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Choices on the road to the clean energy future

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ABSTRACT

While numerous indicators may point to an optimism about a global transition to a carbon-free world, that transition can occur down divergent possible roads, driven by how the following questions about the future are answered today: Will the transition be equitable enough? Will the transition be fast enough? Will the transition be driven by 21st Century institutions and governance, or will it be stuck in the 20th Century? Lessons learned from the last century's fossil fuel system and the last several decades clean energy expansion may provide guidance down a road that is more sustainable and equitable.

Two roads diverged in a wood, and I —

I took the one less traveled by,

And that has made all the difference.

-Robert Frost

By many measures, the great energy transition from fossil fuels to renewable energy has begun and is irreversible. 2016 was the first year that additional renewable electricity capacity was greater than fossil fuel capacity [1]. Job growth in clean energy is significant in both the industrialized north and the developing south [2]. Investments in R&D for new renewable technologies continues to grow and clean energy continues to be an engine of economic growth. The cost of deploying renewable energy continues a dramatic decline to the point where some renewable technologies in some areas are commercially competitive with fossil energy [3]. Company after company, and country after country, continue to commit to full electrification of vehicles by dates that five years ago would have seemed impossible. The Paris Agreement in 2015 marked a moment of global consensus and political momentum on “[r]ecognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response...” [4]. Increasingly, the strength of the clean energy sector is manifest in the political economy of both domestic and international arenas [citations from this special issue].

While these indicators may point to an optimism about a global transition to a carbon-free world, that transition can occur down divergent possible roads, driven by how the following questions about the future are answered today: Will the transition be equitable enough?

Will the transition be fast enough? Will the transition be driven by 21st Century institutions and governance, or will it be stuck in the 20th Century? The answers will, as Robert Frost put it, make “all the difference.”

1. Energy equity in an unequal world

While many indicators of energy production show increasing global deployment of renewable energy, questions remain how that deployment will evolve. The road traveled in the last century was fossil-based development that transformed global, regional and national economies. It demonstrably led to massive human development and the alleviation of poverty for many millions, but it also resulted in unequal distribution of the benefits and negative impacts of the 20th Century's energy growth [citations from this special issue]. Thus, the possible roads [5] to a carbon-free future are characterized by two fundamental challenges around energy equity.

1.1. Energy access

The first is how energy distribution and wealth distribution remain related, whether fossil-fuel dependent or renewable-energy driven. Currently, whether on a macro-scale or micro-scale, there continues to be a divide between the rich and poor, and between developed and developing countries, in terms of access to reliable and adequate energy. Such unequal distribution of energy leads to persistent energy insecurity in significant communities and regions, and stagnation of energy-dependent human development, for example, in areas of education, access to clean water, health care, and economic growth. A comparison of the United States per capita electricity use (12.83 MWh/

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capita) and that in a developing country such as Tanzania (0.1 MWh/capita) illustrate this large energy security divide [6]. However, in developing countries that have shown economic development and reduction in poverty, that growth has been accompanied by expansion of energy access and energy security. The past two decades of rapid economic growth in China and India are prime examples of this. In both countries, the expansion of energy access relies on rapid deployment of renewable energy.

1.2. Distribution of costs and benefits of the energy system

The second equity challenge focuses on the winners and losers in an energy system. Research that cuts across multiple disciplines identifies unequal distribution of the benefits of the past century of energy development, as seen above in the energy use, but also in the economic development associated with the capital-intensive mining, extraction, refining, delivery and production of fossil fuel energy. In addition, significant externalities and unequal distribution of costs has also characterized fossil fuel development and use [7]. Already existing vulnerable communities, least developed countries, and communities of color have experienced, and are projected to experience, disproportionate negative effects of a fossil fuel system, whether measured in local air and water pollution, ecosystem degradation, or impacts of climate change.

2. How fast a transition to a clean energy future

Even within the Paris Agreement, the likelihood of reaching emissions reduction targets on a timeframe that could avoid severe climate impacts was questioned:

Emphasizing with serious concern the urgent need to address the significant gap between the aggregate effect of Parties' mitigation pledges in terms of global annual emissions of greenhouse gases by 2020 and aggregate emission pathways consistent with holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C [8].

