizing Japan. February 2017.
[60] Resources for the Future. 2019. Global Energy Outlook 2019: The Next Generation of Energy. Report 19-06 by Newell, R., Raimi, D., Aldana, G. July 2019.
[61] Dagnachew, A. G, Hof, A. F. Lucas, P.L. and van Vuuren, D.P. 2019. Insight into Energy Scenarios: A comparison of key transition indicators of 2° C scenarios. *PBL Netherlands Environmental Assessment Agency.*

in other publications. This has been done to showcase scenario options outside the center of the 'scenario cone', which are less likely, but have tremendous impacts on the energy system, akin to the COVID-19 pandemic.

3.1. Global Energy Foresight

This sub-section summarizes commonalities and highlights differences among five dozen global energy scenarios (Table 1). In most scenarios, our energy future is defined by the state of future technology and the policy frameworks. None of the scenarios deny that a global energy transition is underway, but they differ in projecting both the speed and the means for the transition in different sectors. For example, Skolkovo (2019[26]) compiled a list of questions that summarize some unknowns:

- How quickly will energy intensity drop?
- How quickly will electrification spread?
- How RE will become grid-integrated and who will pay for resilience and reliability?
- What would be the features of the centralized/decentralized smart electric grid?
- What will be the role of the government in decarbonization?

One of the sobering findings of the scenario review, in line with Ansari et al. (2020[40]) is that neither business-as-usual, nor 'current policies' scenarios will bring humanity close to the Paris Agreement target of keeping global temperature increase well below 1.5^{o} C. There are only several scenarios (e.g. Sky by Shell, Renewal by Equinor, Sustainable Development by EIA, 1.5 C by OurWorldInData) that align with the Paris targets, while most other scenarios do not achieve these targets. It becomes clear that meeting the climate targets requires ambitious, large-scale, and rapid action. Scenarios agree that meeting climate targets requires a game-changer, such as a large-scale employment of carbon-negative technologies. Scenarios allude that technologies like carbon capture utilization and storage (CCUS) and hydrogen-based fuels (and electrolysis) will reach scale by 2040. In addition to new technologies, the concept of a circular economy becomes a new paradigm in many countries. For example, Saudi Arabia elevated the concept of the circular carbon economy in their policy making, focusing on the 4Rs: 'reduce, reuse, recycle, repeat'. Several scenarios mentioned the need for a socially just energy transition, as well as the rise of prosumers and decentralized consumer-oriented system with on-demand energy access.

Most scenarios transparently state their assumptions, such as population growth, economic growth, energy demand, and changes in energy intensity per unit of GDP. In addition to these exogenous variables, scenarios often incorporate public policies, level of international cooperation, and technological innovation as drivers for potential energy futures. Based on their assumptions and results, some energy scenarios have been criticized as controversial (Breyer and Jefferson, 2020[62]), while WEO

[62] Breyer, C., Jefferson, M., 2020. Use and Abuse of Energy and Climate Scenarios – A Week of Controversy on Scenarios. Economics of Energy & Environmental Policy 9(1), pp. 7-19. https://doi.org/10.5547/2160-5890.9.1.mjef

scenarios developed by the International Energy Agency has been recently called out for favoring the status quo (Mohn, 2020[63]).

