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Climate Change — The Role of Program and Project Managers

Key Points

- Addressing global climate change represents a significant system of systems problem.
- Reversing climate change is faced with a set of emergent challenges as well as a range of potential emergent outcomes.
- Driving forces will be as much economic and political as they will arise from a concern about the planet.
- Feedback loops exist within individual systems, each loop complex, and many more will exist across systems representing system of systems feedback loops.
- The challenges posed are great, weakly understood, with different time constants and a myriad of mismatches, and they change both by everyone's actions and inactions.
- The risks faced are uncertain and in some instances unknown and potentially unknowable.
- A herd of Black Elephants (rare and significant risks that all acknowledge but do not want to discuss) now are present and growing in size and danger with each passing day.
- Risk modeling will require incorporation of evolving assumptions and risk models.
- New governance structures, founded on principles more than objectives, will be needed.
- Governance challenges related to equity, social justice, economic dislocations, benefits, and burden sharing will grow in importance.
- Management uncertainties and basis for strategies that are already understood by only a small subset of stakeholders must now be communicated more broadly.
- Current management paradigms must be eliminated in order to deal with the challenge of reversing climate change.
- Program managers have much to bring to meeting the challenge of reversing climate change—if deeper, broader thinking becomes the norm so that it is recognized that "all are better than one."

Introduction

An essential question is: What are the roles and responsibilities that project and program managers have with respect to global climate change?

This is a challenging question. Likely, it will be an increasingly important one for the next 50 years and beyond. The question can be posed to reflect the efforts needed to address climate change and even to reverse it. Hopefully, some fraction of the damage already done can be reversed. This reframing of the question reflects the engineering roots of project execution and the post-disaster experience that has already occurred such that building back even better is an essential tenant.

Outlining some of the systems of systems challenges that society will likely face can provide a framework to discuss the emergent nature of both the challenges and the potential resultant outcomes. Drawing attention to some of the driving forces acting on this system of systems as well as the national and sectoral programs that may emerge as a result will provide insights on how to respond. Highlighting some of the feedback loops that may exist or emerge from both apparent and hidden coupling also may provide an increased understanding about the system of system risks, from which current perceptions are derived.

Outlining some challenges for program managers regarding climate change will provide direction and insight as to where the efforts are moving. The work that results from this exercise is far from complete and not intended to represent an endpoint, but rather one potential starting point. Much remains to be done by industry and by the broader society in general.

Systems of Systems Challenges

Addressing global climate change represents a significant system of systems problem, characterized by:

- Extreme levels of interdependence and a varying degree of impact across society and economic environments.
- Feedback loops, both known and unknown, with uncertain behaviors and differing time-scaled constants.
- Broadest possible geographical and spatial extent.
- Emergent behaviors and protective instincts, compounded by the multiplicity of complex systems and actors.
- Continuous system and system of systems level transitions introducing new and unseen challenges as well as opportunities.
- Decision-making independence across geographical landscapes along with operational independence of deployed and evolving technologies.
- Disparate linkages and effects with existing social systems, including socio-technical, socio-economic, and socio-environmental.
- Unequal cost and benefit distribution and opportunity.
- Lack of singular clarity on desired outcome, timeframe, and metrics to measure progress and success.

This insight will use an ESPRIT[1] framework, which was previously utilized in evaluating international development and construction projects. Table 1 provides a less than complete summary of some on the challenges likely to be encountered in seeking to reverse climate change.

