Hazards Ahead

Speedbumps on the Road to Decarbonization – Part 2 of Highlights of JP Morgan Report

Robert Lyman 6/13/21

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EXECUTIVE SUMMARY

In this article, I examine the technological and cost barriers to the conversion of much of the world's economy to use electricity as its primary energy source in place of fossil fuels.

Electricity Storage

Utilities that have a large share of wind and solar energy in their generation mix must ensure that supply is available during the seasons when production from these sources in low. Without thermal power generation to call upon, proponents believe that grid-level electricity storage, in the form of pumped storage (from reservoirs) or batteries will solve this problem. Pumped storage provides about 97% of grid power storage in Canada and the United States. Expansion of pumped storage reservoirs and facilities is possible, but there are relatively few sites available that would be suitable for it. In 2018, grid-scale battery storage in the United States provided about 1 GW-hr of capacity.

Storage is expensive. Pumped storage costs about U.S. $2,000 per kilowatt and grid-scale battery storage costs about $2,500 per kilowatt for a discharge duration of two hours or more. The longer the storage is needed, the higher the cost. Roger Andrews, a geophysicist with world-wide experience in the energy and mining industries, has estimated the combined wind and solar levelized cost of electricity without storage to be US $50/MWh and at least US $700/MWh with it. His estimates are in a range similar to that of the Clean Air Task Force (a Boston-based energy think tank), as reported by the MIT Technology Review. Battery storage, in short, is not an option that will ensure an affordable energy future based on high levels of renewables generation.

Electrification of the Light Duty Vehicle Fleet

By 2019, battery electric vehicles (BEVs) constituted 0.77% of the global light duty vehicle fleet and only about 1% of vehicle sales. Ignoring the slow rate of EV market penetration, several countries and sub-national jurisdictions have publicly committed to eliminating sales of internal combustion light duty vehicles as early as 2035.

Recharging a BEV with a 64-kilowatt battery at home with a level II, 240-watt charger requires up to ten hours, which can be done overnight. Not everyone will have access to a home charger. Electric vehicle owners living in a town house, row house or an apartment without access to a level II charger would have to rely entirely on the public fast-charging network. The significant number of people who park their cars on the street would also be dependent on the public fast-charging network, which in most countries is quite immature.

At the end of 2019, the U.K. had around 100,000 BEVs, representing about 0.3% of the light duty vehicle fleet (Gautam Kalghatigi[1]). These numbers would have to increase by at least 300-fold if the U.K. government is to replace all light duty vehicles. Further, if one were to assume a (very unlikely) 100-fold increase in BEV numbers to 2030 to 10 million, this would represent only 27% of the light duty vehicle fleet; 85% of U.K. transport would still rely on internal combustion vehicles. In 2019, 37,800 BEVs were sold in the U.K.; at this rate it would take 263 years to reach 10 million units.

The Electrification of Railways

The electrification of freight railways in the United States and Canada would require building and maintaining a high-voltage catenary system (an overhead system or wires along the railbed) that, within the United States alone, would span close to 140,000 miles in a wide variety of geographic locations. This probably would require delivering electricity through thousands of rail tunnels and rebuilding major bridges to provide clearance and support for the catenary wires.

Complete electrification would require conversion of 140,000 miles of rails, so the minimum direct capital cost would be in the order of $280 billion and the probable cost much higher. To that should be added the cost of replacing the more than 24,000 Class 1 locomotives in the existing fleet, which according to the Association of American Railways would be close to $100 billion. This does not include the cost of adding the electrical generation capacity that would be needed, for which no current estimates are available. If the cost of converting the present system to an electrified one were placed on the current industry, it would impose financial risks that many would be unwilling to accept. That means the conversion would have to be funded in part or in whole by governments, with the costs and risks largely borne by taxpayers.

The Electrification of Residential Heating and Cooling

The best studies of the probable costs of decarbonizing housing have been done in the United Kingdom. A major pilot project there concluded that emissions could be reduced by 60% for an average expenditure of 85,000 pounds (Cdn $146,000), and by 80% for an average expenditure of 135,000 pounds (Cdn $231,000). Assuming that these costs could be significantly reduced through a national effort, Professor Michael Kelly concluded that most existing U.K. residential housing stock could be retrofitted for a cost of about 70, 000 pounds each, or 2 trillion pounds (Cdn $3.43 trillion). In 2016, the Energy Technologies Institute estimated the cost of "deep retrofits" of the U.K. housing stock was more than 2 trillion pounds. In 2018, the Institute of Engineering and Technology published figures of 80,000 to 90,000 pounds per home. It is clear that only a small fraction of British

[1] Gautam Kalgaghatgi. *The Battery Car Delusion*. The Global Warming Policy Foundation. 2020

households could afford such a cost. Taking into account the cost of adding electricity generation based on wind, and including heat pumps, the cost per house could rise to 150,000 pounds (CDN $257,000) or a national total approaching 4 trillion pounds (Cdn $6.85 trillion).

