

Report on the Megaprojects Leadership Forum

March 5–6, 2024



THE CANADIAN ACADEMY OF ENGINEERING
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Executive Summary

This report summarizes the proceedings of the Megaprojects Leadership Forum (MLF), sponsored by the Canadian Academy of Engineering (CAE) and held in Ottawa March 5–6, 2024.

Achieving Canada’s goal of net-zero greenhouse gas emissions by 2050 will require an unprecedented transformation of Canada’s energy system, necessitating massive investment on a very ambitious timeline. This investment in an unprecedented number of concurrent megaprojects will be over and above a significant baseline level of ongoing investment and must occur in a global context where many other countries face very similar challenges on very much the same timeline. While the challenge appears daunting, the commensurate opportunity is very compelling. Successful investment in transformational megaprojects would stimulate Canada’s domestic economy, contribute significantly to progress toward Canada’s net-zero goals, create opportunities for Canada to be an impactful participant and partner in global initiatives, and enhance Canada’s global “brand.” There is a significant potential prize in getting this right.

The CAE is an independent, self-governing, and non-profit organization established in 1987 to serve the nation in matters of engineering concern. The CAE comprises over 900 Fellows who have made outstanding contributions to engineering in Canada and around the world. As a national organization of distinguished professional engineers in various engineering fields, the CAE occupies a unique position to significantly contribute to the national dialogue on engineering-related capacity and expertise required to lead Canada’s journey toward net zero and to tackle the engineering challenges related to megaprojects.

The impetus for the CAE to hold the MLF was twofold. The first is the view that, despite past megaproject successes, Canada is not currently well positioned to plan and execute megaprojects at the volume and scale contemplated within the required time frame. The second is the view that the pragmatic and realistic voice of engineers needs to be more visible and influential in the national dialogue about net zero.

For the purposes of the MLF, the following definition of megaprojects was adopted:¹

Megaprojects, sometimes called major programs, are large scale, complex ventures that typically cost more than \$1 billion USD, take many years to build, involve multiple public and private stakeholders...and impact millions of people.

The focus of the MLF was on megaprojects through their entire life cycle, because these projects are generally the source of the greatest benefit and opportunity to achieve our goals, while also being most at risk for significant cost and schedule overruns. Examples of the types of megaprojects discussed at the MLF were hydroelectric dams, carbon capture and storage projects, offshore wind farms, and nuclear generating stations. In the context of the MLF, the term “engineering” was defined very broadly, encompassing engineering and design; permitting and project approvals; supply chain; project management; construction; project delivery, execution, and commissioning; and early operations support.

The participants in the MLF were an exemplary group of 30 senior leaders from across Canada with a wealth of engineering experience related to megaprojects, both within Canada and internationally. The MLF was centred on three topics discussed in separate workshop sessions and in plenary:

¹ Flyvbjerg, B. 2014. What You Should Know About Megaprojects and Why: An Overview. Project Management Journal 45(2). <http://dx.doi.org/10.1002/pmj.21409>.

- Best practices.
- Meeting the capacity challenge.
- Canada’s global competitiveness.

The outcome of each of these workshops is captured in Section 3 of this report.

The key themes that emerged from the workshops and plenary dialogue at the MLF are summarized below and outlined in detail in Section 4 of this report:

1. Developing an industrial strategy and “roadmap” framework for net zero:
 - In the context of net zero, this theme addresses the broad national and regional framework necessary to clarify intended outcomes and consequential impacts, align interests, and create a sense of urgency to take necessary actions, including planning and executing megaprojects.
 - An industrial strategy (the “what”), developed on a national and/or regional basis would outline opportunity areas to be pursued and intended outcomes, along with the elements that need to be in place to achieve these outcomes.
 - The “roadmap” (the “how”) provides the plan(s) as to how the intended outcomes will be achieved, along with the actions that need to be taken, the resources required, and related time frames and milestones.
2. Addressing the need for policy clarity and regulatory reform:
 - This theme focuses on the policy and regulatory environment necessary to enable successful planning and execution of megaprojects.
 - For Canada to be a leader in megaprojects, the current lack of policy clarity and certainty, along with complexity and delays in the regulatory system, must be addressed.
3. Embedding future-oriented best practices in megaproject planning and execution:
 - This theme, along with the fourth theme immediately below, focuses on the necessary conditions to successfully plan and execute megaprojects.
 - “Institutionalizing” the documentation, sharing, and transfer of best practices throughout the megaproject engineering life cycle is imperative to avoid repeating the mistakes of the past and to accelerate education and adoption on a forward-looking basis.
4. Building the necessary capacity to plan and deliver megaprojects:
 - Realizing our megaprojects objectives will necessitate increasing Canada’s skilled workforce and making significant improvements in efficiency and productivity through step-change initiatives in areas such as workforce participation, training and development, leveraging technology, and improving the supply chain.
5. Enhancing Canada’s megaprojects “brand”:
 - Building on the four themes above, this theme focuses specifically on the importance of Canada’s “brand” with respect to enabling opportunities to play a meaningful role in megaprojects in the global arena.

- Considering Canada’s “brand” in a holistic manner and demonstrating the ability to successfully deliver megaprojects at home would enhance our ability to establish partnerships and to provide technology and services outside Canada (particularly with our key allies).

More broadly, the MLF was characterized by a sense of both urgency and optimism regarding net zero by 2050, but with a strong and pervasive view that action in the thematic areas outlined above must be prioritized and is a necessary condition to achieving this goal.

The MLF is intended to be a starting point, rather than an endpoint, for the CAE’s leadership and engagement on this important topic. Each of the key themes outlined above lends itself to potential actions to better position Canada to meet the megaprojects challenge. In Section 5 of the report, a number of these actions are outlined for further consideration, some providing an opportunity for the CAE to play a leadership role, and some where the CAE could act as a catalyst or play a supporting role. In the near term, the CAE plans to meet with governments and other stakeholders to discuss these potential actions, determine the manner in which the CAE can best contribute, and prioritize those areas where the CAE has the capacity and expertise to make a meaningful contribution toward the successful delivery of megaprojects on a scale and timeline that are unprecedented in this country. Final decisions on specific follow-up action by the CAE are beyond the scope of this report and will be communicated separately.