Table 1: Scenario overview

Organization	Year	Scenario (more climate-friendly scenarios mentioned first)
Global Focus		
BloombergNEF 2019	2050	Two degrees, Coal phase out, 100% electrification scenario, New Energy Outlook
BP 2019	2040	Rapid transition, Less Globalization, Evolving Transition, More energy
EADP 2019	2055	Green Cooperation, Climate Tech, Business as usual, Survival of the fittest
IEA World Energy Outlook 2019	2040	Sustainable Development Scenario, Stated Policies Scenario, Current Policies Scenario
Equinor 2019	2050	Renewal, Reform, Rivalry
IPCC 2019 RCPs	2100	Representative Concentration Pathways: RCP 2.6, RCP 4.5, RCP 6.0, RCP 8.5
IRENA 2019	2050	Remap Case, Reference case
Nordic West Office 2020	2050	Downshift, Cyberworld, Belt & Road, War-War
Our World in Data 2020	2100	1.5°C consistent, 2°C consistent, National pledges, Current climate policies, No climate policies
Shell 2019 (Sky) & 2013 (Mountains, Oceans)	2070	Sky, Mountains, Oceans
WEC 2019 Global	2040	Unfinished Symphony, Modern Jazz, Hard Rock
National Focus		
India: Climate Policy Initiative 2018	2042	Optimistic scenario, Business as usual, Pessimistic scenario
Japan: WWF Japan 2017	2050	100% Renewable Energy Scenario, Bridge Scenario, Reference Scenario 2015
Russia: Skolkovo 2019	2040	Energy transition, Innovative, Conservative
Proskuryakova 2019	2030	Technology breakthrough, Technology adaptation
Saudi Arabia: KAPSARC 2019	2030	Full Fuel Price Reform, Clean Energy Standard, Partial Fuel Reform, Portfolio Standard, Business as Usual
Meeting Nationally Determined Contributions (NDCs)	ca. 2050	Scenario 1: economy diversification, Scenario 2: domestic use of oil resource, Scenario 3: Combination of Scenario 1 and Scenario 2 to meet NDCs
USA: America's Pledge 2019	2030	All-In Scenario, Bottom-up Scenario, Current measures

Most scenarios agree that large-scale electrification is imminent, and it will result in further decarbonization. A notable exception is the BloombergNEF (2019) electrification scenario that suggests a net increase in emissions resulting from 100% electrification. Shift to RE in the power sector is likely and is underway, but there are several sectors that are more challenging to power with renewables (notably, industrial, maritime, and air transport). A number of scenarios foretell a 'new mobility revolution' with large-ranging implications for the whole energy system, which includes large-scale adoption of EVs and autonomous vehicles (AVs) for personal transportation and beyond. All scenarios consider a dramatic increase in the share of RE in the energy mix. For example, WEC (2019[44]) estimate that electricity demand requires 2-6 TW new cumulative installations, mostly wind and solar, natural gas, with the need to mobilize between $670 and 890 billion in annual investment. Most scenarios highlight that in addition to producing energy from cleaner sources, energy efficiency will be another leading force in energy transition.

Another striking trait is that energy scenarios tend to focus on the center of the scenario cone, rarely considering the effects of events (e.g. Fukushima accident, COVID-19) that can change the future of energy systems. None of the reviewed scenarios have considered a pandemic as an option. There were two organizations that considered a pandemic in their scenarios: Federal Emergency Management

[63] Mohn, K. 2020. The Gravity of Status Quo: A Review of IEA's World Energy Outlook. *Economics of Energy & Environmental Policy* 9 (1). https://doi.org/10.5547/2160-5890.9.1.kmoh.

Agency (FEMA) and National Intelligence Council (NIC). FEMA (2019[64]) scenario that was not focused on energy, but rather disaster response to pandemics, wildfires, and earthquakes. National Intelligence

[64] FEMA. 2019. 2019 National Threat and Hazard Identification and Risk Assessment (THIRA). Overview and Methodology. Report. 25 July 2019.

Council (2017[65]) considered a global pandemic in their 'Islands' scenario, which was associated with lower volumes of global trade and decline in productivity. In order to be better prepared for the unexpected, we might need an updated paradigm for scenario planning, taking into account exogenous demand and supply shocks.

It is clear that COVID-19 will have a strong short- to medium-term impact on energy markets. The long-term impact will depend on the health outcomes of the pandemic as well as the speed of economic recovery. Energy ministers around the world (some EU members, India, Canada, Indonesia, New Zealand) consider a 'green recovery' as the way of stimulating the slugging post-COVID19 economy (Recharge News, 2020[66]). Similar calls for action have been heard from prominent thinkers in the US (The Guardian, 2020[67]), as the US Congress is discussing the next potential stimulus package (CNN, 2020[68]). According to a global survey, 65% of respondents expect government to follow a 'green' economic recovery post pandemic as well as act on climate change in order not to fail the voters (Ipsos, 2020[36]). The type of measures included in the recovery packages will define the responses in energy industry. In general, the recovery path is not clear and might follow a variety of scenarios.