The Feasibility of Meeting the Mineral Supply Requirements

Mark Mills of the Manhattan Institute has examined the physics of fueling society, including the potential for wind, solar and biomass energy sources to meet the energy requirements now met by conventional energy sources. One of his key findings was that building wind turbines and solar panels to generate electricity, as well as batteries to fuel electric vehicles requires, on average, more than 10 times the quantity of materials, compared with building machines using hydrocarbons to deliver the same amount of energy to society.

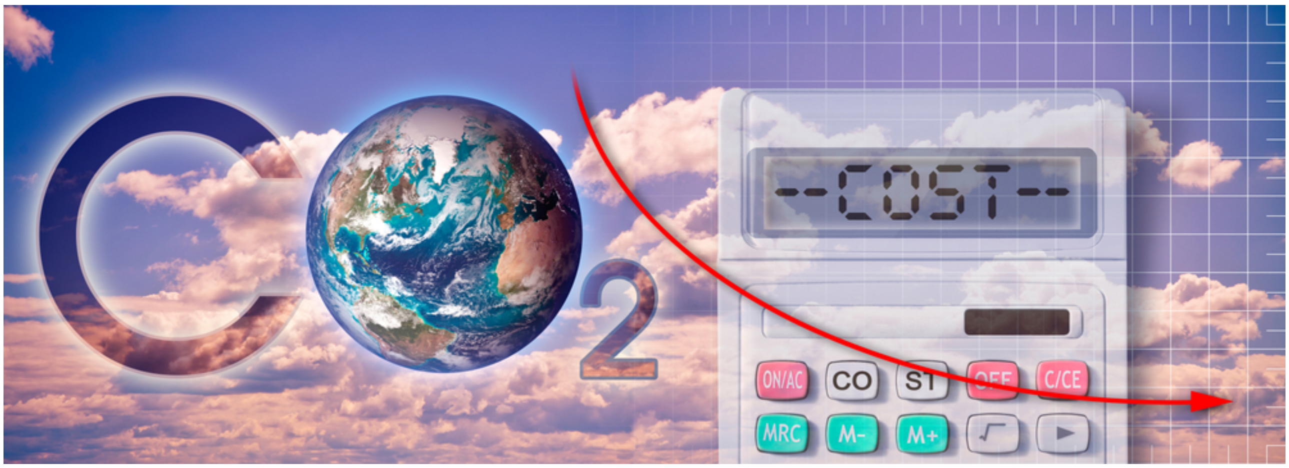
In May 2021, the International Energy Agency (IEA) issued a report on "*The Role of Critical Minerals in Clean Energy Transitions*". The report projected that the demand for key minerals such as lithium, graphite, nickel, and rare-earth minerals would explode, rising by 4200 percent, 2,500 percent, 1,900 percent, and 700 percent respectively, by 2040. The world does not have the capacity to meet such demand and there are no plans to fund and build the necessary mines and refineries. In addition, sharp increases in demand for these metals will raise commodity prices, which in turn with raise the prices of many other goods. It takes over 16 years for mining projects to go from discovery to first production. If countries started tomorrow, new production for these materials might begin after 2035. This places into context the claims by the governments of the United States, the United Kingdom and Germany that they will have carbon-dioxide-free electricity by 2035.

There are significant but often ignored security risks. The top three producers of three key "green" energy materials control more than 80 percent of global supply. China's share of refining is about 35 percent for nickel, 50 to 70 percent for lithium and cobalt, and almost 90 percent for rare earth elements. Russia is in a dominant position in the supply of natural gas to western Europe. By comparison, the top three oil producers, including the United States, account for less than half of world supply. The most important security risk of all resides in the possibility that, having completely electrified western economies and then achieved high levels of reliance on wind and solar energy for the needed generation, there might be major interruptions in power supply because of weather, the failure of transmission systems, cyber-attacks, or sabotage. The economies of western countries would be at risk of severe and prolonged blackouts, with no alternative capacity available.