The CAE would like to express its sincere appreciation to the participants in the MLF, each of whom graciously contributed their time and expertise. The CAE is also extremely grateful to Natural Resources Canada for providing the grant funding to enable the CAE to conduct the MLF.

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1. Background and Context

The Megaprojects Challenge

The Canadian government, numerous other governments, and many businesses and organizations have committed to net-zero greenhouse gas emissions by 2050. While the pace and alternative pathways to achieve this aspiration remain uncertain, one thing is certain: the journey to net zero will require an unprecedented transformation of the entirety of Canada’s energy system, from supply to transmission, to distribution, to consumption. The investment in megaprojects to transform Canada’s energy system on this very ambitious timeline is massive—hundreds of billions of dollars at a minimum, and estimated by some to be in the \$2 trillion range over the next three decades.² Potential regional priorities include liquefied natural gas (LNG) and electrification in British Columbia; carbon capture, utilization, and storage and hydrogen in Alberta and Saskatchewan; nuclear and critical minerals in Ontario; electrification in Quebec; and offshore wind in Atlantic Canada.

While these investment estimates and the determination of the pathway(s) to net zero are inherently uncertain, the scope of investment is daunting under any scenario. Furthermore, these investments in an unprecedented number of concurrent megaprojects, along with a large number of major projects, are over and above a significant baseline level of ongoing investment in other areas, such as infrastructure, transportation, mining, education, health care, and defence. These additional investments are significant themselves and would potentially increase the total investment over the next few decades to well in excess of \$2 trillion. The transition will impact all key sectors of our economy, including electricity, oil and gas, buildings, transportation, heavy industry, mining, information technology, and agriculture. They will also impact all Canadians, either directly or indirectly—as employers, workers, consumers, and citizens.

Canada has successfully undertaken multiple concurrent megaprojects in the past, examples being Alberta’s oil sands, Ontario’s nuclear program, and Quebec’s hydroelectric development. These successful endeavours required a collaborative approach between industry, a diversity of stakeholders, Indigenous Peoples, and governments, as well as visionary leadership. Notwithstanding these past Canadian successes, it is important to recognize that net zero by 2050 is a significantly larger challenge than these previous undertakings and will necessarily involve megaprojects in all areas of the country executed in the same time frame.

Importantly, in the context of the role of the Canadian Academy of Engineering (CAE) and the Megaprojects Leadership Forum (MLF), realizing this scope of investment will require a very high reliance on scaling up engineering resources for planning, design, execution, and operation of these megaprojects.

The Canadian and Global Contexts

It is also important to recognize that these challenges are not unique to Canada. Many other countries, including our major trading partners, face very similar challenges on very much the same timeline. Canada will be in an intense competition for global resources. Relying on external resources, as we have often done in the past, may be problematic. Additionally, to the extent that Canadian engineering firms are successfully competing in international markets, there will be a greater demand placed on the capacity of the Canadian workforce.

² RBC. 2021. The \$2 Trillion Transition: Canada’s Road to Net Zero. <https://thoughtleadership.rbc.com/the-2-trillion-transition/>.

While Canada has considerable experience in delivery of megaprojects, our overall domestic capacity and capability to deliver these types of projects on time and on budget has been in decline. In short, at anywhere near the scale of investment contemplated, Canada appears to have some significant challenges at a time when leadership in megaproject engineering has never been more important. There is a compelling case to address this issue with a heightened sense of urgency.

Notwithstanding the rather daunting challenges outlined above, the commensurate opportunity is compelling. Successful investment in transformational megaprojects would stimulate the domestic economy (e.g., creation of high-paying jobs, development of subject matter experts, expansion of the clean-tech sector), contribute significantly to progress toward Canada's net-zero goals, create opportunities for Canada to be an impactful participant and partner in global initiatives, and enhance Canada's global brand.

In summary, there is a significant potential prize to be realized in getting this right.

The Role of the CAE

The CAE is an independent, self-governing, non-profit organization established in 1987 to serve the nation in matters of engineering concern. The CAE is an active member of the Council of Canadian Academies, the International Council of Academies of Engineering and Technological Sciences and the Partnership Group for Science and Engineering.

CAE has over 900 Fellows, who have all made outstanding contributions to engineering in Canada and around the world. These Fellows have demonstrated their dedication to the application of science and engineering principles to advance social, environmental, economic, and technical solutions.

The primary mandate of the CAE is to demonstrate leadership in the responsible application of engineering knowledge for the benefit of Canadians, which encompasses providing strategic advice to decision-makers and contributing to the future direction of engineering. The CAE Fellows have earned their fellowship by fulfilling this mandate. It is important to note the CAE's role is not to advocate for a particular outcome, but rather to provide well-founded advice based on the expertise and experience of its members. As a not-for-profit organization and registered charity, the CAE does not engage in lobbying governments.

As a national organization of distinguished professional engineers in various fields, the CAE occupies a unique position to significantly contribute to the national dialogue on engineering-related capacity and the expertise required to lead Canada's journey toward net zero and tackle the engineering challenges related to megaprojects. This led to the CAE's decision to bring together a select group of CAE Fellows and other leaders with experience in megaproject planning, design, and execution across a range of economic sectors and jurisdictions to address this subject.

2. Purpose and Expectations of the MLF

Impetus for the MLF

The impetus for the MLF largely followed from the themes outlined in Section 1.

The first is the view that Canada is not well positioned to plan, design, and execute megaprojects at the volume and scale required, particularly within the time frame contemplated by the aspiration to achieve net zero by 2050. If not addressed, this has the potential for poor investment decisions, inefficient use of limited resources, and failure to realize desired outcomes.

The second is the view that the pragmatic and realistic voice of engineers needs to be more visible and influential in the national dialogue about net zero. To be very clear, this is not with the objective of conveying denialism or negativity, but rather to be a constructive party to the dialogue about what it would actually take to achieve the ambitious net-zero goals that have been articulated, concurrent with other megaprojects and major projects.

Why Focus on Megaprojects?

