Clean Energy and Climate Change - A Forward Perspective Through the Lens of Policy, Technology and Market Dynamics

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The collective response in combating climate change is implicit in the mitigation goal to hold the earth's average atmospheric rise temperature to less than 1.5^{O}C. Transforming the energy sector based on clean energy technology innovations can be a major contributor to that response. The ability to deploy sufficient capital to finance clean energy projects is key to implementing this strategy. Investment decisions in deploying clean energy technologies at scale require a confluence of factors affecting the dynamic interaction of technology, markets and policy (TMP). However, this TMP dynamic interplay alone is insufficient: political leadership, will and commitment are also necessary. This commitment must be supported by definitive actions including broad international cooperation/coordination and assistance to less developed economies in capacity building for clean energy.

Introduction

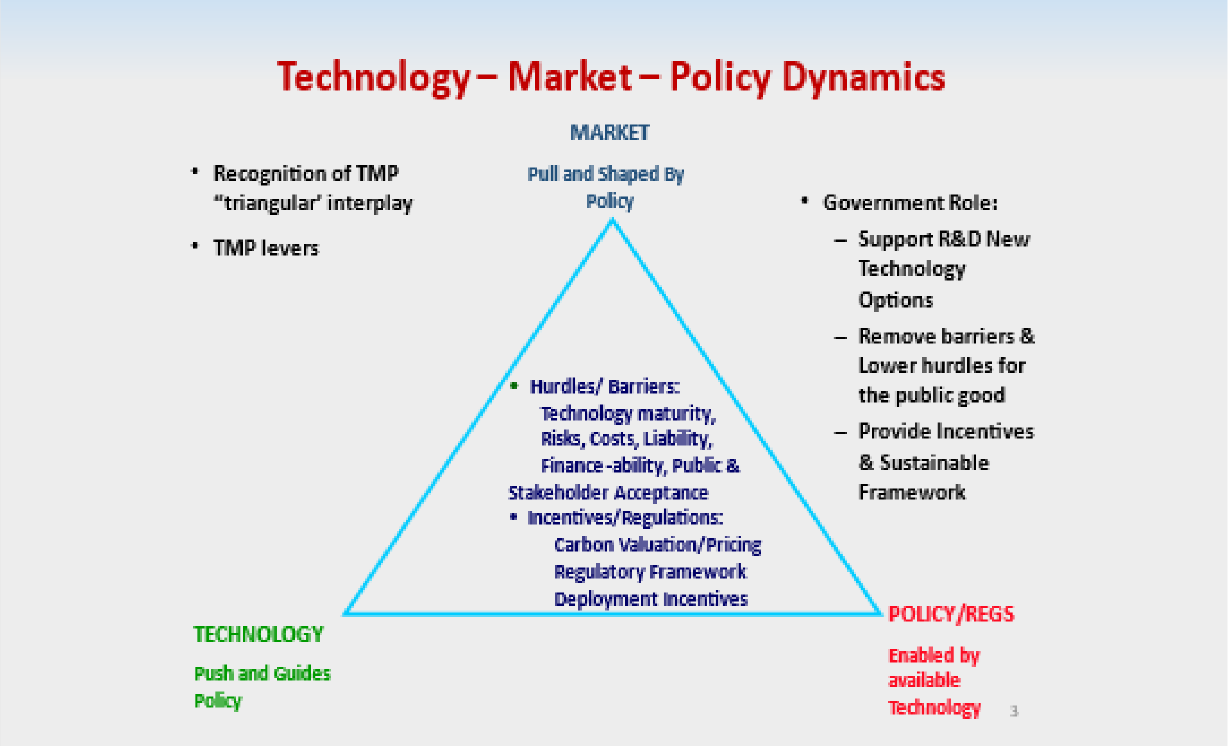
Notwithstanding the importance of collaborative programs and coordinated networks to set goals and compare strategies, we need to accelerate the collective progress towards meeting the goal of staying below the <1.5 C atmospheric temperature increase- the shorthand target for the mitigating climate change impacts. We are already experiencing the onset of these impacts via land mass devastations from droughts and floods; increased frequency and intensity of major storms and wild fires; continued loss of coast lines and shrinking islands; increased ocean acidification; and more.