[1] ESPRIT – Economic, Social, Political, Religious, Intellectual, Technology

Table 1 System of Systems Challenges Faced in Reversing Climate Change Utilizing an ESPRIT Framework		
Framework Category	**Challenge**	**Comments**
Economic	Defining the problem	This will likely be emergent and multidimensional.
	Unclear prioritization of objectives and actions	No alignment is emerging.
	Inadequate coordination of investments globally	There is no governing framework, and every constituent is singularly focused.
	Harmonization of multiple systems	Harmonization of renewable energy, energy storage, and electric vehicle fleets is one example. Moving to the most resource-conserving food production is an example.
	Life-cycle benefit optimization	Challenged by both emergent objectives and outcomes.
	Leverage complexity	Using data-driven technologies to simplify understanding.
	Law of unintended consequences	Using a "5 Whys" methodology to determine outcomes that are layers deep in the thinking.
	Nonlinear feedback mechanisms	Start with the end in mind and determine current actions yielding unintended consequences.
	Perverse incentives	Well-intentioned incentives working against overall goal (sub-optimizing). Direct challenges to overall wellbeing and making decisions that affect the whole, but benefit a subgroup.
	Systemic risks not understood	New system of systems level risks not understood and assessed.
Social	Socio-economic	Realities, tolerances, and perceptions vary broadly.
	Socio-technical	Realities, tolerances, and perceptions vary broadly. The science is not well understood, and the technologies may not be

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		the best outcome, but a small step toward an even better outcome.
	Socio-environmental	Realities, tolerances, and perceptions vary broadly. Not every society is aligned in purpose and vision.
	Scale of behavioral and societal changes	Demand reduction and other social changes are under-appreciated and presume that more time is available.
	Articulation of cross cutting principles	With a varying degree of direction, cross-cutting principles are not clear.
	Decision making under uncertainty	No clear decision-making process or authority.
	Engaging multiplicity of stakeholders with different and often competing interests	There is no singular forum for communication, engagement, or decision making.
	Emergent objectives	Multiple, temporal, and contradictory objectives at both national and system levels.
	No single version of the truth (SVOT). The science outcomes are delivered over time, where action seems apparent but outcomes are not clear.	Lack of shared understanding degrades system of system performance.
	No common semantic space (common mental models and language). The median age of the world population is 30 years and the percentage of people under 15 years is 25 percent.	Short-term, generational understanding throughout the world system is not available.
	Social dynamics	Inadequate engagement with stakeholders and society at large.
	Timescale	Multi-generation problem with short-term urgency in solutions.

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Political	Agreement processes	Lack of a central authority limits effectiveness of agreements.
	Aligned, consistent leadership	Change points become convenient political battlegrounds, retarding progress. The political nature of hardships is not expedient.
	Leadership in a multi-political (nation state) environment	There is no alignment, and the players keep changing.
	Legal and regulatory	Alignment with broad objectives while addressing transitional needs is not efficient with safeguarding systems that use past precedent as future guidance.
	Workforce dislocations	Global interconnections allow for understanding of what a minimum acceptable need is.
Religious including cultural	Climate change views reflect or are influenced by religious or cultural views or belief sets.[2]	Deep cultural beliefs can be resistant to fact-based arguments.
	Shared ethical objectives	Not every society has the same basic tenants for treatment of people and the earth.
Intellectual	Fact base and interpretation not universally accepted	Facts come over time and if complex outcomes are drawn the information must be studied.
	Inadequate trust in science	Science has been presented with a perspective. It is not the math but the story problem.
	Governance under emergent objectives	Program enabling processes must reflect emergent objectives that continue to change over time.
	Inadequate innovation in solution set development where new ideas are required	Think about what can be done, what must be done, and how to bridge the gap.

[2] How Religion Impacts American's Views on Climate Change and Energy Issues; Pew Research Center; October 22, 2015

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	Engaging versus managing complexity	Complexity is in the framing of solutions and the ability to grasp the vision.
	Inadequate and inefficient knowledge sharing mechanisms	Driven by objectives of competitive advantage versus driven by the outcomes that all can agree to.
	Tipping points	After the tipping point, describe the next step.
Technology	Transition away from existing installed base of major systems	Understanding the cost, people effects, and the environmental outcomes.
	Effective output measures not easily linked to outcomes metrics	Focus upon society and its people and the environment and its resource usage.
	Accelerating to scale the development and deployment cycles	As policy drives funding and the entire system moves to react to its drivers, the development and deployment will follow. Not everything can be the highest priority.
	Introduction of new failure mechanisms in systems undergoing transition	The alert to what failure is and the early warning of moving toward failure should be built into the system.
	Increased requirement for self-adaptive systems	Systems that monitor its environment, work toward hard trends in the economy, and help people thrive in their personal situations will be necessary in every endeavor.
	Inadequate or absent common semantic space	Work toward a common business language and all points of view should be required to explore other views dialectally.
	System and system of systems level configuration management inadequate for tasks at hand	The overarching system approach must be more broadly understood, but of course economically the cheaper, faster

Table 1 System of Systems Challenges Faced in Reversing Climate Change Utilizing an ESPRIT Framework		
		to market outcomes are always first produced and consumed.
	Technology development and disruptive ability is important	The simplest disruptors will win the day.