Canada's net-zero ambitions cannot be achieved without the successful implementation of multiple concurrent megaprojects throughout Canada. The focus of the MLF was therefore megaprojects, because they are generally the source of the greatest benefit and opportunity to achieve our goals, while also being most at risk for significant cost and schedule overruns. This is not to diminish the importance of other projects and initiatives, but the determinants of the success or failure of megaprojects are different and must be assessed in a focused and coherent manner.

Megaprojects can take at least two forms. The first is very large (\$1 billion+) integrated projects, such as hydroelectric dams and carbon capture and storage developments. The second is similarly large distributed or independent projects (such as heat pumps) executed on a broad scale within a common time frame. The discussion at the MLF focused largely on the former, although the latter has many similar issues and challenges.

Bent Flyvbjerg, one of the world's leading experts on megaprojects and co-author of *How Big Things Get Done: The Surprising Factors That Determine the Fate of Every Project, from Home Renovations to Space Exploration and Everything In Between*, defines megaprojects as follows:³

Megaprojects, sometimes called major programs, are large scale, complex ventures that typically cost more than \$1 billion USD, take many years to build, involve multiple public and private stakeholders...and impact millions of people.

Flyvbjerg notes that 90% of megaprojects have cost and schedule overruns. He highlights political, technological, economical, and aesthetic drivers as the key factors in leading decision-makers to underestimate megaproject risks and overestimate benefits.

Additionally, there is an increasing sense that the time may be right for a more integrated and grounded approach to the megaproject investments required to realize the aspiration of net zero by 2050. The scale of investment and the unprecedented build-out of new infrastructure are becoming increasingly evident to

³ Flyvbjerg, B. 2014. What You Should Know About Megaprojects and Why: An Overview. *Project Management Journal* 45(2). <http://dx.doi.org/10.1002/pmj.21409>.

policymakers and other key interests, along with the necessity of addressing the types of issues that were the focus of discussion at the MLF. Successfully delivering the investments necessary to reach net zero will require much stronger public consensus, as well as alignment and collaboration between governments and with business and other key stakeholders.

The MLF

The MLF was held in Ottawa March 5–6, 2024.

The program for the MLF is provided in Appendix A. Context-setting presentations were provided by Soheil Asgarpour (president, CAE), Monica Gattinger (founding chair of Positive Energy, University of Ottawa), Drew Leyburne and Colette Kaminsky (Government of Canada), and Don Winter (chair, US National Academy of Engineering). The discussion then centred on three separate workshops (see Section 3), followed by discussion among all participants in plenary.

The MLF participants were an exemplary group of 30 senior leaders from across Canada, most of them CAE Fellows. They included Indigenous leaders, academics, senior executives from the engineering and construction industry, senior executives from project sponsors, and leaders in technology and innovation. A list of the MLF participants is included in Appendix B. The MLF was held under the Chatham House Rule.

The following points further clarify the scope of the MLF:

- While the impetus for the MLF was largely challenges related to net zero, the scope necessarily included consideration of megaprojects in other areas, because the total portfolio of megaprojects (both nationally and globally) will draw on the same scarce resources, and in many cases these other projects will be necessary to deliver net-zero megaprojects (e.g., transportation, mining, social infrastructure).
- The entire project life cycle for megaprojects was considered, from early-phase conceptual planning to the early stages of operations, particularly given that the key issues and challenges often arise in the very early stages of these projects, and good planning and upfront risk mitigation is absolutely critical.
- “Engineering” was considered in a broad context, encompassing engineering and design; permitting and project approvals; supply chain; project management; construction; project delivery, execution, and commissioning; and early operations support.
- Recognizing that there are numerous other challenges related to the energy transformation and it is sometimes difficult to narrow scope, the primary focus was on those areas where the CAE and its members have legitimacy and credibility in offering independent advice.
- Participants were asked to be creative and forward-looking in their deliberations at the MLF, both in identifying critical challenges and in proposing creative paths to solutions.

3. Workshop Objectives and Key Outcomes

This section of the report outlines the objectives and key outcomes of each of the three workshops the MLF was centred on.

Workshop #1: Best Practices

Framing

Workshop #1 focused on the best practices required to successfully deliver multiple concurrent megaprojects in Canada. The workshop brought together experienced business and industry leaders, project delivery professionals, and academics who shared their experiences and lessons learned from delivering projects globally. From this shared experience, the group developed a prioritized listing of those best practices that will have the greatest impact on delivering the net-zero objective.

Current State of Project Delivery

A scan of the literature on megaproject performance globally indicates that over 90% do not meet their initial investment decision baseline target for cost and schedule. In addition, project delivery performance has not improved over the last 70 years. Causes for failure have been analyzed, and recommendations have been made, yet costs and schedules exceed plans again and again. We are not learning from our failures, nor are we learning from our few successes.

The reasons for failure are many. Some of the most common reasons include unrealistic expectations and targets, optimistic forecasting, inadequate planning, failure to face reality, unmitigated risks, unforeseen events, uncontrolled changes of scope, and rushed decisions made without adequate information, to name a few. To meet the 2050 objective, we cannot afford a 10% success rate for projects. Best practices that lead to success must be applied, from shared learnings and from introducing innovative practices that may lead to improved project delivery performance.

Key Outcomes

The five key best practices that will have the greatest impact on the successful delivery of multiple megaprojects are outlined below. The workshop participants were of the view that implementation of these best practices represents the minimum threshold required to meet the 2050 net-zero objectives.

Establish an industrial strategy framework

Collaboratively develop a strategy (the “what”) to provide a framework for a megaprojects plan, or “roadmap,” to achieve the goal of net zero by 2050.

The purpose of an industrial strategy is to provide a consistent and persistent framework for the plan, or roadmap, on how to get to the 2050 objective. The strategy provides the requirements (the “what” of the objective), so that the roadmap (the “how”) can be developed. This is not a list of all the essential projects, but rather of what needs to be in place for the wide range of essential projects to be completed successfully. Initially, the strategy framework should be developed in an iterative process with the roadmap. Consistency of framework is required so that best practices are entrenched and project processes are clear; persistence is required so that the policies survive political changes that may occur.