The road to an emissions scenario that can limit temperature increases to 1.5 °C is highly uncertain. While a clean energy transformation seems inevitable, a fundamental question is whether or not that transition can happen soon enough to avoid the greatest impacts of climate change. In addition, recent actions by the United States, especially in beginning the process to withdraw from the Paris Agreement and recently beginning to repeal the Clean Power Plan, raise additional barriers to successful global implementation of the accord.

In the four-plus decades of United Nations actions on environment and sustainability, the road to unequivocal success has been rare. The Montreal Protocol and resultant decrease in the use of ozone-depleting chemicals is one of the rare exceptions. A path to timely success in reining in climate change will need to withdraw from the Paris Agreement and recently beginning to repeal the Clean Power Plan, raise additional barriers to successful global implementation of the accord.

3. 20th century institutions and governance for a 21st century challenge

The road that characterized 20th Century fossil fuel development and expansion was characterized by centralization and natural monopoly business models – whether they were local utility companies or the Organization of Petroleum Exporting Countries (OPEC). This model held for large multi-national corporations or nation states where large concentrations of capital, investment, and political power characterized the landscape nationally and globally. Mining, extraction, refining and transportation for coal, petroleum and natural gas are all capital intensive and have developed an entrenched political economy with implications on global and national security, both economic and military,

and international geopolitics. In the electric power sector, the United States' path was replicated throughout the world and consisted of a general model of centralized power generation, large-scale transmission, natural monopolies and regulated utilities.

In a world in which there are rapidly expanding renewable energy and clean tech sectors, how well these models of an energy system can continue to deliver energy security, while solving equity and environmental imperatives, is unclear. There is no question that new energy, such as commercial-scale offshore wind, requires large concentrations of capital, global supply chains and large-scale production facilities and infrastructure. But much of the innovation in this sector can result in distributed forms of energy, not dependent on centralized power generation or transmission systems and not dependent on a system of global fuel supply and transportation. Wind, solar (electric and thermal), storage, microgrids and electric vehicles will all be components of a clean energy future and necessary for attaining compliance with the Paris Agreement. All challenge the energy road already travelled.

4. A new, smarter road to the clean energy future

Several lessons learned from the experience of the last century of energy development and more recent understanding of addressing complex and interdependent issues of sustainability, environment and human development point down a road that has never been traveled in the way that needs to be in order for there to be success across dimensions of environmental protection, economic development and equity.

4.1. Fundamentally link responses to climate change and equity

At a public address at the University of Massachusetts Boston in 2016, Christiana Figueres, the executive secretary of the U.N. Framework Convention on Climate Change and one of the lead architects of the Paris Agreement, stated, “We must tackle climate change not as an end in itself, but as a means to a resilient society, to sustainable development and to more fulfilling and enriching lifestyles and livelihoods” [9]. The Agreement stated, “[e]mphasizing the intrinsic relationship that climate change actions, responses and impacts have with equitable access to sustainable development and eradication of poverty...[10]. Energy choices impact equity in numerous ways, from production to delivery to consumption. If questions about equity are not integrated into thinking about the transition to a clean energy economy, there is a risk that both the negative impacts and lost opportunities of the last century will be repeated.

4.2. Integrate across levels of governance

There is a growing awareness that governance at one level (e.g., global) can impact governance and decision making at other levels (e.g., local). Barriers can be created or synergies can be fostered. This notion is manifest in the Paris Agreement, a global accord, in which the term “subnational” is used six times, and the term “local” is used seven. This is particularly critical in the electricity sector, where a variety of utility regulation models occur at national through local jurisdictions, whose regulations can be at odds with one another. This might pose significant challenges in the energy transition since so much of that transition will be driven by smaller scale, local innovations [citations from this special issue]. When the battery in an individual's electric vehicle can now deliver electricity back to the grid, how should that be governed most effectively?

4.3. Rely on sustainability science and adaptive management

The causes and solutions of climate change are complex and interactive. In the newly emerging field of sustainability science, these

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