Clean energy solution paths allow technology innovation to play a major role in climate mitigation through carbon management. The prospects of clean energy deployment can be viewed through the lens of the interactive dynamics of TMP. However, it cannot be fully realized without committed global political will and social acceptance. This brief aims to examine technology, market and policy dynamics of clean energy as a foundation upon which political will and social acceptance can be built.

The Interactive Dynamics of Technology-Market-Policy

Technology-Market-Policy (TMP) dynamics influences actionable decisions in clean energy development, market deployment, and formulation of policy incentives and regulations. No single solution path is applicable to all socio-economic settings or sectors, and no single solution alone can adequately meet the climate mitigation target of staying below the 1.5^{O}C global temperature increase.

The interplay of TMP dynamics is illustrated in the figure below.



This interplay between each of these parameters (along each side of the triangle) is discussed as follows.

• The dynamics of the **technology push** –Technologies bring more options to the table to consider, create competition, and inform policy decisions and their timing.
• The **market pulls**– tests whether there is a business case given the policy/regulatory levers in place for market mechanisms to act on policy signals while evaluating the benefits and risks.
• **Policy/regulations** – primary aim is to achieve a **public good**. The market tests whether the policies/regulations are well conceived and timed such that the technology is market-ready given the incentives and compliance requirements. **Regulations** are often phased in to allow for technology readiness and accompanied by policy incentives.
• This **healthy tension** when orchestrated harmoniously can result in **beneficial outcomes** of low carbon, clean energy technology deployment.
• The test of effectiveness is in the market acceptance as a business case.

<u>Technology</u>
A technology portfolio approach creates competition resulting in cost reductions and improved performance. The portfolio also creates opportunities for hybrid energy systems across applications to various market sectors. Negative carbon and carbon removal technologies as part of the portfolio become essential if we "overshoot" interim emissions targets.

Some examples of innovative low/no-carbon energy systems under development with broad applications to either stationary or transportation markets, (and in some cases to both) are listed as follows:

- New generations of photovoltaic (PV) cells/panels and wind turbines are gaining market share. PV systems are a growing part of the clean energy portfolio as costs continue to drop and performance improves. Wind turbines, already a low- cost renewable source, are also expanding for on- and off-shore siting.
- Energy storage can take various forms such as batteries, hydrogen-based fuel cells and turbines, geothermal, biofuels and nuclear. Energy storage will become increasingly important in supporting the transportation sector's electric vehicles as well as the intermittency of renewables.
- Microgrids are an increasing trend for end-use reliability and security as part of distributed energy systems.
- Hydrogen and fuel cells are another clean option for the transportation sector. Hydrogen technology for on-board generation (e.g., ammonia as a hydrogen carrier) and fueling infrastructure can be co-located with existing stations. Hydrogen storage (such as in salt caverns) can also be an energy storage option.

- Bio-based feedstock has versatile applications in energy and chemical production that can co-optimize biofuels with high efficiency engines and conversion processes. When coupled with carbon capture and utilization/storage (CCUS) these systems can yield negative carbon footprints.
- Advanced small modular reactors such as the NuScale design as well as small molten salt reactors designed for fail-safe from going critical can be a significant contributor to clean energy.
- New combustion-based power or energy systems with pressurized supercritical CO_2 cycles (such as the Allam cycle distinct to NetPower's power cycle) can reduce energy penalties associated with compression of CO_2 for geologic storage. Geologic storage in saline reservoirs can be combined with potable water production via osmosis for desalination and purification.
- Carbon capture from the atmosphere commonly referred to as air capture will be needed especially if we "overshoot" our emissions allocations. Costs of air capture have been driven down significantly from $600/million metric ton (MMt) of CO_2 to well below $100/MMt.
- As a form of conservation and efficiency waste energy for hydrogen development is also being pursued as an alternative to the water electrolytic path to hydrogen production.