The strategy framework should be at a high level and cover all the facets required for successful implementation of projects to meet the objective. It must include financing and financial support, labour and skills development,

Indigenous participation, standardized permitting processes, resource sourcing, and global competitiveness and collaboration.

The industrial strategy framework should be developed by representatives of industry, labour, financiers, three levels of government, Indigenous groups, universities and colleges, project delivery service providers, and the fabrication and manufacturing supply chain. This approach has been successfully employed in some regions of the country.

Apply megaproject execution rigour

Comprehensive planning and performance metrics should be undertaken from the earliest stages of a project, with rigorous, objective, and transparent review of progress and consequential decision-making throughout the megaproject life cycle.

Given the number and extent of project failures, there is no shortage of analysis, data, and knowledge of lessons learned. Many of these lessons reside with organizations such as the Construction Industry Institute, the Project Management Institute, and Independent Project Analysis, but also with many individuals in all industries and sectors. From these lessons learned, best practices in all facets of projects are evident.

The fundamental learning from all projects is that nothing replaces the ethos of “doing our homework.” This means applying professional rigour to project execution. This rigour includes detailed planning, following front-end loading processes, conducting risk assessments and mitigation plans, holding rigorous gate reviews (including consequential decision-making) as the project is developed from initial concept to final approval to proceed, and assigning teams led by experienced project professionals.

Projects often fail because they are rushed to execution by taking shortcuts, by skipping steps or gate reviews, or before they are ready to execute. This is frequently driven by best-case or unrealistic expectations of costs and schedule that leads to poor decisions and compromises quality, safety, and the business case. The problems of starting before being ready manifest themselves during execution, at a time when change is very expensive and causes massive delays. Best practice, therefore, is to complete enough work to independently assess that the project is ready for implementation. This assessment should be done by an impartial third party. Some other best practices to combat unrealistic expectations are to follow the front-end loading process, limit procurement of equipment and materials to what is required to complete engineering, limit construction to early enabling work, and not start construction without well-advanced designs.

In some cases, following rigorous project development processes may not be possible. This is often required due to a crisis, a rush to market, or an unavoidable event. Should this occur, innovative processes are required. Best practice in such cases requires smart risk-taking. Smart risk-taking means everyone involved is aware of the risks of taking shortcuts; that plans may change along the way as the project develops; and that the initial scope, cost, and schedule may change. Smart risk-taking requires following two important processes. The first is a rigorous risk management process, continuously identifying new risks and developing mitigation plans to address them. The second is a rigorous change management process, where the scope, schedule, and cost impact of the risk mitigation plan are visible, understood, agreed, and approved.

One of the best practices that helps combat unrealistic expectations and unwarranted optimism and allows for “whistleblowing” on shortcuts to the required rigour for successful project development and implementation is to establish a project executive committee of the key stakeholders. The committee should meet regularly to allow unfiltered project information to reach the key decision-makers and owners of the project—that is, for the

reality of the project performance to surface and to support decisions on actions to be taken to correct any issues raised.

Projects do not end at completion of construction. They must be commissioned, started up, ramped up to full production, and operated and maintained for many decades. The transition from construction to full production is a key factor in project success. Best practice is to plan for and establish pre-operational testing, cold and hot commissioning, and business-readiness processes early in project development. These practices include hiring and training operators and maintainers, establishing safe operating processes and procedures, and creating the systems required to run a successful business to take over the commissioned project and ramp up to full production. Each of these steps requires time and specialized resources. These factors should be explicitly addressed in project plans.

Establish collaborative contracting models

Collaborative contracting is an effort to reduce overall project risk, apportion risk appropriately, and ensure all parties to the contract are treated fairly.

Implementation of megaprojects requires a multitude of services to be procured. These services include design, engineering, supply, fabrication, labour, installation, transportation, construction, and commissioning. Most of these services are typically supplied by service providers contracted by the owner. One of the key failures on projects is that sometimes the contract places undue obligation and risk on the contracted party. This leads to the party behaving to protect itself from risk rather than to focus on what is best for the project. This behaviour leads to padding of cost estimates and a focus on administration of the contract rather than on the project itself, and it invariably leads to claims, counterclaims, and long legal battles. Too much energy and focus spent in these areas detracts from the real work and deliverables required by the project, leading to poor performance, lack of resilience and shared problem-solving, cost growth, and schedule delays.

Contract requirements are often driven by owners and financiers who fallaciously believe that onerous contracts deliver cost and schedule certainty. If that were the case, 90% of projects would not be failing. Best practice in contracting is to establish a collaborative contracting model for megaprojects. Collaborative contracting does not mean that the contracted party does not have risks and obligations they must meet. On the contrary. However, collaborative contracting requires that risk is allocated fairly, to the party that can best control that risk, at a time when that party has done enough homework on the risk so it can properly mitigate it. When this is done, the contracting parties can lock down the scope, schedule, and cost accountability with greater certainty, driving the right behaviour for the good of the project as a whole. The experience of the workshop participants is that such a contracting model leads to overall higher efficiency; improved productivity; and improved overall safety, quality, schedule, and costs. It was also noted that a less abrasive and confrontational project participant framework enhances job attraction and retention, particularly among younger workers. Collaborative contracting is a best practice at this time of increased and potentially acute talent shortages, when a focus on productivity, rapid and collaborative problem-solving, and job satisfaction is crucial.

Another best practice is to apply fair labour practices in contracts. Successful megaprojects require motivated and skilled labour. The labour must be attracted to the project. Many projects in Canada are in remote, inhospitable sites that not only require labour to make onerous personal sacrifices, but also lead to family, community, social, and personal physical and mental health issues. Contracts should require all bidders on contracts to apply equal, fair labour practices to overcome these issues and to attract the required labour force.

Adopting modular construction

Modular construction has the benefit of making a one-of-a-kind megaproject into a series of smaller, more manageable projects constructed in a more controlled environment, which also positively impacts the project learning curve.

Implementing multiple simultaneous megaprojects will require many hundreds of thousands of skilled craftspeople. While Canada needs to do much more to attract, train, and develop these craftspeople, the group believes that the required labour capacity will not be achieved. Fewer young people are attracted to becoming craftspeople, and many are not willing to make the sacrifices and lifestyle changes required to work at remote sites.

