



Short communication

Extraordinary interventions: Toward a framework for rapid transition and deep emission reductions in the energy space



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ABSTRACT

A survey of key processes at work in the energy space suggests that a rapid transition away from fossil fuels is possible, and for several reasons. The energy policy environment is increasingly supportive of innovation and rapid system change. Zero carbon replacement technologies are available now. Transition outcomes are firmly established and affordable. The energy space is resourceful and flexible enough to accommodate novel solutions. However, to fully mobilize and accelerate these processes, a universal acknowledgment of the climate crisis will be required. When acknowledgement occurs, the world must be ready for action. It will need a framework for rapid energy transition.

Any such framework will focus on the main instigators of climate change: the billion or so mechanical devices (gasoline engines, industrial boilers, etc.) worldwide that burn fossil fuels. Those devices are to be replaced or modified. An effective framework would organize this task along four energy sector pathways: electricity generation, transportation, heavy industry, and buildings. The framework would maintain system functionality as transition occurs. With such a framework in hand, the global community will be prepared to face the climate emergency head on, and respond with certainty and speed.

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1. Introduction

Energy transition has historically been driven by innovation. Electric lights replaced gas lights; internal combustion engines replaced horses. Such transitions were discrete and unfolded at their own pace, governed by the socio-economic forces of the day. Energy transition in the present era is different. It is driven by a policy agenda aimed at ending the destructive consequences of fossil fuel combustion. The agenda has unprecedented demands: energy transition must occur across all energy sectors. It must happen worldwide. To avoid catastrophic impacts on society, habitat and possibly the planet itself, transition must occur as rapidly as possible.

While energy transition alone has no common definition (Sovacool, 2016) [1], Randers and Gilding (2009) [2] and Brown (2009) [3] assign to present day energy transition an *operative principle* similar to one that guided mobilization at the outset of World War II. A classic example of the principle was America's abrupt entry into the conflict. Responding to the Japanese attack on Pearl Harbor, the US government made *extraordinary interventions* in the US econ-

omy and steered the nation's formidable industrial sector toward weapons production in a matter of months.

The focus and speed of such extraordinary intervention is the main theme of this short communication, so the reasons for its occurrence in wartime merit a brief summary. First of all, the attack on Pearl Harbor triggered a national emergency. The emergency consolidated public and political will. Consolidation of will opened the door to unrestrained action. Secondly, the technical focus of mobilization – weaponry, in this case – was already fully developed and required none of the time consuming experimentation, testing and scale-up steps associated with introducing new technologies. Finally, war production outcomes were known, and there was no path dependent resistance from existing methodologies [4]. Manufacturers simply stopped what they were doing and focused on a new task. For example, General Motors' Fisher Body division rapidly retooled to build the M-4 Sherman tank, a weapon in production elsewhere in the US [5]. At Fisher Body's plant in Flint, Michigan, the first tank rolled off the assembly line 47 days after the end of automobile production. Meanwhile, hundreds of classes taught tens of thousands of employees entirely new skills [6]. As war progressed, the US government and its allies "fast-tracked" new weapons such as the bouncing explosives that destroyed the Möhne and Edersee Dams in Germany [7] and the atomic bomb.

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Rapid transition of the global energy space will require similar ambition, but obviously with a different purpose: instead of building the instruments of mayhem, energy transition will replace or modify a suite of fossil fuel-based energy conversion devices (ECDs) that are polluting the earth's atmosphere: coal- and natural gas- burning industrial boilers; internal combustion engines; jet engines; stove top burners; oil and gas furnaces [8]. Transition will occur on a more constructive battlefield: namely, the four sectors of the world economy where these ECDs are deployed: 1) electricity generation; 2) transportation; 3) heavy industries (steel and cement); and 4) buildings (ETI&B). In these sectors, ECDs will be replaced or otherwise deprived of their capacity to change the climate.