Considering the scale of this system of systems challenge, now highlighted are some of the systems that are constituents in this broad endeavor. They include:

- Economic – funding and financing systems for transformation, including subsidies and support for change efforts and dislocations.
- Social and community – jobs, standard of living, and engagement are the basis for being attracted to this effort.
- International trade and agreements – vision, purpose, principles, goals, commitments, and alignment enforcement mechanisms enhance success of the efforts.
- Political – systemic changes in policy are required to sustain focus on multi-generational goals.
- Energy – extraction, generation, storage, transmission of pre- and post-generation energy, and efficient and temporal usage is an important focus area as a system connection to climate change.
- Transport – alternatives and mode alternatives using regenerative motive power and energy sources. This requires infrastructure modification, usage, and temporal profile changes and resilience and sustainability.
- Industry and manufacturing – modifying energy sources and production efficiency while using sustainable materials, limiting by-products, and eliminating waste streams.
- Water infrastructure – rethinking potable and process water use cycles. Reimaging water storage and transmission while simultaneously managing flood and coastal water mechanisms.
- Built environment – commercial, institutional, and housing are built for the next 100 years as environmental cooperative.
- Health and education, including science, technology, engineering and mathematics (STEM) – change curriculum and job descriptors to meet demand for services and emergent skills.
- Agriculture, land use – move to efficient food production with less animal uses for food directly.
- Resource, waste, and greenhouse gas management – resource extraction and utilization is optimized with recycling a basic tenant. Waste streams are minimized and reuse is optimized. Greenhouse gases are removed as part of the basic production system.
- Management – systems and approaches to deal with global scale challenges are taught, studied, and improved over time.

Emergent Nature of Challenge and Resultant Outcomes

Reversing climate change is faced with a set of emergent challenges as well as a range of potential emergent outcomes. An example of an emergent challenge was the withdrawal by the United States from the Paris Accord and the reversal of this decision by the subsequent administration. The prospect of future on-again/off-again political reversals must be considered a real possibility, and not just for the U.S.

Another example of a recently emergent challenge was driven by the COVID-19 pandemic during 2020. During this period, a broad drop in economic activity globally occurred as various shutdown and quarantine measures were implemented. Carbon emissions were reduced by an estimated 17 percent, but global CO_2 concentrations continued to increase. This has reinforced some skeptical views that climate change[3] is not a man-made phenomenon.

But just as challenges will be emergent, so will opportunities, especially as economic and technological tipping points are reached. Examples of some emergent opportunities include:

- UK's acceleration of its Net Zero goals from a previous 80 percent reduction target and the coupled policy actions.
- Australia's focus on exporting "sunshine" through renewables-based ammonia production.
- Norway's nod to the "Longship" carbon capture and storage (CCS) project, a first at scale.
- Growing acceptance and acceleration of offshore wind along portions of the U.S. Eastern coastline.
- U.S. proposal to shift its federal vehicle fleet to an all-electric fleet as they are replaced, providing support for the growing industrial base for electric vehicles (EVs).

The complexity of the climate change challenge and the system of systems nature of its solution suggests the desired outcomes and paths towards them will be emergent. There is no singular solution and even the desired outcomes may shift as progress is made. The multi-finality of this problem suggests many paths are possible. These paths encompass:

- Demand reduction of greenhouse gas (GHG) producing activities.
- Improved efficiency of GHG producing activities.
- Substitution and replacement of GHG emitting activities with non- GHG activities and processes
- Atmospheric removal of carbon and other GHGs.

In each broad category a wide range of paths exists, including stopping global population growth; mandatory vegetarianism; power and transport fuels replaced by hydrogen using ammonia and electrons; and global scale atmospheric carbon capture and storage. As these examples demonstrate, path choices may vary across the globe.