3.2. Meta-scenarios

This section develops the narratives for four meta-scenarios that are inspired by the common traits present in previously reviewed scenarios. In spite of different timeframes and countries, the scenarios tend to consider several universally applicable trade-offs concerning the future of the energy systems. The scenarios have different drivers (summarized in Table 2) and are discussed with implications for the policymakers, consumers, and entrepreneurs.

Table 2: Overview of proposed meta-scenarios

Drivers	**Scenario**	**Inspiration from reviewed scenarios**
Technological stalemate, limited public action on climate	*Bad Economy, Hotter World*	Hard Rock (WEC), Rivalry (Equinor), Survival of the Fittest (EADP), War-War (NWO)
Market-driven innovative energy transition	*Innovation Unleashed*	Modern Jazz (WEC), Reform (Equinor), Oceans (Shell), Climate Tech (EADP), Cyberworld (NWO)
Policy-driven collaborative energy transition	*Big Government*	Unfinished Symphony (WEC), Renewal (Equinor), Sustainable Development (IEA), Mountains (Shell), Green Cooperation (EADP), Belt& Road (NWO)
Major technological breakthrough	*Dark Horse*	Inspiration indirectly drawn from work of N. Taleb on Black/White Swans[69]

[65] NIC, 2017. Three Scenarios for the Distant Future: Islands, Orbits, Communities. Available online at: https://www.dni.gov/index.php/global-trends/three-scenarios

[66] Recharge News. 2020. Global energy ministers plan green rebound from coronavirus – without China and US. Written by Lee, A. 24 April 2020. Available online at: https://www.rechargenews.com/transition/global-energy-ministers-plan-green-rebound-from-coronavirus-without-china-and-us/2-1-797875

[67] The Guardian. 2020. Climate Crisis will Deepen the Pandemic. A Green Stimulus Plan Can Tackle Both. Written by Aldana, D., Kammen, D. 20 April, 2020. Available online at: https://www.theguardian.com/commentisfree/2020/apr/20/climate-crisis-will-deepen-the-pandemic-a-green-stimulus-plan-can-tackle-both

[68] CNN, 2020. Next Covid stimulus already facing Hill fight as both sides draw red lines. Written by Foran, C., Barrett, T. Available online at: https://www.cnn.com/2020/04/29/politics/coronavirus-stimulus-congress/index.html

[69] Taleb, N.N., 2007. The Black Swan: The Impact of the Highly Improbable. Random house.

Some reviewed scenarios did not neatly fit into the proposed mold of the meta scenarios, because they either compared different levels of policy efforts (e.g. current, planned, and future policies such as EIA, IPCC, or IRENA scenarios) or focused on specific technology-driven future (e.g. coal phase-out or 100% electrification scenarios of BloombergNEF). KAPSARC's scenario focused on different options to achieve Saudi Vision 2030, either through fuel reform or establishing a clean energy standard. The think tank also looked at several ways of achieving the country's nationally determined contributions (NDC) to meet the Paris climate targets, comparing the option of economy diversification with the option of focusing on strong industrial base. Climate Policy Initiative developed an optimistic, a pessimistic, and a business as usual scenario for India to achieve 175 GW of renewable energy capacity in the coming decade.

Russian think tank Skolkovo developed three scenarios that specifically mention the role of nuclear power, as well as the speed of technological transfer among countries. These two aspects did not get that much prominence in other reviewed scenarios. For example, the *Innovative* scenario assumes acceleration of technological progress, but limited technological transfer. Under this scenario, China will become world leader in nuclear power, followed by USA and India. In contrast, *Energy Transition* scenario of Skolkovo assumes accelerated technological progress in several key tech hubs and swift technological transfer to the rest of the world. Similar to the *Innovative* scenario, China and the US will emerge as the world leaders in nuclear power, but the third place is claimed by Russia and not India. Russian GDP is the highest under *Energy Transition* scenario, but a significant adaptation is necessary, including a decrease of subsidies for national gas consumption, decrease in the cost of capital to 6-7%, and introduction of carbon pricing of ca. $20 per tonne. Another remarkable trait is that all three scenarios by Skolkovo assume a rather large market share of EVs, ranging from 12-32% of automotive market.