Best practice to address this issue is to expand the adoption of modular design and construction. Modularization is the concept where parts of the project physical assets are constructed in one location, transported to the required location, installed, and connected to the other parts of the assets. All projects use modularization to some extent if the cost of modularization, transportation, and site installation is lower than the cost of transporting parts and building it on site (i.e., a so-called stick build). However, for the 2050 objective, modularization will be very attractive for reasons other than cost trade-offs. Modularization is a way to reduce schedule, improve safety and quality, remove labour from remote sites, and increase labour capacity, as module construction yards can be located where labour is readily available, even outside Canada.

Modularization requires transportation infrastructure such as module yards, ships, roads, and harbours. Best practice is to establish module yards and other infrastructure to serve multiple projects simultaneously. This requires careful planning and coordination between projects.

Best practice is to standardize designs across many megaprojects so that repeatable design and construction can occur with continuous improvement between successive modules. An example could be to modularize and standardize elements such as structures, buildings, pipe racks, and precast concrete foundations.

Digital design and delivery of projects is another best practice, which facilitates standardization, reduces engineering and labour requirements, and improves efficiency in project design and execution.

Create coordinated industry groups

Bringing together megaproject stakeholder representatives to foster alignment and a shared sense of purpose.

Experience indicates that best practice to achieve successful implementation of a large-scale program of work is to create coordinated industry groups. These groups are made up of representatives from across the affected sectors (e.g., energy, metals, infrastructure), but with additional representation from service providers, suppliers, contractors, operators, financiers, and other stakeholders. The purpose of creating these groups is to ensure the development and monitoring of the industrial strategy framework and the roadmap mentioned above. The groups provide a forum to share best practices, learn from each other, and advise on common risks and how to overcome challenges. Invited observers and guest participants from government and other stakeholders at key points can greatly improve the creation and adoption of standards, performance-based regulations, and permits to pilot innovative designs.

Workshop #2: Meeting the Capacity Challenge

Framing

Based on trending data from Canadian universities and colleges and information from Engineers Canada on the demographics of available, skilled technical resources to support megaprojects, there is a growing capability gap. This is a risk to the successful completion of megaprojects in terms of meeting technical scopes, timing, and cost estimates. The risk to Canada, ultimately, is not achieving net zero by 2050.

Assuming funds are available and the timing remains fixed with an end date of 2050, we are faced with a key question: How do we build numerous megaprojects in 25 years, given a limited experienced resource pool and a challenged supply chain? This is solvable only through a step change in how we do business today—by building a capacity pipeline. Some top solutions include a redesign of our engineering, procurement, and construction management processes; an expansion of engagement and social skills; the development and use of new technologies; the growth of a reliable supply chain; and the development of numerous skilled persons (or master builders) to execute megaproject work.

Building Capacity

Building engineering capacity

A number of approaches can be employed to increase our engineering capacity to plan and execute megaprojects.

For any megaproject, the project team consists largely of engineers during the design phase. A large number of engineers are also required during construction, to oversee procurement, and as project managers. All these roles are necessary for project success, with a range of new concepts to be developed and used to improve the size and skills of the engineering talent pool.

Certainly, engineers are one of the most critical groups of experts required for completing megaproject engineering designs, duly diligent oversight of all design elements, and meeting the required stamped certification of drawings and key deliverables.

As a specific focus on how to increase the number of active engineers in Canada to serve on megaprojects, several creative approaches are offered, including paying a premium for engineering skills and incentivizing certain critical roles; marketing engineering roles to youth; retaining retirement-age engineers with attractive flexible work arrangements to coach and mentor less experienced practitioners; creating inclusive workplaces to attract greater diversity, especially women; training Indigenous Peoples; upskilling technologists to an engineering level of proficiency; fast-tracking engineering immigrants into Canada with an efficient process for attaining Canadian professional engineering designations; and creating rapid education and accreditation programs within Canadian universities for output of a larger cohort of graduate engineers.

As a complementary opportunity, Canada can grow the engineering base beyond the nation's borders by using offshore third-party engineering companies and pulling geographically distributed engineering resources from Canada's large, international engineering firms onto Canadian megaprojects (e.g., from India, South America, and Southeast Asia). This would enable skill and knowledge transfer, as well as more efficient use of available resources (for example, by leveraging time zone differences). To be successful, this would require a deep understanding of cultural differences in risk assessment and decision-making.

Increasing our capacity to deliver engineered megaprojects can also be achieved through more effective engineering, procurement, and construction management methods and processes. For engineering work,

process improvements include creating an aligned national standard for engineering legislation and regulations to readily allow interprovincial and inter-territorial practice; ensuring oversight and compilation by lead engineers while technologists and junior engineers contribute to design elements; increasing the use of artificial intelligence (AI) to guide or complete some of the lower-level design elements; creating new apprenticeship and skills training programs, including social/communications for engineers working in complex systems; and creating targeted mentoring programs with a range of senior lead engineers with specific expertise and disciplines assigned to a cohort of mentees, similar to an engineers-in-training rotation program. There may also be further opportunities to transition highly skilled engineers between megaprojects as a form of parallel processing, thus preventing bottlenecks associated with a potential low availability of skilled persons with unique or rare engineering experience.

Building non-engineering capacity

Successful delivery of megaprojects will also require focus on other key roles, beyond engineering.

Similar to engineering, there is an emerging opportunity for Canadian universities, colleges, and third-party education institutes to provide geared programs to educate and accredit students in other megaproject duties, including project management, construction management, estimation and cost tracking, site construction, commissioning, and quality assurance/quality control. Some of these programs can be online, while others require in-person training. Time in the field will need to be defined and tracked, with creative use of senior engineers and supervisors, as well as online certification programs and testing systems to assure the quality of the education and training.

Building procurement and construction capacity

Redesign of key processes will enable growth of procurement and construction capacity in Canada.