Outcomes from any effort to reverse climate change will similarly be emergent. Leaders will move ahead based on science and conviction and a willingness to translate any short-term pain they may experience into a national competitive advantage. Some of these attributes are seen in the UK acceleration of its Net Zero efforts. Conversely, laggards will challenge the science, study implications *ad nauseum*, challenge others to move first or faster, and likely pay for their delayed response in economic competitive disadvantage.

In terms of measurable outcomes with respect to reversing climate change, these goals themselves to may be emergent as the following are confronted:

- Potential effects from huge carbon, methane, and heat sinks and already established trajectories.

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[3] Global emissions of methane reached the highest levels on record, driven primarily by growth of emissions from coal mining, oil and natural gas production, cattle and sheep ranching, and landfills.

- Increased emissions of nitrogen and oxygen from ammonia and electrolysis processes.
- Free riders gaining short-term competitive advantage.
- Political instability from various dislocations.
- Emergent concerns of overshooting and thus creating a new Ice Age.
- Implications of new technologies and global economic[4] and social models.

Importantly, control mechanisms that focus on initial conditions and compliance of activities to plans are not as effective as control mechanisms that direct behavior to certain goals and incentivizes simple rules for the emergence of desirable behavior.

Driving Forces

Driving forces that will act to accelerate efforts on reversing climate change will be as much economic and political as they will arise from a concern about the health and well-being of the planet and its denizens. These driving forces will shape not only what is done, but how those efforts will be governed and managed. In many ways, climate will become a new battleground for superpower supremacy as those superpowers seek to carve out large shares of the resultant impacts and effects.

These include:

- Capturing significant shares of the $2-4T in annual investment likely required to move towards Net Zero.
- Gaining the advantages, more broadly, from the significant annual investments in research and development that will be required.[5]
- Shifting from energy sufficiency and independence to energy supremacy.
- Supply chain leverage and attendant economic dividends.
- Changing international trade patterns driven by climate policy, perceived leadership positions, and access to critical materials with trade restrictions or end markets.
- Effectiveness and extent of a “climate financial market.”

Other driving forces include:

- Securing critical rare raw materials such as lithium, cobalt, and nickel in enough quantities to drive geopolitical activities and conflicts.
- Developed versus developing world income gaps.
- Developing world urbanization rates.
- Frequency and extent of extreme climatic events.
- New innovations in gene modification, specifically in plants and phytoplankton and other biology-based approaches such as enzymes, to facilitate carbon fixation outside of cells to promote carbon sequestration.

[4] Current rate of electricity consumption by bitcoin miners is estimated to be 0.08 percent of total global electricity consumption.
[5] Estimated at $100B annually.

Possible Feedback Loops and Hidden Coupling

Numerous possible feedback loops potentially exist in reversing climate change. Even more have yet to be identified. Feedback loops exist within individual systems, each are complex, and many more will exist across systems, representing system of systems feedback loops. Potential feedback loops would include:

- *Economic dislocations reduce the appetite for the needed changes, their timing, and extent.* For example, the anticipated energy transition from carbon-based fuels to renewables that is already underway may accelerate as the result of strengthened global commitments to de-carbonization. Attendant unemployment and economic dislocations become politically unacceptable.

- *Sharp political swings in energy policy related to de-carbonization result in lost political influence and policy setting as free market factors guide energy company actions.* Energy majors continue to move away from carbon-based fuels irrespective of more pro-carbon policies during the last U.S. administration. This has been driven by increased investor focus on ESG (environmental, social and governance) and the shifts in market capitalization away from carbon-based to renewables players. The market cap of the largest renewables companies already has surpassed the market cap of their oil equivalents.

- *Reduced oil demand drops prices to levels that discourage lesser developed countries from making required changes to reduce climate change.* Their failure to act becomes a counter-argument in developed countries.

- *Global warming trends already in motion unlock greenhouse gases trapped in previously frozen tundra.* Warming creates feedback loops that encourage destabilization of tundra ecosystems and the release of methane from deteriorating permafrost. This further drives the thawing cycle, while higher temperatures drive vegetation, changing soil temperature and preventing snow from reflecting heat.