The Bottom-Up Scenario developed by America's Pledge examines how sub-national actors, such as states, cities, and municipalities, can drive ambitious climate action. This scenario describes strong state and local policies that could lead to 37% reductions of net emissions: energy efficiency in buildings standards, zero-emissions vehicle mandates, incentives for CCUS, incentives to use land carbon sinks in forestry and agriculture, setting aspirational emissions goals. Their All-In Scenario creates a vision for a new American economy. By 2050, the country achieves 100% zero-emission in power generation, road transport and buildings. This is achieved by implementing a number of ambitious federal policies, such as methane regulations, federal phase-out of coal, clean electricity standards, federal standards for EVs, federal policy incentivizing use of CCUS. In both scenarios, relevant nuclear share declines only slightly.

WWF Japan developed three alternative scenarios to meet Japanese Government's long-term supply-demand outlook for 2030. In *100% Renewable Energy* Scenario, WWF Japan presents a future where all of country's energy is from 100% renewable sources by 2050, which is achieved by carbon pricing, gradual nuclear phase-out, and drastic increases in energy efficiency. An interesting aspect of this scenario is that it explicitly mentions the use of flash memory for data storage instead of hard discs, use of fuel cell vehicles and a full-scale built-up of hydrogen infrastructure by 2030, but it doesn't discuss CCUS.

Another interesting scenario that merits a special mention is Downshift Scenario developed by the Nordic West Office. This scenario allows the warming to stay below 2 degrees, but the means of achieving this target are neither technology nor policy-driven (even though rapid technological development is assumed). This scenario is driven by the zero economic growth and a change in values, which leads to hyper-local energy production, rapid decrease in energy demand, and decentralized decision-making. The scenario paints a green future that is based on the gig economy, dubbed the New Hunter-Gatherers. This scenario can be seen as the 'back to the roots' scenario that is somewhat outside the plausible scenario cone.

Finally, Table 2 shows that none of the reviewed energy scenarios considered a general-purpose technology such as AI as the central driver for energy transition. Casting the net, a little wider, it is possible to find several publications with scenarios including AI. For example, Business for Social Responsibility (BSR, 2018[70]) developed a scenario *Total Information Awareness*, where proliferation of AI companies erodes away data privacy, but also automates most tedious jobs, securing the social acceptance of the new technology. In contrast, OECD (2018[71]) developed a scenario *Artificial Invisible Hands*, where no entity is in control of the data due to radical decentralisation of governance. Yet another option, European Commission's Joint Research Centre (JRC[72]) developed a vision for a *Super Collaborative Government* that is enabled by AI and citizen participation in governance. Integration of AI into the energy system is a novel aspect of this paper.

Scenario 1: Bad Economy, Hotter World

This scenario materializes if the worst predictions about the economic cost of COVID-19 epidemic come true. The economic slowdown would turn into a major recession that lasts a decade, paired with high unemployment, inflation, and perhaps a seasonal return of the virus. Governmental stimulus would not work as expected and most economies experience very slow or no growth. Economic slowdown is so severe that a wave of sovereign bankruptcies wipes out confidence in the financial markets. The technological innovation is stalled due to dried out financing. The 2020-2030 would become a 'lost decade' for climate change, with fragmented national policies and uncoordinated actions.

Economy would start recovering by 2030, but the valuable time would be lost for addressing climate change challenges. Most government funds would be spent on post factum catch-up disaster relief, rather than forward-thinking energy infrastructure and R&D investments. By 2040, the effects of climate change would be more obvious and worrying, with the temperatures rising in certain parts of the world. For most private citizens, climate issues would become secondary compared to health and employment concerns. At the same time, there would be certain parts of the society that are disproportionately affected by all three: COVID-19, bad economy, and climate impacts. This would create social unrest. To close the loop, climate migration becomes a driver for nationalism and protectionism. In the international context, the countries would focus on narrow national interests, erecting protectionist barriers and strengthening national supply chains. The collaborative spirit of climate negotiations would be nonexistent, with the UN and other international organizations losing their importance. In this

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[70] BSR. 2018. Doing Business in 2030: Four Possible Futures. Written by Park, J. Report. San Francisco, CA. Available online at: https://www.bsr.org/reports/BSR_Report_Doing_Business_in_2030.pdf

[71] OECD. 2018. OECD Scenarios for Digital Transformation. Paris: Organisation for Economic Cooperation and Development.