Growing procurement and construction capacity in Canada will require a redesign of many processes, including procurement strategies that leverage and support vertically integrated supply partners and focus on priority metrics for a given project (beyond lowest cost); development of open source databases for estimating, along with estimate-vs.-actual updates from each megaproject team as work progresses; sharing of procurement data from project to project; and early engagement with contractors and construction groups in the engineering feasibility study design phase. Construction work process improvements and redesigns include expanded use of modularization, fabrication, assembly, and technologies to build efficiency into the system. Separate work groups, such as non-engineers, can be used for sub-tasks, while a broader group of workers can be solicited, trained, and ladder up as each person's proficiency grows. A training, tracking, and accreditation process is needed to streamline availability of resourcing using accessible online tools such as job banks and sourcing agencies. Training centres of excellence may prove viable for strategic upskilling and certifications particularly geared to a range of defunct industries and jobs (e.g., pipefitters) into new vacancies within megaprojects.

Building project management capacity

A creative approach to management of megaprojects will be required and should be supported by a longer-term focus on research and development.

Management of megaprojects will need to move beyond traditional project management processes, with the use of agile approaches such as stand-ups, scrums, action boards, and continual adjustments to the latest information. Other management process improvements include increased use of conceptual designs to rapidly short-list options for trade-offs and lock into an approved feasibility design, creation of an efficient gated

process and a consistent decision-making process, and use of team-based project management software tools with electronic document-sharing platforms and digital systems.

As a longer-term focus and parallel effort, university researchers at the post-graduate level can be assigned to look at executing megaprojects with the use of creative engineering processes, AI, and changing social frameworks. The research and development aim is to improve the effectiveness of megaprojects through a technical, social, and financial lens to ensure achievement of on-time, on-budget, and net-zero targets.

Building community engagement capacity

The social engagement dimension of megaprojects is increasingly a critical success factor.

The social engagement surrounding megaprojects is another critical element to address as a core segment of the capability pipeline. Given the heightened focus on Indigenous communities where many projects are to be built and the much-needed relationship with labour unions, there is a growing need for engineers and project managers to be well versed in ways to build consensus and trust.

Building technological capacity

Numerous potential technology solutions must be developed and deployed to enable the effective and efficient delivery of successful megaprojects.

Innovative technologies offer a means to support the effective delivery and high quality of megaprojects through the design, execution, and operations phases. Priority technology solutions include:

- Standardization of digital tools and models to assess and/or predict performance.
- Software tools to assess project readiness as well as risks and estimations.
- Development of digital tools to incorporate lessons learned and allow for simulation of new solution processes.
- Leveraging centres of excellence on a global scale to develop and/or apply technologies to enhance delivery of megaprojects.
- Creation of forums for innovation sharing, design thinking using modularization, and development of digital twins during design phases.
- Virtual reality and immersive environments for training programs and engineering design reviews.
- Database systems and intelligence software based on common project metrics collected according to a gated process.
- AI-driven project advice modules.
- Fit-for-purpose laddering-up training and experiential learning to develop master builders.
- Standardized digital backbones and communication systems to enable project instrumentation for monitoring and controls.
- Drones and electronic devices for routine investigations and measurements.
- Remote control and automation of excavation and building processes.
- Access to financial stimulus and processes for accelerating Canadian-made technologies and equipment.
- Test beds to trial approaches prior to field applications.
- Research studies within Canadian universities to better understand cutting-edge computational tools for megaprojects, including simulation, design, and modelling.

Building supply chain capacity

Supply chain capacity is an integral component of successful megaprojects. Solutions are identified to de-risk megaprojects by bolstering Canada's supply chain.

The supply chain challenge in North America is very real, with a projected shortfall of minerals and metals to enable the electric vehicle transition, let alone to support the construction of megaprojects. The goal of Canada's supply chain is to de-risk megaprojects by securing nationally sourced materials with processing and manufacturing facilities and supplementing with trade partners. Supply chain solutions include estimating supply vs. demand for consumables and identifying options to fast-track projects into production, standardizing supplier information requirements within Canada and via trade policies to streamline reporting and reduce costs, building relationships between suppliers and projects to reduce wait times and costs, using state-of-the-art supply management tools to estimate and forecast, incentivizing vertical integration and investments in Canadian facilities, and identifying and reducing waste in the supply chain.

Key Outcomes

Key actions to address the capacity pipeline to enable megaprojects to be built in Canada are summarized below.

Workforce development

- Implement strategies to attract, retain, and develop skilled professionals.
- Offer incentives and training programs for engineers and other core technical roles.
- Utilize mentorship, apprenticeship, and fast-track immigration programs.
- Collaborate with universities and colleges to expand relevant education programs.
- Focus on diversity and inclusion, including training for Indigenous Peoples.

Technology integration

- Standardize digital tools and models for project assessment and prediction.
- Develop AI-driven solutions for lower-level design tasks.
- Utilize virtual reality for training and design reviews.
- Invest in research and development for innovative engineering processes.
- Establish centres for technology development and promote innovation sharing.

Supply chain management

- Evaluate and optimize supply vs. demand for materials and resources.
- Standardize supplier information requirements and streamline reporting.
- Build relationships with suppliers to reduce wait times and costs.
- Invest in Canadian facilities and incentivize vertical integration.
- Implement state-of-the-art supply management tools for estimating and forecasting.

By focusing on these three areas—workforce development, technology integration, and supply chain management—Canada can effectively address the capability gap and ensure the successful completion of megaprojects while working toward the goal of achieving net zero by 2050.

Workshop #3: Canada's Global Competitiveness

Framing

The anticipated investment in megaprojects in Canada over the next several decades represents a significant challenge in attracting, developing, and retaining the resources to deliver the megaprojects that are necessary to meet our domestic aspirations, including climate change goals. Recognizing that many other countries have similar aspirations on similar timelines, there is also an opportunity to grow our domestic economy and contribute to outcomes beyond our borders by providing engineering, construction, technology, and related services to global markets. In both cases, it will be imperative that Canada positions itself as both a viable competitor and a valued partner.

The Global Context

The global context in which Canada must position itself for successful delivery of megaprojects is clearly changing, with significant shifts in geopolitics, increasing protectionism, the waning impetus toward globalization, and increasing focus on defence and security. These trends both impact the nature of megaprojects that may be undertaken (for example, there may be a greater focus on investment in the defence sector) and have consequential impacts on key factors such as labour availability, supply chain, and access to technology.