Like the political and industrial landscape prior to World War II, the modern energy space has certain properties that would allow such interventions to occur rapidly. To begin with, the research, development and deployment (RD&D) policies of leading industrial nations have long supported strategic and, if necessary, rapid innovation. Secondly, there is unprecedented and growing support for strategic intervention in the energy space from a host of private sector and civil society actors (Kern, Rogge, 2016). Policy conflict, a major barrier to mobilization, is thereby diminishing. Thirdly, zero carbon ECD technologies are, like the Sherman tank, fully developed; and they are already cost-competitive in some jurisdictions. Finally, energy transition in the ETI&B sectors is well underway and has well-established outcomes in many jurisdictions worldwide. Meanwhile, technologies to clean up and dispose of CO₂ pollution (the legacy of the fossil fuel era) are ready to be fast-tracked; they have been proven in the laboratory and some are nearing full deployment.

Some kind of international epiphany – the peacetime equivalent of a Pearl Harbor – may be required to convert these potentialities into full mobilization. If and when that happens, decision makers worldwide will no doubt resort to a framework for focused, cooperative and rapid action. This paper presents key components for such a framework. The framework is built around an inventory of energy conversion devices.

2. Taking inventory

Technically speaking, global energy transition must start with the world's inventory of fossil fuel-based ECDs – for the simple reason that these artifacts determine how many billions of tonnes of CO₂ enter the atmosphere. These ECDs are deployed in:

- roughly 4500 coal [9]- and gas-fired [10] electric power plants,
- over one billion motor vehicles [11],
- an estimated 20 thousand passenger jet aircraft [12], and over 360 thousand general aviation aircraft [13],
- 50 thousand-plus merchant ships [14],
- numerous heavy industrial sites worldwide which produce about 1.6 billion tonnes of steel [15] and about 4.2 billion tonnes of cement [16] annually,
- uncounted oil production and refining sites (to be phased out),
- uncounted small devices such as lawn mowers, furnaces, out-board motors.

The core task of energy transition is to *replace* these ECDs with zero-carbon alternatives that are already on the market, or *modify* them to eliminate carbon dioxide pollution.

3. Outcomes in the zero carbon energy space

Our rapid action framework now organizes the large sum of these tasks along established pathways and outcomes in the four ETI&B sectors as follows:

3.1. Electricity generation

Electric grids use any number of zero carbon ECDs and ancillary equipment: wind turbines, photovoltaic (PV) solar panels, concentrating solar panels, electric storage devices, hydro electric turbines, geothermal turbines, the latest nuclear reactors [17], coal- and gas- fired boilers equipped with carbon capture technology [18]. The grid is expanded and refurbished to access electricity generated in regions with high renewable energy resources [19].

3.2. Transportation

Surface vehicles of all types use electric motors for propulsion: automobiles, transport trucks, railway locomotives and short-haul ships. Batteries or hydrogen fuel cells supply the electricity. Small nuclear reactors [20] power ocean going ships. Aircraft engines remain unchanged, powered by fuels derived from high-yield biomass [21]. Fuelling infrastructure is in place for all transport modes.

3.3. Heavy industry

Steel and cement producers use electricity or biofuels to generate the heat needed for production. Where fossil fuels cannot readily be replaced, carbon dioxide emissions are captured from flue gas and sequestered or transformed into valuable products. Industry fast-tracks novel steel and cement processes such as electrolysis [22,23].

3.4. Buildings

Buildings use carbon neutral design standards. Super insulated houses, office buildings and factories minimize the energy needed for heating, ventilation and air conditioning (HVAC). Depending on local geography and climate, energy for HVAC is supplied by any number of sources: a zero-carbon electric grid, geo-exchange systems, district heating systems, solar (passive, photovoltaic and thermal) and wind.

3.5. Energy efficiency and reduced demand

All sectors, including the four key sectors above, employ diverse strategies to consume less energy: mass transit, cycling, walking, building insulation, and energy efficient technologies. The resulting drop in energy demand reduces long-term energy costs to the user, and reduces the need for new zero carbon electricity generation and infrastructure.

3.6. Cleaning up and disposing of CO₂ pollution

Carbon capture technology removes pollution from the outgoing fossil fuel energy space. Direct air capture (DAC) [24] facilities, now at the demonstration stage, are scaled up. The facilities pump super-critical (liquefied) CO₂ underground into saline rock formations where it slowly mineralizes over thousands of years. Public-private partnerships fast-track carbon capture and utilization (CCU) technologies (Section 5.4)

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