[72] JRC. 2019. Government 2030+: A Citizen-Centric Perspectives on New Government Models. Written by Vesnic-Alujevic, L., Stoermer, E., Rudkin, J-E. Scapolo, F & Kimbell, L. EUR29664 EN. Luxembourg: Publications Office of the European Union.

scenario, the inability to address an unexpected pandemic lead to a (more severe) long-term climate crisis.

Scenario 2: Innovation Unleashed

This scenario assumes that COVID-19, paired with already existing tensions in the society, creates the momentum needed for rapid market-led energy transition. In this state of the world, the central figures of these scenario are entrepreneurs, who support technological breakthroughs and rapidly transfer technologies from the lab to the market. Most governments embrace green recovery and invest stimulus funding into large energy infrastructure projects (e.g. transmission) and aggressive energy R&D programs that support commercialization of early-stage technologies. Governments on every level make a conscious effort to cut red tape to allow experimentation with new technologies, but also take steps to harmonize and simplify permitting among different jurisdictions. In general, the governments are focusing on removing institutional barriers to entrepreneurship. This scenario represents a more equitable energy transition than Scenario 1, when access to technological innovation is available to all parts of the society.

Green finance flourishes, most institutional investors divest from fossil fuels, allowing new energy technologies access cheap and plentiful capital. Impact investment becomes mainstream and foundations direct considerable funds towards sustainability issues. In most countries of the world, economic growth becomes decoupled from energy consumption, which is supported by technological breakthroughs like remote-sensing, blockchain, and use of carbon-negative technologies. These technologies are likely to lead to just-in-time energy supply and a more flexible energy system. Most energy consumers would become prosumers by producing energy themselves and trading with neighbors (peer-to-peer trading), but also will start investing into green energy through community solar, as well as financial instruments (e.g. green funds). The consumers are likely to insist on changing the 'default option' to reduce path dependency, thus 'green defaults' become the norm not only for electricity purchase, but also for vehicle, housing, and retirement investments.

These changes call for new business modes for utilities, which gradually lose their status as sole electricity producers, a trend that is already underway. Internationally, there will be competition among countries in attracting the brightest entrepreneurial talent, so countries emulate the success of the Silicon Valley, setting up regional or national equivalents (e.g. Skolkovo in Russia).

Scenario 3: Big Government Solutions

In line with predictions by some pundits, COVID-19 would make governments grow larger and more impactful. 'Rallying around the flag' would increase the citizens' trust in the government, expanding its mandate on climate actions. Already in 2020, IEA estimate that government decisions guide about 70% of the world's spending on energy (The Economist, 2020[73]). As a stimulus, significant public funds would be invested into large energy infrastructure.

International climate action plans would experience a revival, spurring international race to the top in decarbonization. The climate change would become an important topic internationally, swiftly bringing about large-scale deployment of RE, large gains in energy efficiency. At the same time, this scenario

[73] The Economist. 2020. The pressure to make the post-covid rebound green. Briefing. 21 May 2020. Available online at: https://www.economist.com/briefing/2020/05/21/the-pressure-to-make-the-post-covid-rebound-green

might have some negative implications. For example, the government policies might be structured in a way that unintentionally pick the winning technology. It is plausible to assume that the technological innovation in this scenario is on par with the *Innovation Unleashed* scenario, but is driven by the government. This scenario represents a more equitable energy transition than Scenario 1, when access to technological innovation is available to all parts of the society.

