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ELECTRICITY OVERSUPPLY: MAXIMIZING ZERO-CARBON POWER TO ACCELERATE THE TRANSITION FROM FOSSIL FUELS

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Executive Summary

Decarbonizing and growing the power sector are critical steps to reducing greenhouse gas emission in a cost-efficient and timely manner. As more renewable energy enters the market, the higher penetration of solar and wind sources means periods of temporary overgeneration are likely to increase. There are signs that renewable electricity oversupply is now actively being sought in order to create opportunities to decarbonize other sectors or build export markets for products derived from that additional energy.

This commentary discusses the role of electricity in deep decarbonization efforts, and how zero-carbon oversupplies might be deployed. Policy makers must assess what public benefits to prioritize under this recent phenomenon. This commentary examines four countries—Germany, New Zealand, Saudi Arabia, and the United States—where excess generation is providing novel opportunities.

The case of New Zealand is particularly illustrative of the choices countries and policy makers are facing. There, extra zero-carbon supply has suddenly appeared due to the closure of an aluminum smelter. The reduced load means this new abundance could be used to: expand the transmission infrastructure to feed electric loads elsewhere in the nation, decarbonize non-power sector applications (e.g., transportation or industry), produce and sell new products with near-zero carbon footprints (e.g., hydrogen, ammonia, chemicals, fuels), or operate machines that remove CO_2 from the air and oceans.

Following are some takeaways from the commentary:

- There is no single best answer for what to do with electricity oversupply. Governments at all levels must balance whether they are seeking to maximize climate, economic, or community benefits.
- Analysis should frame these discussions and inform decisions. Most jurisdictions have made no decision on what to do with existing overgeneration, and some (such as California) support the creation of overgeneration but have no target regarding the amount of overgeneration, its role in decarbonization, or a clear understanding of trade-offs.

- To avoid wasting public funds and delaying climate goals, municipalities, states, and nations should commission or launch serious analysis on the economic growth, local benefit, and greenhouse gas abatement associated with specific sources of electricity overgeneration.
- Specific consideration should be given to actual displacement of greenhouse gas emissions and the economic costs and the opportunities associated with local policies and investments.

Introduction

Many argue that zero-carbon electricity will be the essential backbone of the net-zero global economy. This expectation is widely reflected in policy measures and recommendations, leading to proposals to accelerate the transition to 100 percent zero-carbon power (recently, from the House Select Committee on the Climate Crisis, Vice President Biden's infrastructure and clean energy plan, and the EU's European Green Deal roadmap).[1] Profound reductions in costs for wind, solar, and offshore wind supplies as well as batteries have helped to underscore this argument.[2] With the cost of capital at historic lows (and, on occasion, negative interest rates), some have proposed a strategy of zero-carbon power overgeneration to accelerate the transition while making good use of capital.

Indeed, research to date indicates that in order to decarbonize the economy at a reasonable cost and on a reasonable timeline, the power sector must both decarbonize and grow. Furthermore, evidence supports the combined use of 1) zero marginal cost supply technologies (e.g., wind and solar), 2) firm and dispatchable electricity supply technologies (e.g., nuclear power, natural gas with CCUS[3]), and 3) energy storage to quickly and practically decarbonize power supplies. Combined, these three technology groups create a robust zero-carbon electricity supply that is capable of supporting an increasingly electrified economy across diverse regions.[4]

This transition will almost certainly lead to temporary overgeneration and curtailment in some geographies—a market failure that can be managed with both technology (i.e., smart grids) and by building out the power transmission grid. Increasingly, however, groups are anticipating and even designing overgeneration of zero-carbon power as a pathway to decarbonizing other sectors or creating export markets for products like green hydrogen or synthetic fuels. These actions prompt a simple question: what are the best uses for surplus zero-carbon electricity?