Hazards Ahead

Speed Bumps on the Road to Decarbonization – Part 2

Several western governments have recently declared their political commitment to significant reductions in greenhouse gas (GHG) emissions by 2050 and complete "decarbonization" by 2050. In Part 1 of this series, I drew on the examples included in a recent J.P Morgan analysis, focusing on the major technological or cost barriers to rapid transformation of the global energy economy. In this part, I will continue the focus on technological and cost barriers, but look specifically at the challenges of electrification of the world economy. In doing so, I will draw upon the analysis and case examples offered by experts in the United States, the United Kingdom and Canada.



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According to the British Petroleum Statistical Review of World Energy, world electricity generation in 2019 was just over 27,000 terawatt hours (TWh). Almost two thirds of that generation were from the combustion of fossil fuels. Coal-fired generation totaled 9,824 TWh, natural gas-fired generation 6,298 TWh, and oil-fired generation 825 TWh, for a total of 16,947 TWh. Generation from sources treated as not emitting GHGs totaled 10,053 TWh. Renewables (wind, solar and biomass) produced 2,806 TWh, or 10% of global electricity generation. In terms of primary energy demand, renewables supplied 5% of the world's needs, and fossil fuels 84%. This data should illustrate that the road to decarbonization is longer than most people realize.

I will not here review the potential for wind, solar, biomass and other renewable energy sources to increase their shares of global generation or the costs and benefits of that happening. I addressed those subjects in previous articles.

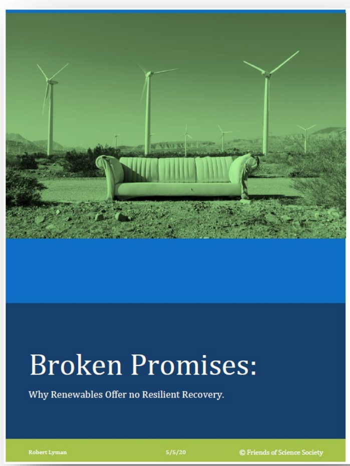
Instead, I will try to examine the examine the obstacles to the conversion of much of the world's economy to use electricity as its primary energy source in place of fossil fuels.

Allianz 2006 risk assessment https://www.yumpu.com/en/document/read/6134749/power-blackout-risks-

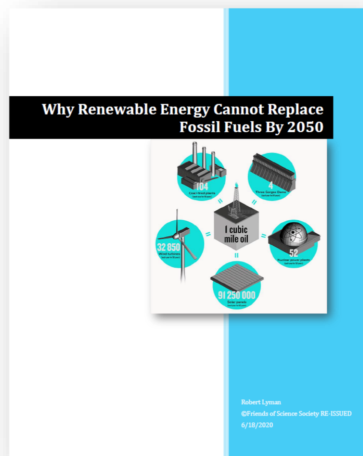
Specifically, I will examine the barriers to:

- The supply of bulk, or system-wide, electricity storage systems;
- The electrification of the entire light duty vehicle fleet;
- The electrification of railways;
- The electrification of residences; and
- The feasibility of meeting the minerals supply requirements, as recently documented by the Manhattan Institute and the International Energy Agency.

Previous reports or series of reports related to this topic by Robert Lyman:



https://blog.friendsofscience.org/2020/05/05/broken-promises-why-renewables-offer-no-resilient-recovery-part-1/



https://blog.friendsofscience.org/wp-content/uploads/2020/06/WHY-RENEWABLE-ENERGY-CANNOT-REPLACE-FOSSIL-FUELS-BY-2050-FINAL-2.pdf

https://blog.friendsofscience.org/2020/11/29/ballparking-the-cost-of-electrification/

Electricity Storage

Wind and solar energy generation share three important characteristics - they are variable, intermittent and unreliable – the facilities produce electricity when the weather, daytime or seasonal conditions permit, not when consumers demand it. The short-term variability of electricity supply from renewables can be accommodated in various ways, including constructing additional dispatchable energy sources that can be called upon when needed, trading power with neighbouring systems when that is possible, and constructing short-term storage in the form of pumped storage (using reservoirs) or battery storage. Pumped storage, not batteries, provides about 97% of grid power storage in Canada and the United States. According to the U.S. Energy Information Administration, in 2018, US power plants generated 4.2 million TWH of electrical power. Pumped storage capacity was about 23 GW-hrs. Expansion of pumped storage reservoirs and facilities is possible, but there are relatively few sites available that would be suitable for it.