Internationally, the governments might start a covert war for most productive researchers that produce the most patents, as well as intellectual property. This would divide the countries into those leading R&D and those that are waiting for international dissemination of the new discoveries. Another worrying trend in this scenario would be big government's encroachment on individual liberties in all aspects of life. Data sharing would become wide-spread, so that energy usage is easier to direct centrally. The central planner would minimize the society's energy use and emissions at the expense of the marginal preferences of the individual.

Scenario 4: Dark Horse

This is a wild card scenario that ventures towards the edges of the scenario cone. In the post-COVID-19 world, planning for the unexpected seems more reasonable than ever. Thus, the Dark Horse scenario is dedicated to the emergence of a General Purpose Technology (GPT) that would transform not only the energy sector, but would spread across most other sectors in the economy (Breshnahan and Trajtenberg, 1995[74]). Use of GPT would keep lowering the cost of technology to its users and would result in a wave of new inventions that translate into new products and processes (ibid.). Often-given examples of such a technology are stream engine, electricity, computer, and the internet. Recently, scholars began recognizing AI as the next GPT (OECD, 2018[15]). AI has innumerous applications in the energy space, promising a disruption of currently existing energy system. There are heated debates about the drivers for GPT (e.g. global leadership (Coccia, 2015[75]), but it seems likely that GPT would rejuvenate economic growth (Lipsey et al., 2005[76]; Bekar et al., 2018[77]). The role of the government in promoting such a technology includes dedicating large R&D investments that allow experimentation and application of basic research to the real-world problems. Another important point is to support entrepreneurship, by providing low-cost financing and prototyping capabilities. The consumer needs to be open to new experiences, so that social acceptance does not become an issue that stifles technological advances (Wuestenhagen et al., 2007[78]).

It must be noted that all four scenarios can co-exist in the global context. The fourth scenario might require a perfect storm to materialize, bringing together the elements from Scenarios 2 (*Innovation Unleashed*) and Scenario 3 (*Big Government Solutions*), as it requires both global leadership as well as entrepreneurial activity. Still, the emergence of this scenario might be more likely than expected, as

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[74] Bresnahan, T.F. and Trajtenberg, M., 1995. General purpose technologies. Engines of growth? Journal of Econometrics, 65(1), pp.83-108.

[75] Coccia, M., 2015. General sources of general purpose technologies in complex societies: Theory of global leadership-driven innovation, warfare and human development. Technology in Society, 42, pp.199-226.

[76] Lipsey, R.G., Carlaw, K.I. and Bekar, C.T., 2005. Economic transformations: general purpose technologies and long-term economic growth. OUP Oxford.

[77] Bekar, C., Carlaw, K. and Lipsey, R., 2018. General purpose technologies in theory, application and controversy: a review. Journal of Evolutionary Economics, 28(5), pp.1005-1033.

[78] Wüstenhagen, R., Wolsink, M. and Bürer, M.J., 2007. Social acceptance of renewable energy innovation: An introduction to the concept. Energy policy, 35(5), pp.2683-2691.

there are several candidate GPTs that might make meeting Paris Agreement targets less of a daunting task.

At the same time, COVID-19 might create momentum for Scenario 1 (*Bad Economy, Hotter World*) due to its economic impacts and Scenario 3 (*Big Government Solutions*) by strengthening the governmental role, thus making Scenario 2 (*Innovation Unleashed*) less likely. The epidemic would have an ambiguous impact on the likelihood of Scenario 4 (*Dark Horse*): on the one hand, the big government might provide the leadership that might be required for GPT, on the other hand, economic impacts of COVID-19 might inhibit the diffusion of a GPT. Some pundits believe COVID-19 epidemic might encourage international collaboration (*Scenario 3, Big Government Solutions*), which would spill over into climate collaboration. In some cases, government stimulus needs to be funded by imposing new taxes, so a carbon tax become somewhat more likely, reducing the possibility of emergence of the *Hotter World* of the Scenario 1.

3.3. Implications for Estonia

As a small open economy, Estonia is likely to be subject to the global, as well as European impacts from climate change, demographic growth, and other factors. The meta-scenario approach places international outlook into the Estonian context. As a result, these scenarios might miss some important drivers that are unique to the Estonian energy market. These country-specific drivers include geopolitical considerations in regard to Russia, interconnectedness of energy markets with neighboring countries, pressure to phase out oil shale while maintaining employment in Eastern Estonia and following through on decarbonization targets for 2030 according to the state plan. Discussion of these trends is outside of the scope of this paper and merits future research.