<u>Policy/Regulatory</u>

Policies aimed at achieving climate goals must be deemed workable in order for investments and actionable decisions to take hold. Policy and regulatory frameworks must convey confidence in its certainty. As such the frameworks must be:

- *Coherent* –it must make sense and not conflict with other policies and regulations that could lead to unintended results.
- *Consistent*- as in being technology neutral with a level playing field based on desired outcomes rather than favoring a particular energy technology;
- *Credible* – ensuring a reliable, workable framework that is believable and will not change after investments are made to comply (i.e., transcending changing political winds with assurances the "goal post" is not moved after investments have been made).
- *Cost-effective*- in fostering the creation of sustainably cleaner, better, faster, cheaper energy systems. Will the policy incentivize investments in carbon emissions mitigation be a choice over some other action or inaction? Will it be a de-risking strategy in avoiding potential stranded assets (such as diminished value of in-situ fossil resources under new carbon constraints)?

<u>Markets</u>

Carbon valuation (whether priced by regulatory caps or by a tax) is the policy signal to the market in clean energy especially for investments in first movers. Although cap and trade markets and carbon taxes exist at some national and state/provincial level, there is currently no single mechanism for carbon pricing that is globally adopted.

A common notion is that a clean energy economy should be driven by electrification. Often overlooked are other drivers such as a hydrogen economy. In fact, both may exist alongside other clean energy economies such as biofuels, carbon-neutral fossil with CCUS, and advanced nuclear (for both electricity and heat). The future marketable prospects of various clean energy technologies and their applications should be made on a technology neutral basis.

Role of International Cooperation

International cooperation in coordinating, reporting and tracking of policy commitments and practices is essential in combating climate change. Absent access to affordable clean energy solutions, developing nations will pursue a path of lowest cost available fossil energy paved with long-term carbon lock-in. Industrialized economies can lead by example and assist developing economies by investing in their capacity building through financial support, project management best practices, technological capability, education/training and social acceptance.

Where are we now?

The innovations in clean energy through R&D investments have yielded a myriad of promising technological approaches. Demonstrating scalability for various market applications will make them potential game changers. Furthermore, clean energy technology has real promise through modularization which enhances the flexibility of distributed energy. Modular systems have many advantages including demand-driven sizing, lower initial investment, transportability, and improved fabrication quality and reliability. Modularity also lends itself to a host of potential hybrid energy (and chemical) systems combining various aspects of these technologies. Their flexibility can take advantage of off-peak periods of usage as energy for processes to produce hydrogen and other feedstock chemicals.

The confluence of TMP factors combined with political will and socio-economic acceptance can be a driving force for climate change mitigation. This transformation into a sustainable economy can stimulate new jobs, new markets for products and services, and the modernization of aging, outdated, vulnerable infrastructures resilient to forces of nature and to physical and cyber assaults.

Dr. Victor K. Der retired after more than 37 years with the U.S. Department of Energy (DOE) and its predecessor agencies, the Atomic Energy Commission (AEC) and Energy R&D Administration (ERDA). Under the AEC and ERDA, he worked on nuclear fast-breeder reactor systems, components, materials and standards. Subsequently, he served as a manager in DOE's civilian radioactive waste management program. Dr. Der concluded his government service as Acting Assistant Secretary with the Office of Fossil Energy programs. He was twice recipients of the Presidential Rank Award for Meritorious Executive. Currently he serves as Executive Advisor to GABI and Adjunct Professor, Department of Earth and Environment Engineering at Columbia University in New York. He is also a Principal at Vicaris Energy and Technology, LLC.