> The United States (U.S.) has over 30 PSH facilities with a combined capacity of 22 gigawatts. U.S. facilities generate around 23 000 gigawatt hours (GW.h) per year, and consume 29 000 GW.h to operate their pumps. Despite this net loss of energy, the grid reliability provided by PSH facilities and the ability to generate when demand is strong is highly beneficial and will become increasingly important as Canada and the U.S. integrate more renewable power into their grids.

Pumped storage can be a useful source of bridging power, but creating the pumped storage required more power than generated in this example from the NEB.

Consequently, the additional storage capacity needed before wind and solar power generation can rise to much higher shares of power generation must come from use of grid-scale batteries. In 2018, grid-scale battery storage in the United States provided about 1 GW-hr of capacity.

Storage is expensive. Pumped storage costs about U.S. $2,000 per kilowatt and grid-scale battery storage costs about $2,500 per kilowatt for a discharge duration of two hours or more. The longer the storage is needed, the higher the cost.

In many countries, electricity supply from systems with a significant share of renewable energy generation would have to deal with the large difference between summer and winter demand. They need more than the short-term balancing of energy demand and supply – the capacity to store sufficient energy to meet many days and weeks of supply.

What will be the cost of long-term electricity storage in batteries? The short answer is that no one knows for sure, as the industry is in its infancy. Even with significant reductions in current battery costs, Roger Andrews, a geophysicist with world-wide experience in the energy and mining industries, has estimated the combined wind and solar levelized cost of electricity without storage to be US $50/MWh and at least US $700/MWh with it.[2] His estimates are in a range similar to that of the Clean Air Task Force (a Boston-based energy think tank), as reported by the MIT Technology Review.[3]

Similar studies have been done of the cost or energy storage needed to meet consumers' needs in Alberta. Comparing the cost of a wind-solar-battery option against a gas-fired option and using data from the U.S. Energy Information Administration, it was found that the gas option would have a capital cost of Cdn $13 billion and an annual operating cost (assuming a natural gas price of $2.25 per gigajoule) of Cdn $2 billion. This is less than one percent of the cost of the wind, solar and batteries option.[4]

An important technical issue concerns the life of utility-scale lithium-ion batteries. Battery lifetime is affected by several factors, including cycling, temperature management, and depth of discharge. A NREL paper entitled *Life Prediction Model for Grid-Connected Li-ion Battery Energy Storage System*[5] indicates that lifetimes ranging from seven to ten years may be expected. The cost of replacement, added to the enormous upfront cost of the

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[2] Roger Andrews, *The cost of wind and solar power: batteries included*. Wattsupwiththat, November 22, 2018.
[3] Ibid
[4] *The True Cost of Wind and Solar Electricity in Alberta*, Friends of Science, 2021
[5] https://www.nrel.gov/docs/fy17osti/67102.pdf

systems, makes them not economically viable for serving a high proportion of a power system's needs.

To illustrate this in simpler terms, a recent analysis published by the Friends of Science, a Calgary-based organization, estimated that the cost of supplying batteries to backstop enough commercial solar generation to supply Alberta's annual electricity demand would be about two trillion dollars, or about Cdn $1.9 million for an Alberta family of four.[6]

Battery storage, in short, is not an option that will ensure an affordable energy future based on high levels of renewables generation.

Euan Mearns: The Holy Grail of Battery Storage
http://euanmearns.com/the-holy-grail-of-battery-storage/
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Electrification of the Light Duty Vehicle Fleet

By 2019, battery electric vehicles (BEVs) constituted 0.77% of the global light duty vehicle fleet and only about 1% of vehicle sales. Ignoring the slow rate of EV market penetration, several countries and sub-national jurisdictions have publicly committed to eliminating sales of internal combustion light duty vehicles as early as 2035. In Canada, the Trudeau government has declared that the sale of new internal combustion light duty vehicles (cars, SUVs and pickup trucks) will be banned by 2040.

The technological and market barriers to vehicle electrification vary depending upon whether one is considering the likely short market trends or the longer term goal of completely eliminating the use of internal combustion vehicles.