- *Ocean heat sinks that have stored up to 90 percent of excess heat trapped by anthropomorphic greenhouse gases grow to even more significant levels, driving increased speed of ocean warming, sea rises, and hurricanes.* Reversing climate change will not occur overnight. Ocean warming will disproportionately continue. Coastal flooding will create severe challenges for population centers along the world's coasts, diverting required financial resources from climate change to resilience. Strengthened hurricanes will not only be more frequent and create even more damage, but may put some offshore wind energy in danger. Changed current patterns will create new deserts and tropics, potentially and significantly impacting the global food supply. Reductions in atmospheric temperatures will be tempered as heat is rebalanced between the ocean and atmosphere.

- *Shifts to a hydrogen energy system, using ammonia as an energy storage and transport solution, will provide great advantages, but create new challenges with respect to oxygen and nitrogen releases to the atmosphere.* Will increased nitrogen releases as part of an ammonia cycle contribute to greenhouse gas effects as it moves concerns from carbon to nitrous oxides?

- *Do accelerated shifts (either those underway or desired) create increased global exposure to new disease pathways that could impact global health and population levels?* Will a climate-driven pandemic cause a significant reduction in global population, reducing demand for greenhouse gas producing food, materials, and energy?

- *Demand for key renewable materials (lithium, cobalt,[6] nickel) drive new regional conflicts with the potential to degrade into a limited superpower conflict.*

- *Digitalization of society creates growing energy demands that impact the rate of energy transition.*

- *Temporal dislocations between action and effect create challenges in sustaining commitment and investment.* Lags stretching from years to decades can be reasonably expected between meaningful actions and measurable results (thermal inertia; random variations; ecosystem resilience; social resilience; denial; missing governance structures; social resistance; investment lags; research and development lags; carbon cycle inertia; diffusion of innovation; sink flow reversals/search for equilibrium). This is further compounded by natural background variations and the previously described existence of significant sinks.

- *Reforestation efforts are negatively impacted by climate trends already underway*. New areas suitable for afforestation must compete with agricultural uses similarly affected by global climate change. Biodiversity and ecosystems are also affected. Political factors that arise limit the agility of a response.

- *Direct air capture of carbon technologies, while providing benefits, delays shifts in materials and fuels industries.* Apparent net zero cement, plastics, and fuels are found to not have fully accounted for carbon from extraction. Availability of some net zero materials delays shifts to alternative carbon neutral or negative ones.

- *Strategies to address global sea rise destroy wetlands, reducing an important global carbon sink.* Land use policies fail to recognize the needs and opportunities associated with land use in coastal zones.

- *Strategy mismatches develop across systems and regions.*

Each of these potential feedback loops as well as those not articulated or yet discovered creates unique governance and management challenges for the various programs that will be required to move towards this global paradigm shift. Forward-looking metrics focused on second- and third-order changes will be required. Emphasis on innovation and continuous improvement are core attributes of any such efforts and their management.

Risks and Risk Appetite

The challenges posed by reversing climate change are great, weakly understood, with different time constants, and a myriad of mismatches, and changeable by both actions and inactions. As such, the risks faced are uncertain and in some instances unknown and potentially unknowable until they fully manifest as true Black Swans (unpredictable/unforeseen events, typically with extreme consequences).

[6] More than 70 percent of the world's cobalt is produced in the Democratic Republic of the Congo (DRC).

Yet a herd of Black Elephants (rare and significant risks that all acknowledge but do not want to discuss) is growing and becoming more dangerous with each passing day. Addressing this herd will result in missteps and potential loses, some likely significant. But inaction could result in complete loss.

In addressing climate change, a risk appetite needs to be adopted, one that recognizes the high degree of uncertainties and accepts that failures and unintended consequences along the way are inevitable. This appetite must include a healthy dose of acceptance of these realities, but also include mechanisms to learn, transparently, and fail forward.

The metrics by which risks are assessed will evolve as society learns more about the presence of Black Elephants, the intervening terrain, and the improvements they will require.

The base against which risks are measured will be changing. This continuous reassessment of risk will act to redefine desired outcomes, rates of action, and reweight tradeoffs against other societal risks. New risks, previously unseen or underappreciated both within the global climate change domain but more likely in the broader system of systems, will emerge and include likely concerns about "overshooting."