Another implication from energy transition is that decarbonization creates a challenge for governments to procure public revenues, which have historically been levied on fossil-based energy sources (e.g. excise duties, pollution charges, resource taxes). The tax reform might be needed to balance the public budgets and create higher tax inflows by taxing public 'bads'. Another strategy to pursue is to stretch the existing budgets by attracting substantial investment from abroad for large infrastructure projects, while allowing the innovation to thrive by reducing the red tape.

Table 3. Key implications of scenarios

Impact area	**Bad Economy, Hotter World**	**Innovation Unleashed**	**Big Government Solutions**	**Dark Horse**
General	Long-term economic downturn, inflation, and unemployment slow down innovation and climate action. Climate change impacts become more tangible	The entrepreneur is central to this scenario and the government acts in a supportive role, creating a nurturing entrepreneurial framework.	Government steers the energy markets, creating impetus for international climate collaboration, but also distorting energy markets and limiting individual freedoms.	A general purpose technology (GPT) fundamentally changes the energy landscape and other areas of the society, helping achieve deep decarbonization at low cost by mid-century.

	and difficult to mitigate.			
Electricity Mix	Coal phase-out has not been completed, even though most new capacity is renewable energy. Gas maintains its role as a flexible fuel. Carbon capture technologies do not reach scale, considered as too expensive.	Dominated by low-carbon technologies. Quick increase in adoption of zero and negative-carbon technologies is likely.	Rapid decarbonization, possibly slower uptake of low-carbon technologies due to over-regulated energy markets.	Zero or negative-emission technologies experience explosive growth supported by the AI.
Decarbonization	Decarbonization is not on the political radar, as it is crowded out by heath and economic concerns.	Decarbonization is rapid and market - driven. However, it might be uneven internationally, as technologies take time to disseminate.	Decarbonization is front and central in policymaking, government mandates are dominating the process.	Deep decarbonization achieved by applying a GPT to a variety of applications.
Energy Access	Equity is a major concern in this scenario. The situation with the energy access is exacerbated by adverse COVID19 impacts, economic downturn, as well as climate change impacts. Certain segments in the society are baring the negative consequences from all three of these factors.	Entrepreneurs find innovative business models to services different segments of the population, but it is still difficult to offer the most cutting-edge technologies to the most disadvantaged. The overwhelming majority of the population enjoy the highest-tiered energy access, as defined by the World Bank.	Energy access becomes part of the central policy-making goals, speeding up high-tier energy access for the disadvantaged populations (as defined by the World Bank)	Due to falling cost, GPT enables a more universal energy access, spreading even to the most disadvantaged parts of the society.
Investment Flows	National beggar thy neighbour policies make international investment flows much lower in volume. Most capital is tied up in other areas.	Government heavily invests into R&D and commercialization. Green and cleantech finance is flourishing and is able to provide significant cash-flow. Most pension funds divest from fossil fuels.	Public investment somewhat crowds out private investment. However, government involvement saturates the energy system with affordable capital.	For scaling, GPT requires access to considerable capital. It might be available due to attractive returns from GPT, which in turn is likely to increase growth.
Regulation	In absence of government support for energy transition and perhaps due to an increase in red tape, regulation might	The focus of regulations is to enable early-stage entrepreneurship and simplifying permitting on all levels of the government.	Heavy-handed regulations might be stifling innovation. A balance between enabling and hampering regulation is needed.	In the beginning, GPT is not regulated, but as the technology matures, more regulation is introduced. Finding the right balance between safety and

	slow energy transition.			supporting innovation is the key.
Resilience and crisis response	The society is reacting to economic vows and climate impacts, rather than proactively making plans about energy transition.	Crisis response is faster and more efficient, as it is not slowed down by precautionary principle. Due to market forces, some goods and services become more expensive, which leads to renewed discussions about price controls and need for regulations.	Government is able to react quickly due to having central authority. At the same time, inefficiencies in response are likely.	GPT is likely to help in crisis response, due to its adaptive nature.