In the short term, the main impediment to increased consumer acceptance is the time and cost involved in recharging a BEV battery. Recharging a BEV with a 64-kilowatt battery at home with a level II, 240-watt charger requires up to ten hours, which can be done overnight. Not everyone will have access to a home charger. Electric vehicle owners living in a town house, row house or an apartment without access to a level II charger would have to rely entirely on the public fast-charging network. The significant number of people who

[6] The Sun, Reality vs. Fantasy

park their cars on the street would also be dependent on the public fast-charging network, which in most countries is quite immature. Electric trucks would need to be charged for 24 hours, resulting in less time on the road, unless there is an extensive infrastructure for battery swapping. No country has yet even begun to establish such an infrastructure.

An often over-looked problem is the reduction in BEV ranges in cold weather conditions. EVs are designed for peak performance at 21.5 degrees C (70 degrees F). Above or below that temperature, range is lost. At -15 degrees C., a typical winter daytime temperature in much of Canada, BEVs drop to 54% of their rated range, so a car rated for 402 km (250 miles) will on average get only 217 km (135 miles). More frequent recharging would be necessary.

Expanding the number of chargers poses a significant financial challenge. In California, where the state government plans to ban the sale of internal combustion vehicles by 2035, the state will need 1.5 million electric vehicle chargers[7] by 2030. It has 670,000 chargers available today with another 121,000 in the pipeline. By 2030, the state would need an additional 3,600 megawatts of power during the peak charging period at night, when solar panels do not work. That would mean absorbing an additional 15 percent of demand.

Additional multi-billion-dollar transmission lines and distribution line upgrades will be necessary as more and more EVs are added incorporated into society. These costs will make electricity unaffordable for most people.
Image licensed from Shutterstock.

The results of recent studies have called into question the emissions reduction benefits offered by BEVs. A peer-reviewed study of the life cycles of EVs and ICEs in the United Kingdom concluded that, when a new BEV enters the show-room, it has already been responsible for 30,000 pounds of carbon dioxide emissions, compared to 14,000 for a vehicle with an internal combustion engine (ICE).[8] Once on the road, the CO2 emissions of a BEV depend on the power-generation fuel used to recharge the battery. If it is mostly from

[7] https://www.eenews.net/energywire/2021/01/25/stories/1063723243?utm_campaign=edition&utm_medium=email&utm_source=eenews%3Aenergywir)
[8] Troy Hawkins et al. *Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles*. Journal of Industrial Ecology

a coal-fired power plant, it actually produces more emissions than an ICE. Even if the power source is fueled by natural gas, a BEV will achieve only a 24% reduction in CO2 emissions compared to an ICE over its life cycle.

At the end of 2019, the UK had around 100,000 BEVs, representing about 0.3% of the light duty vehicle fleet (Gautam Kalghatigi[9]). These numbers would have to increase by at least 300-fold if the U.K. government is to replace all light duty vehicles. Further, if one were to assume a (very unlikely) 100-fold increase in BEV numbers to 2030 to 10 million, this would represent only 27% of the light duty vehicle fleet; 85% of U.K. transport would still rely on internal combustion vehicles. In 2019, 37,800 BEVs were sold in the U.K.; at this rate it would take 263 years to reach 10 million units.

Kent Zehr, a retired electrical engineer, examined the implications of requiring 100% of Canada's light duty vehicles to be electric. He found that more than 10,000 megawatts of additional electrical generation capacity would be required. Each such power generation plant project requires a 20-30 year horizon from planning to operation. At present, Canada has two very large hydroelectric generation projects under construction, Site C in British Columbia and Muskrat Falls in Labrador. Combined, they will have a capacity of 1,924 megawatts. They will take more than five years to reach production, and there are no more projects of this magnitude on the planning horizon. It is therefore virtually impossible for even Canada, with its enormous power generation potential, to meet the additional demands that would be associated with complete conversion of the vehicle fleet to electricity in the foreseeable future.

The Electrification of Railways

The electrification of railways is a common practice in Europe, Japan and some other areas, and this has led a number of proponents to suggest that freight railways in the United States and Canada should also be electrified as one means of reducing GHG emissions. Electrification would require building and maintaining a high-voltage catenary system (an overhead system or wires along the railbed) that, within the United States alone, would span close to 140,000 miles in a wide variety of geographic locations, including plains, deserts, mountains, congested urban areas and across waterways. This probably would require delivering electricity through thousands of rail tunnels and rebuilding major bridges to provide clearance and support for the catenary wires.