Recent trends show that much of the developed world is moving quickly to a situation of electricity oversupply. Announcements this summer, ranging from high renewables curtailment levels in California to the near-term availability of excess hydropower in New Zealand due to the shutdown of an aluminum smelter, signal that things are moving more quickly than previously expected. *What we do next—particularly the degree to which we use these types of opportunities to support and accelerate decarbonization efforts—will be determined by policy design and political will.*

This commentary discusses the role of electricity in deep decarbonization efforts and the use cases for zero-carbon electricity oversupply. It then explores recent announcements about and growing trends in electricity oversupply due to curtailment and demand shifts taking place around the developed world, in countries as different and distinct as Germany, New Zealand, Saudi Arabia, and the United States. The commentary concludes by discussing how governments can act in the face of these growing trends—with a particular focus on New Zealand, given its illustrative choices at the moment—to support the accelerated decarbonization of their economies and the need for rigorous, facts-based analysis to frame discussions and inform decisions.

The Free, Green Electric Grail

Electricity is already the workhorse of the global economy, with emissions to match—all told, the power sector represents 21 percent of global greenhouse gas emissions.[5] The wide range of options to generate zero-carbon electricity has placed the power sector on track to be the first major part of the energy sector to achieve near-zero emissions. This progress has accelerated with the dramatic price drops and performance increases seen in renewable power technologies—particularly in wind and solar as well as in batteries.

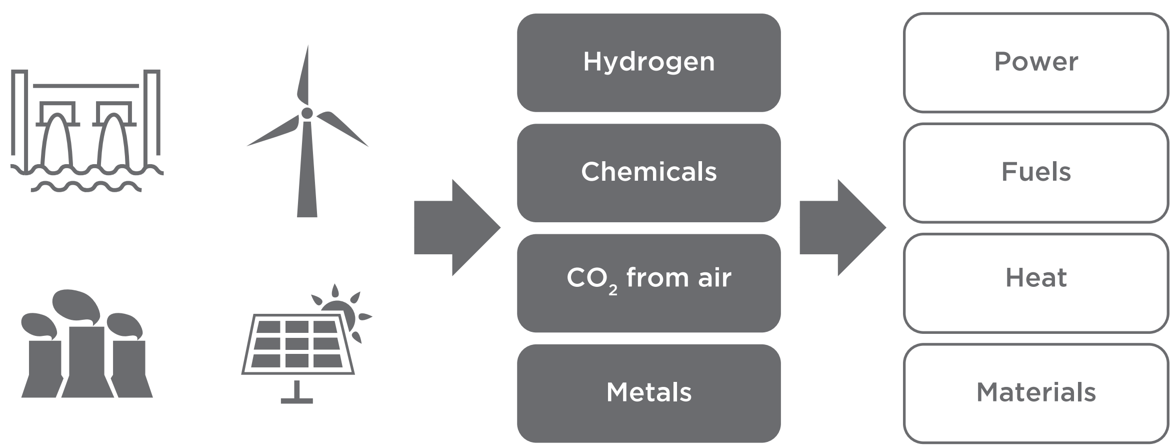
The drive to zero-carbon power as an enabling agent of economy-wide decarbonization is now enshrined in policy. In the US, nine states (representing 35 percent of the US population) have declared net-zero power mandates by 2045 or earlier. Austria, Denmark, France, Iceland, Japan, Norway, Singapore, the United Kingdom, and others have enacted net-zero policies led by net-zero power commitments. The same is true for many power companies, including ENGIE, National Grid, Southern Company, and Xcel Energy.[6] Companies including Amazon, Microsoft, and Walmart have made commitments to procure 100 percent renewable power on an annual basis. Google has committed to net-zero power that would time-match its demand hour-by-hour with zero-carbon electricity supplies, and other companies are considering following Google's lead.[7]

In particular, policies to support the build-out of renewables have led to significant price drops for new renewable power capacity, new companies and industries, and new market structures that are better able to support zero-carbon electricity. These policies have also led to congestion, curtailment, and negative pricing in some locations; as one example of many, California has curtailed over 1.3 TWh of renewable power already in 2020.[8] Furthermore, shifting demand has led to excess zero-carbon generation in some instances (e.g., through changes in industrial load).

This growing opportunity has prompted many inventors, entrepreneurs, and policy makers to pursue use cases for zero-carbon electricity. One important decarbonization use case, light-duty vehicle electrification, has grown rapidly through a mixture of innovation (e.g., by Tesla), subsidies (e.g., in China and France), and infrastructure build-out policies (e.g., in Norway), which has helped to enable future bans on internal combustion engines (e.g., in California, France, the Netherlands, and the United Kingdom).[9] Another use for excess green electricity is to decarbonize residential heat, including both the construction of new homes with electric heating and retrofits of existing homes with heat pumps.