Risk and risk perception, therefore, become important feedback loops.

Challenges for Program Managers

Managing in a dynamic risk environment unlike one ever faced is a monumental challenge. Risk modeling will require incorporation of evolving assumptions. Uncertainties may widen long before they level out, then become narrow and even more sensitive to the effects of correlation. Exposure to emerging objectives and the effects of actions on various systems and the feedback generated will require consideration of new system of system level risks and metrics. These new metrics will include:

- Risk assessment against a range of potential desirable outcomes.
- The probability that emergent strategies will produce desirable outcomes even considering the uncertainty around what a desirable outcome may be.
- Assessment of potential risk impacts from both known and unknown feedback loops.
- Inclusion of opportunities represented by yet unknown technologies.
- Factoring in future actions and events, not directly related to system of system level concerns, which act to mitigate concerns or extend timeframes for action (significant reduction in global population and activity from manmade or natural events of global scale such as regional nuclear war or a significant global pandemic (even more significant than COVID-19).

Look to identify hard trends. These are ones that will happen. Spilt these away from soft trends. These are probably going to happen, but that is not certain.

How will risk and its range of impacts and probabilities in a system of systems environment be expressed?

A second challenge from a management perspective relates to governance of such an endeavor. New governance structures, founded on principles even more so than objectives, will need to exist at a:

- System of systems at a global level.
- National level.

- Individual system levels such as energy, transportation, and agriculture sectors.

Governance challenges related to equity, social justice, economic dislocations, benefits, and burden sharing will grow in importance. Climate may become a new international area of competition, creating not just new political blocs, but perhaps even more important ideological ones.

High degrees of uncertainty related to causes, mitigation strategies, and required or desired outcomes will challenge governance most broadly, but also the ability to commit to sustained action over extended timeframes. At what point is "climate exhaustion" reached, similar to the "quarantine exhaustion" experienced during the COVID-19 pandemic?

A third challenge will be a recognition that flows, both their directions and rates, become the dominant control points from a management perspective. Individual projects are important because of their contributions to improving the "rates" of defined actions but the "rates" are the real metrics. System level metrics must focus not just on the "velocity" of a system, but more importantly on the "acceleration" and "jerk" or the change in the rate of acceleration. An open question remains whether these flow measures suffice at a system of systems level or are even higher-level measures of rates of change required to be assessed.[7]

Distribution of system of system level flows becomes increasingly important as the understanding increases of global mixing between hemispheres; atmosphere and ocean; and ocean surface and deep ocean sinks. These distributions will also highlight free riders in any global effort.

A fourth management challenge relates to stakeholder engagement and education. This last point cannot be understated and is given increased importance by the effectiveness of "fake news" efforts created by the social media accounts everyone holds and no one controls. A single version of the truth is desirable, but whose truth? The need for transparency has never been greater. Importantly, management uncertainties and basis for strategies that are already understood by only a small subset of stakeholders must now be communicated more broadly. Understanding levels must be improved and engagement in solving the problem or implementing the solution sets will be essential. Management communications must take the complex and reduce the messages communicated at an elementary level.

Conclusion

Be prepared to move beyond current management paradigms and into largely uncharted territories. In doing so, society will meet the challenge of reversing climate change. One of the unique challenges of that reversal as a system of systems problem is to recognize that not only is everyone a part of the "system," acting on it as it acts upon everyone, but that importantly everyone represents only one such actor and one perspective. There are billions of other perspectives that must be recognized and accounted for.

The current ascertainment of a control strategy and controlling mechanisms is influenced by a singular or small group of shared perceptions, but the effectiveness of any control strategy and mechanisms is

[7] Velocity, acceleration, jerk, snap, crackle, pop

highly influenced by the collective perceptions of others who are part of this system of systems. Those collective other perspectives must be acknowledged and all must attempt to understand them.

As individual and collective perceptions shift so must control strategies and mechanisms. This requires a form and level of engagement not typical in large programs and at an even greater scale.

Program managers have much to bring to meeting the challenge of reversing climate change if they are prepared to think deeper and broader and recognize that all are better than any single one. While policy, principles, and technology may reside in the domains of others, management of these efforts will most assuredly reside with project and program managers.

About the Author

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