There is little doubt that the operation of an entirely electrified freight rail system would reduce GHG emissions compared to the continued use of diesel powered locomotives, although the magnitude of the emissions reductions would vary depending on the fuel generated to produce the electricity. There are two significant issues that stand in the way of such a proposal – cost and financing.

[9] Gautam Kalgaghatgi. *The Battery Car Delusion*. The Global Warming Policy Foundation. 2020

Unfortunately, there is little agreement on how much such a system would cost. Proponents quote $2 million to $2.5 million per railroad track miles, while opponents estimate that the costs in the more difficult-to-traverse areas could be $4.8 million per mile. Complete electrification would require conversion of 140,000 miles of rails, so the minimum direct capital cost would be in the order of $280 billion and the probable cost much higher. To that should be added the cost of replacing the more than 24,000 Class 1 locomotives in the existing fleet, which according to the Association of American Railways would be close to $100 billion. This does not include the cost of adding the electrical generation capacity that would be needed, for which no current estimates are available.

The reason why North American railways have relied on diesel-powered locomotives throughout most of their history is that the railways are privately-owned and operated. They build, maintain and finance their own infrastructure. If the cost of converting the present system to an electrified one were placed on the current industry, it would impose financial risks that many would be unwilling to accept. That means the conversion would have to be funded in part or in whole by governments, with the costs and risks largely borne by taxpayers.

How much would freight rail electrification reduce GHG emissions? According to the U.S. Environmental Protection Agency, the US freight railroads account for 1.9% of transportation-related GHG emissions and just 0.5% of total GHG emissions. That would be a very small payout for a very large expenditure.

The Electrification of Residential Heating and Cooling

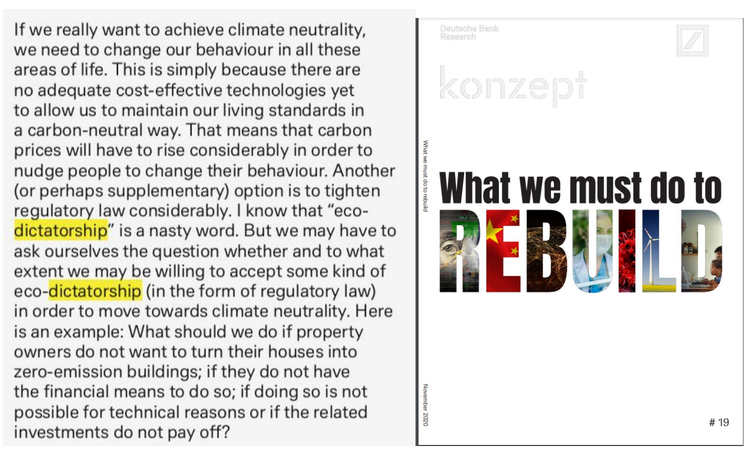
Buildings account for only about 12% of GHG emissions in Canada, but higher shares in other industrialized countries. Most of the policy efforts to reduce emissions in Canada have focused on providing incentives for increased appliance efficiency and increased insulation, although the federal and provincial governments have committed to developing a “net zero” emissions building code to be implemented by 2030. No analysis has been provided to the public to show what the cost of implementing such a code would be.

The best analysis of the probable costs of decarbonizing housing may be available from the work that has been done in the United Kingdom, much of it led by the Global Warming Policy Foundation. The late Professor Michael Kelly of Cambridge University analyzed the cost of decarbonizing domestic home heating through retrofitting insulation. His findings were based on a pilot project conducted by the UK Department of Communities and Local Government on the cost of retrofitting social housing units. The pilot concluded that the costs of retrofitting varied considerably by unit, but that with an average expenditure of 85,000 pounds (Cdn $146,000), the average reduction in carbon dioxide emissions was only 60%. To get to 80% emissions reduction, an expenditure of 135,000 pounds (Cdn $231,000) would be required. Assuming that these costs could be significantly reduced through a national effort, Kelly concluded that most existing U.K. residential housing stock could be retrofitted for a cost of about 70, 000 pounds each, or 2 trillion pounds (Cdn $3.43 trillion).