More recently, applications that use these zero-carbon electrons to create goods and services (sometimes called "Power-to-X") have drawn increasing attention. One prominent example is green hydrogen, which itself can be used as a fuel, chemical feedstock, residential heat source, or industrial heat source. In Europe, the EU Green stimulus plan prominently features zero-carbon hydrogen.[10] The Danish government is building offshore islands for Power-to-X, starting with hydrogen and building out to other fuels, chemicals, and products made from electricity.[11]

Figure 1: Graphical representation of Power-to-X pathways



Source: CGEP/Julio Friedmann (2020)

A completely different use case for these electrons is CO_2 removal services. On an energetic basis, 1 TWh of zero-carbon electricity could be used to extract about 400,000 tons of CO_2 from the air.[12] This extracted CO_2 could be disposed of or recycled—for example, into chemical and fuels, which are also part of the Power-to-X pathway. These and other options have created the tantalizing opportunity for CO_2 removal services as a potential user of energy company skills and infrastructure.[13] In a similar way to price reductions for zero-carbon electricity and heat, the ability to separate and remove CO_2 from the air and oceans has risen. Indeed, companies that do direct air capture have received over $150M of investment in 2020 alone.

Recent Announcements Are a Sign of Things to Come

Announcements this summer, ranging from high renewables curtailment levels in California and the near-term shutdown of a hydro-powered aluminum smelter in New Zealand, signal that the power system is moving more quickly toward increasing levels of electricity oversupply than previously expected.

Even before the global Covid-19 pandemic hit, curtailment of electricity from wind and solar in California were already higher than in previous years. According to reports, the California

Integrated System Operator (CAISO) curtailed 138 GWhs of wind and solar in January alone, an increase by more than a factor of 10 over the previous year.[14] In 2020, California has already curtailed over 1.3 TWh of renewable power (a factor 2 increase year on year).[15] In Saudi Arabia, enormous new combined wind and solar facilities will produce 650 tons green hydrogen per day for fuel synthesis and export.[16] Sweden is using its abundant green electrons to replace existing steel production with hydrogen electrolysis-fueled direct reduction of iron plants.[17] And France and Germany are driving light-duty vehicle electrification with unprecedented subsidies, in some cases giving away such cars for free.[18]

A particularly interesting announcement was made in New Zealand in July when Rio Tinto and Sumitomo Chemical announced that they would close the Tiwai Point aluminum smelter. This case is relatively rare because it involves a hydropower facility that has been supplying Tiwai Point with electricity but will soon be available for use in other applications. This dispatchable hydropower can be used for a wide variety of applications—including industrial processes that require firm power supplies—without requiring energy storage or other balancing technologies. It is notable that New Zealand has also adopted ambitious policies to electrify their vehicle fleet and to decarbonize industrial production, while simultaneously decarbonizing the balance of their power sector.

The closure of this facility is expected to lead to 1,000 lost jobs, with a further 1,600 being affected indirectly, placing enormous strain on the local economy.[19] But it will also make a large amount of firm, low-cost, zero-carbon electricity available in a country that has committed to economy-wide decarbonization by midcentury. This combination of factors introduces a significant opportunity for existing industry to drive down its emissions through increased electrification and for new industries that can not only bring jobs into the local economy but also achieve the net-zero emissions targets embedded in the country's landmark Zero Carbon Bill. If the New Zealand government is able to connect these dots, it may be able to turn this negative announcement into a more positive outcome that accelerates the country's progress on decarbonization and provides a roadmap for the world to follow.

New Zealand's Local Choices Have Global Implications

The choice New Zealand lawmakers face on how to use their unplanned green electricity bounty is the same choice decision makers face worldwide. At its heart, overgeneration is different from extra capacity—there's no marginal cost to producing electricity, so there's a market imbalance through oversupply. This leads to price collapse, which is good for consumers but bad for investors and operators.[20] Also, electricity overproduction is not a product of market forces but rather of policies that were passed for a broad public good.