The key theme arising from this discussion was that Canada must leverage its relationships with key partners, such as the US, the UK, and Australia, but it must do so in a holistic manner. Canada's "brand" needs to be founded on a demonstrated ability to get things done at home and a willingness to be a broad and committed partner in our engagements with key global partners. As the global context changes, it will be important for Canada to be seen to by our allies to be pulling our weight, particularly when it comes to defence and security.

The Current State—Canada's Strengths and Weaknesses

Canada's key relative strengths and weaknesses were identified as part of the discussion in the workshop.

Perceived strengths as they relate to megaprojects include:

- A competitive cost base, influenced in part by the relative strength of our currency.
- Our talent, experience, and know-how in delivering megaprojects.
- Our rich resource base, including access to critical minerals.
- Our demonstrated ability to successfully develop relationships with governments at all levels and with key stakeholders.
- Progress in advancing partnerships and other relationships with Indigenous Peoples.
- Ongoing investment by governments in the foundational infrastructure required to enable delivery of megaprojects in Canada.

Perceived weaknesses as they relate to megaprojects include:

- The lack of a shared vision and supporting rigour in a strategy and plan to achieve our domestic aspirations, exacerbated by the complexity of the Canadian federation, all of which make it more challenging to compete outside Canada.
- The complexity and lack of clarity and predictability in our policy and regulatory system, which impedes the ability to advance projects at the scale and pace required.

- The lack of alignment among various jurisdictions in the Canadian federation, which adds to the challenge of executing megaprojects.
- Workforce availability, which is viewed as being relatively worse than many competing jurisdictions (recognizing that Canada is heavily reliant on immigration in this regard).
- Workforce productivity, which is viewed as being about average relative to our competitors, but with significant room for improvement.

Overall, the perceived weaknesses outweigh the perceived strengths. That is not to say Canada lacks past successes that provide a diversity of strengths on which to build, but these strengths are very likely to be insufficient to address the scale and pace of the challenge going forward.

Key Outcomes

The key observations and potential actions arising from this workshop are outlined below.

Clarifying the vision, strategy, and plan: the “roadmap”

A comprehensive plan, or “roadmap,” developed collaboratively by key stakeholders on a regional basis using a systems-oriented engineering framework, would increase trust and confidence that the megaprojects required to achieve net zero can be successfully delivered in the time frame required.

The aspiration to achieve net zero by 2050 has not resulted in the necessary “Manhattan Project” sense of urgency, shared commitment, and alignment among Canadians. Additionally, there is a distinct lack of rigour regarding what it would take in terms of strategy and plan to achieve this aspiration (i.e., a comprehensive roadmap). In the absence of an aligned strategy and roadmap, there is a lack of clarity as to what needs to be done and how it will be achieved, with a resultant lack of trust and confidence that the goal of net zero is achievable. Such a strategy and roadmap should be developed by applying a systems-oriented engineering framework, also addressing the consequential impacts arising from this plan, including requirements for labour, financing, supply chain, and technology, and to address societal issues.

In thinking about the roadmap, it was emphasized that we need to get started without delay and should consider the path forward in three time frames: the near term, with a focus on leveraging existing assets to improve performance; the medium term, in which the necessary financial and services capacity is further developed to support the transition to net zero; and the longer term, in which step-change initiatives are undertaken to achieve a sustainable net-zero outcome (an example might be megaprojects founded on circular economy principles).

The workshop participants also noted that ongoing support for action on climate change and concomitant megaprojects will necessarily be dependent on satisfying the social needs of Canadians, importantly including those of Indigenous Peoples. The roadmap toward net zero and enabling megaprojects, both domestically and in Canada’s global initiatives, will require sustained attention to the social dimension of this challenge.

Policy clarity and regulatory reform

Policy clarity and regulatory reform must be addressed for Canada’s domestic aspirations to be achieved, and there must be a more visible engineering presence in this ongoing dialogue.

There was a strongly held view among workshop participants that a lack of policy clarity and complexity and delays in the regulatory system are significant impediments to achieving Canada’s domestic aspirations and a competitive disadvantage in the global arena. In particular, the length and complexity of the regulatory review

process needs to be aligned with the time frame available to meet goals such as net zero by 2050. These issues are not new and continue to be the subject of extensive review, dialogue, and debate. There is a need for a more visible engineering voice in this dialogue, contributing to ongoing work in this area in a collaborative manner.

Improving megaproject delivery

There are numerous opportunities to improve megaproject delivery, thereby improving Canada's competitive position, standing with our key allies, and improving the on-time and on-budget performance of these projects.

Several ideas were discussed with regard to initiatives that would improve Canada's competitive position and standing as a potential global partner, including:

- Institutionalizing the capacity for objective expert advice (e.g., transfer of best practices) and for independent review of megaprojects throughout the life cycle.
- Focusing also on "mega-programs" (a suite of linked megaprojects/large projects with common attributes) in addition to megaprojects, particularly in the public sector, to provide greater certainty of funding, continuity in the labour force, transfer of learnings, etc.
- Improving "customer" capacity for megaproject oversight by enhancing engineering skills and capacity in customer organizations, particularly where the public sector is the customer.
- Broadening the application of pre-fabrication and modular construction practices.
- More aggressively and consistently applying new technologies to both the design and construction phases of megaprojects, the latter being a significant opportunity.

Labour availability and productivity

A number of initiatives were identified to improve Canada's competitive position with respect to both workforce availability and workforce productivity.

With respect to labour availability, several initiatives were identified to improve Canada's competitive position. These included intensifying efforts to improve the participation of underrepresented groups in the workforce, with a particular focus on transfer of best practices regarding Indigenous representation in the workforce and attracting new engineers to the megaprojects sector, especially women. Additionally, there is an opportunity to address accreditation barriers to enable qualified immigrants to Canada to more quickly apply their skills and experience.

With respect to workforce productivity, the feedback from the workshop was that we have many technological tools and best practices that could (and should) be applied much more extensively than is currently the case. We need to work toward standardizing and sharing these practices to realize greater impact.