4. Conclusions

This research synthesized insights from over 60 different energy foresight scenarios and developed 4 meta-scenarios that provide decision-makers with useful framework for uncertainty management. The impacts of the COVID-19 have been recognized as a novel uncertainty, while its short-term and potential long-term impacts are discussed in the paper. Most scenarios viewed governmental policies, economic growth, and technological innovation as the main drivers for energy futures. In line with that insight, this paper dedicates two scenarios to two possible states of the world when technological innovation is unleashed by the incremental technological change (*Innovation Unleashed*) or by the use of a ground-breaking new technology (*Dark Horse*). In the *Innovation Unleashed*, the role of the government is to sustain entrepreneurial society by funding R&D and simplifying experimentation, while cutting the red tape. Two further scenarios examine how the role of the government might change in the aftermath of COVID-19 epidemic. In case of a prolonged economic depression, the scarce public resources are dedicated to health and social issues, making climate action and innovation unlikely (*Bad Economy, Hotter World*). In this scenario, the impacts of climate change become more evident, resulting in an unjust energy transition. The fourth scenario that favors *Big Government Solutions* might become more likely as a result of the COVID-19 pandemic, if the government obtains a renewed mandate to combat societal issues like climate change, while also enacting the green stimulus.

There is a role for the government in all four meta-scenarios developed in this paper. These scenarios have a significant relevance for Estonia. A statistical analysis of over 102 countries have shown that the government plays a central role in reducing emissions among the high-income countries, which also included Estonia (Le et al. 2020[79]). The government engagement ranges from a smaller role of supporting entrepreneurship in the *Innovation Unleashed* scenario to a much larger role in the *Big Government Solutions* scenario, where the energy transition is championed by the central authority. The worst-case scenario that describes a *Bad Economy & Hotter World* cautions the decision-makers about the dangers that a prolonged economic downturn and climate inaction could bring. The quick adoption of a general-purpose technology, described in the *Dark Horse* scenario, can be considerably accelerated by the public leadership.

[79] Le, T.H., Chang, Y. and Park, D., 2020. Renewable and Nonrenewable Energy Consumption, Economic Growth, and Emissions: International Evidence. The Energy Journal, 41(2), pp.73-92. https://doi.org/10.5547/01956574.41.2.thle

Indeed, Estonia has shown impressive growth in RE and EE, but there is still room for improvement. Compared to 34 OECD member countries, Estonia has the highest CO2 intensity and the largest CO2 emissions from heat and power sectors (Pliousis et al., 2019[80]). Estonia received an overall rank of 31 (out of 34) based on its energy security, sustainability, governmental policy, and equity, placing Estonia together with other Eastern European countries in the lower middle group, ahead of Turkey and Mexico (ibid.). At the same time, Estonia was among the top OECD performers with respect to environmental R&D and related technologies in period 2005-2015, which is a promising indicator (ibid.).

Novel public initiatives are needed to facilitate energy transition and this paper would like to highlight the Three Seas Initiative (3SE) that is currently championed by Estonia. Three Seas Initiative seeks to increase infrastructure investments to boost economic growth in the Central European countries located between the three Seas (Baltic, Mediterranean, & Black). One of the aims of the fund is to move towards a single European energy market and to interconnect the energy networks in the Three Seas Countries to the rest of Europe. Such incentives might help finance necessary infrastructure (e.g. seasonal storage, clean liquids pipelines, new ports) and stimulate the economic recovery post-coronavirus. European Commission (2020) recommends that Estonia focuses its investment-related economic policy on two areas that are also important to the 3SE (sustainable transport and energy infrastructure), showing the alignment of visions among the European and Estonian policymakers in this regard.

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[80] Pliousis, A., Andriosopoulos, K., Doumpos, M. and Galariotis, E., 2019. A multicriteria assessment approach to the energy trilemma. The Energy Journal, 40, pp.143-165. https://doi.org/10.5547/01956574.40.SI1.apli