These two circumstances introduce a set of trade-offs that policy makers must consider. Specifically, they must assess what is the highest public benefit to be gained from local overgeneration of electricity: the highest climate value, economic value, or community value.[21] The New Zealand case is interesting because the local use-case options are global options as well:

- Grid build-out. Expand the transmission infrastructure to bring this supply to other electric loads elsewhere in the nation.

- Cross-sectoral decarbonization. Use the electricity to decarbonize non–power sector applications (e.g., transportation or industry).
- Export of green products. Use the electricity to produce and sell new products with near-zero carbon footprints (e.g., hydrogen, ammonia, chemicals, fuels).
- CO_2 removal. Use the excess electricity to operate machines that remove CO_2 from the air and oceans.

Because these options will be pursued as local policy decisions, politics will strongly influence their outcome, as will up-front costs and long-term returns.

Highest Climate Value

To understand the most profound and rapid greenhouse gas abatement potential, one must understand what use the electricity would serve and, based on that, what was displaced. In the case of transmission build-out, the climate value would be highest if the zero-carbon electricity overgeneration displaces high-emission sources of power. In New Zealand, that would be relatively high-efficiency natural gas plants, so the climate benefit might be modest. In contrast, if the electrons served to displace local diesel use or import of fertilizer, the climate benefits would likely be larger. The overgenerated electricity could also be used to run a direct air capture unit or carbon mineralization facility to remove emissions from New Zealand's aviation sector. Ideally, these would be weighed against the marginal abatement cost or the levelized cost, which is difficult to estimate in general and very difficult to estimate across sectors.[22]

Highest Economic Value

The electrons from Tiwai Point produced a product for commercial export (aluminum) with substantial economic return over the capital life of the smelter. Repurposing those electrons could serve to make alternative products (e.g., low-carbon ammonia, fuel, or fertilizer) that would produce tax revenues and improve trade balances for New Zealand. If scaled up, such products might serve to create a national economic opportunity (e.g., a Southern Ocean logistics hub). Assessing the potential value of such opportunities will be a function of many variables, including the cost of capital, government subsidies, growth potential, job creation, commodity prices and other financial input terms.

Highest Community Value

The Tiwai Point smelter anchored the local economy with jobs and tax revenues. It also had local health effects from emissions associated with the smelter. A transmission line out of Tiwai Point would have limited job and revenue potential and small health risks. A chemical plant might be the opposite. It is likely that community discussions, including permitting and local governance, will not focus on global benefits like climate. National decisions made without local considerations could prompt local community backlash, which itself could have national political consequences.

New Zealand is not alone in facing decisions with how it might use excess zero-carbon electrons. Different jurisdictions are pursuing different strategies in the face of this same set of options. For example, in Europe, hydrogen production seems to be a front-runner use case for electricity overgeneration.

Because of the magnitude and timeline of both the Tiwai Point smelter shutdown and New Zealand's decarbonization goals, this country has become a technology and policy testbed. It is poised to serve as a leading exemplar on how economies can rapidly and deeply decarbonize their economies. How and what they decide has global implications, and policy design will determine the outcome.

Do the Math

Different circumstances and jurisdictions will and should underlie decisions regarding investments and policies. The value of each use case will vary as a function of geography, infrastructure, natural resources, capacity factor, local politics, and time. What is universal is that analysis is needed to frame these discussions and inform decisions. Most jurisdictions have made no decision on what to do with existing overgeneration. For example, in some jurisdictions (e.g., California), policies support the creation of overgeneration but have no target regarding the amount of overgeneration, its role in decarbonization, or a clear understanding of trade-offs.

To avoid waste of public funds and delays in achieving climate goals, municipalities, states, and nations should commission or launch serious analysis on the economic growth, local benefit, and greenhouse gas abatement associated with specific sources of electricity overgeneration. Consideration should be given to actual displacement of greenhouse gas emissions and the economic costs and the opportunities associated with decisions. California, Denmark, Saudi Arabia, and New Zealand have very different resource bases and opportunities but share the need for more sophisticated assessment of the value provided by building more zero-carbon generation. The same is true throughout the world.

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