Other authorities have verified this estimate. In 2016, the Energy Technologies Institute estimated the cost of "deep retrofits" of the U.K. housing stock was more than 2 trillion pounds. In 2018, the Institute of Engineering and Technology published figures of 80,000 to 90,000 pounds per home. It is clear that only a small fraction of British households could afford such a cost. Taking into account the cost of adding electricity generation based on wind, and including heat pumps, the cost per house could rise to 150,000 pounds (CDN $257,000) or a national total approaching 4 trillion pounds (Cdn $6.85 trillion).

The UK Department for Business, Energy and Industrial Strategy estimates that simply bringing 19 million homes (two-thirds of the total) that do not yet live up to the latest building code to a "grade C energy performance certificate" would cost between 1,800 and 3,400 pounds per property, for a total cost between 35 billion pounds (Cdn $60,000) and 65 billion pounds (Cdn $111 billion).

In most cases, the costs of such expenditures would far exceed any potential benefits to the homeowners, so they would not make them voluntarily. Governments would either have to bear the enormous costs, thus passing them on to the taxpayers, or force the changes by regulation, imposing costs on lower and middle-income households many would find unacceptable. There are times when political acceptability can be as large a barrier to decarbonization as either technology or economics.



The Deutsche Bank's proposed solution for the dilemma of homeowners unable or unwilling to make their home zero-emissions is to impose an eco-dictatorship.

The Feasibility of Meeting the Mineral Supply Requirements

Mark Mills of the Manhattan Institute has written a series of brilliant articles in which he has examined the physics of fueling society, including the potential for wind, solar and biomass energy sources to meet the energy requirements now met by conventional energy sources. One of his best articles[10] elaborated in considerable detail on the material realities of green energy:

- *"Building wind turbines and solar panels to generate electricity, as well as batteries to fuel electric vehicles requires, on average, more than 10 times the quantity of materials, compared with building machines using hydrocarbons to deliver the same amount of energy to society.*
- *A single electric car contains more cobalt than 1,000 smartphone batteries; the blades on a single wind turbine have more plastic than 5 million smartphones; and a solar array that can power one data center uses more glass than 50 million phones.*
- *Replacing hydrocarbons with green machines under current plans – never mind aspirations for greater expansion – will vastly increase the mining of various critical minerals around the world. For example, a single electric car battery weighing 1,000 pounds requires extracting and processing some 500,000 pounds of materials. Averaged over a battery's life, each mile of driving an electric car 'consumes' five pounds of earth. Using an internal combustion engine consumes about 0.2 pounds of liquids per mile.*
- *Oil, natural gas and coal are needed to produce the concrete, steel, plastic and purified minerals used to build green machines. The energy equivalent of 100 barrels of oil is used in the processes to fabricate a single battery that can store the equivalent of one barrel of oil."*

The International Energy Agency (IEA), once the bastion of western countries' defence against oil supply disruptions, now constantly warns OECD countries about the imperatives of reducing GHG emissions reductions to avoid allegedly catastrophic outcomes. Surprisingly, however, in May 2021, the IEA issued a report on "*The Role of Critical Minerals in Clean Energy Transitions*". While offering a somewhat optimistic account of the long-term availability of minerals to accommodate the "transition", it provided evidence of how extremely difficult and problematic it will be to attain the needed materials.

The IEA projected that the demand for key minerals such as lithium, graphite, nickel and rare-earth minerals would explode, rising by 4200 percent, 2,500 percent, 1,900 percent and 700 percent respectively, by 2040. The world does not have the capacity to meet such demand and there are no plans to fund and build the necessary mines and refineries. In addition, sharp increases in demand for these metals will raise commodity prices, which in turn with raise the prices of many other goods and accelerate inflation. It takes over 16 years for mining projects to go from discovery to first production (assuming environmental assessment processes and environmentalists' legal challenges do not halt them along the way). If countries started tomorrow, new production for these materials might begin after 2035. This places into context the claims by the governments of the United States, the United Kingdom and Germany that they will have carbon-dioxide-free electricity by 2035.

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[10] Mark Mills, *Mines, Mineral, and "Green" Energy: A Reality Check*, July 9, 2020

Green energy proponents often describe renewable energy as environmentally benign, a claim that does not stand up to scrutiny. Mining and mineral processing require large volumes of water and pose contamination risks through acid mine drainage, wastewater discharge and the disposal of tailings. Over 50 percent of today's lithium and copper production is concentrated in areas with high water stress levels. In countries like Canada, stringent regulation governs the production processes and disposition of wastes, but most of the new mines would be in Asia, Africa and South America, where there are far fewer assurances of good practices.

The Institute for Energy Research, in commenting on the IEA report, noted that the production of "green" energy materials is energy intensive and that trend is increasing.

"*In recent years, ore quality has fallen across a range of commodities. For example, the average copper ore grade in Chile declined by 30 percent over the past 15 years. Extracting metal content from lower-grade ores requires more energy, high production costs, and more greenhouse gas emissions and waste volumes. The IEA data show that, depending on the location and nature of future mines, the emissions from obtaining these materials could wipe out much or most of the emissions saved by driving electric cars.*[11]

Neodymium Miners

Victims of the West's Obsession with 'Green"

Villagers Su Bairen, 69, and Yan Man Jia Hong, 74, stand on the edge of the six-mile-wide toxic lake in Baotou, China that has devastated their farmland and ruined the health of the people in their community

Read more: http://www.dailymail.co.uk/home/moslive/article-1350811/In-China-true-cost-Britains-clean-green-wind-power-experiment-Pollution-disastrous-scale.html#ixzz2REA6HFNb

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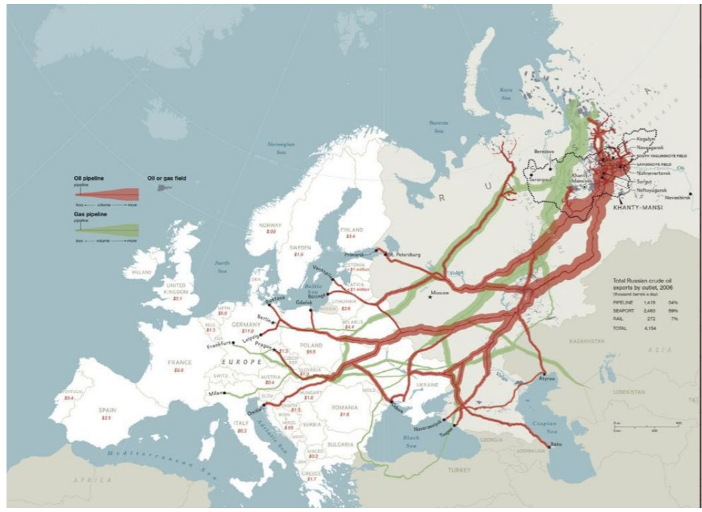
[11] http://www.wsj.com/articles/bidens-not-so-clean-transition-11620752282?mod=opinion_lead_pos5

Geopolitical Risks of Decarbonization



Russian oil/gas pipelines to Europe.

It seems almost passé these days to refer to geopolitical risks, notwithstanding the remarkable efforts by China to enhance its strategic position at the expense of the United States and other western countries. The top three producers of three key green energy materials control more than 80 percent of global supply. China's share of refining is about 35 percent for nickel, 50 to 70 percent for lithium and cobalt, and almost 90 percent for rare earth elements. Russia is in a dominant position in the supply of natural gas to western Europe. By comparison, the top three oil producers, including the United States, account for less than half of world supply.

The most important security risk of all resides in the possibility that, having completely electrified western economies and then achieved high levels of reliance on wind and solar energy for the needed generation, there might be major interruptions in power supply because of weather, the failure of transmission systems, cyber-attacks, or sabotage. The economies of western countries would be at risk of severe and prolonged blackouts, with no alternative capacity available. The contemplation of this possibility flies in the face of all the lessons about energy security that western countries should have learned since 1973. How ironic that the IEA, whose establishment was initially inspired by the need for increased energy security, should now largely ignore this consideration.

About The Author

ROBERT LYMAN is an economist with 27 years' experience as an analyst, policy advisor and manager in the Canadian federal government, primarily in the areas of energy, transportation, and environmental policy. He was also a diplomat for 10 years. Subsequently he has worked as a private consultant conducting policy research and analysis on energy and transportation issues as a principal for Entrans Policy Research Group. He is a frequent contributor of articles and reports for Friends of Science, a Calgary-based independent organization concerned about climate change-related issues. He resides in Ottawa, Canada. Full bio.

About Friends of Science Society

Friends of Science Society is an independent group of earth, atmospheric and solar scientists, engineers, and citizens that is celebrating its 19th year of offering climate science insights. After a thorough review of a broad spectrum of literature on climate change, Friends of Science Society has concluded that the sun is the main driver of climate change, not carbon dioxide (CO_2).

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