All the initiatives summarized above would have a positive impact on Canada's brand as it relates to the delivery of megaprojects, thereby improving competitiveness and positioning Canada as a more credible and reliable global partner.

4. Key Themes and Potential Actions

The purpose of this section is to build on the summaries of the three workshops by synthesizing and summarizing the key thematic outcomes arising from the dialogue at the MLF.

Five overall themes emerged from the workshops and dialogue at the MLF. These themes are outlined below, and each provides a basis for potential follow-up actions.

In the context of net zero by 2050, the first theme addresses the broad national and regional framework necessary to clarify intended outcomes and consequential impacts, align interests, and create a sense of urgency to take necessary action, including planning and executing megaprojects.

Developing an Industrial Strategy and “Roadmap” Framework for Net Zero

Canada’s aspiration to achieve net-zero greenhouse gas emissions by 2050 has been consistently articulated by governments and other interests. However, there was a pervasive view expressed at the MLF that Canada currently has neither a sufficiently rigorous and credible strategy and plan (national or regional) to achieve this goal nor an underlying “Manhattan Project”-type sense of urgency to drive the necessary supporting actions. In the absence of such clarity, there is a lack of urgency, shared commitment, and alignment among Canadians and a resultant lack of trust and confidence that net zero by 2050 is in fact achievable.

An industrial strategy, national and/or regional, would provide further detail as to the opportunity areas that should be pursued, the outcomes we are seeking to achieve (the “what”), and the key elements that need to be in place to achieve the outcomes. This strategy framework should be both consistent (so best practices are entrenched) and persistent (so that policies survive political change).

While the strategy defines the intended outcome (the “what”), the roadmap outlines the “how,” or the plan as to how the outcome will be achieved. The roadmap provides further clarity as to the actions that need to be taken, the resources required, and the related time frames and milestones. The plan can (and should) be periodically updated and must be sufficiently flexible and adaptable to allow any necessary adjustments to be made in response to changing external circumstances. At least initially, the strategy should be developed as an iterative process with the roadmap.

The strategy and roadmap must be much more than a wish list as to what needs to be done and when to achieve net zero. They should be developed by applying a systems-oriented engineering framework, holistically addressing requirements such as financing and financial support, labour and skills development, Indigenous participation, standardized permitting processes, resource sourcing, and global competitiveness and collaboration. Furthermore, they should be developed by applying proven engineering risk assessment methods to identify and mitigate key risks. They should clearly highlight the time frame in which key decisions need to be made and actions need to be taken to realize Canada’s stated goals.

They must also be developed in a collaborative manner involving all key interests—representatives of industry, labour, financiers, three levels of government, Indigenous groups, universities and colleges, project delivery service providers, and the fabrication and manufacturing supply chain.

For additional clarity, the National Oil Sands Task Force initiative from the 1990s might be used as an example of what is meant by an industrial strategy and roadmap framework. The product of the work undertaken by the task force was a vision for revitalization of oil sands development in Alberta, well-defined strategic objectives/outcomes, and a supporting plan to achieve the objectives over time. The key attributes of the

process were visionary leadership (in this particular case, largely provided by industry), collaboration and engagement among key stakeholders, an enabling role by government, and a consistent and persistent commitment to the end goal. This is one example of a framework that, once established, provided the context in which concurrent megaprojects could be successfully planned and executed.

The Regional Energy and Resource Tables recently initiated by Natural Resources Canada embody a number of the objectives and attributes of the collaborative and coordinated framework being proposed. There is an opportunity to improve the effectiveness of these tables by involving the CAE, by ensuring the plans developed by the tables are rigorously assessed from both systems engineering and risk perspectives to provide greater confidence that they are executable and achievable, and by ensuring representation from a broad and diverse group of stakeholders.

The second theme focuses on the policy and regulatory environment necessary to enable successful planning and execution of megaprojects.

Addressing the Need for Policy Clarity and Regulatory Reform

There was a strongly held view among participants in the MLF that a lack of policy clarity and certainty and complexity and delays in the regulatory system as it relates to megaprojects are significant impediments to achieving Canada's domestic aspirations and a competitive disadvantage in the global arena. Opportunities for improvement range from broad reform to improvements within the existing policy and regulatory framework.

Given that these issues are being extensively discussed in other venues and the Government of Canada is currently reviewing its approach to federal oversight and regulation of projects, the MLF participants did not make specific recommendations regarding regulatory reform. That said, if Canada is to be a leader in the megaprojects arena, these issues must be addressed with a sense of urgency, and there is a need for a more visible engineering voice in this ongoing dialogue.

The third and fourth themes are specific to the necessary conditions—embedding best practices and building capacity—to successfully plan and execute megaprojects.

Embedding Future-Oriented Best Practices in Megaproject Planning and Execution

One of the key outcomes from the MLF was the need to “institutionalize” the documentation, sharing, and transfer of best practices throughout the project life cycle, to avoid repeating the mistakes of the past and to accelerate education and adoption of forward-looking best practices. The importance of also looking outside Canada for best practices was emphasized.

In particular, the criticality of front-end planning was repeatedly emphasized—plan, plan, plan, in a collaborative manner with the key stakeholders, and mature designs before the start of construction. The issues arising from “optimism bias” (e.g., political, project, public) and a reluctance to speak the truth and to handle the truth about risks and challenges were both highlighted as significant impediments to the successful delivery of megaprojects.

Best practices that should be applied to future megaprojects are detailed in the workshop summaries, with the key focus areas being:

- Applying execution rigour.
- Establishing collaborative contracting models.
- More broadly adopting prefabrication and modular construction methods.

- Reducing complexity.
- Encouraging “mega-programs” in addition to megaprojects, particularly in the public sector, for standardization and repeatability.

The sharing and adoption of megaprojects best practices is a necessary condition if net zero by 2050 is to be achieved. The CAE has the opportunity to play a significant role in this regard.

Building the Necessary Capacity to Plan and Deliver Megaprojects

To realize our megaprojects objectives, it will be necessary to increase Canada’s skilled workforce and make significant improvements in efficiency and productivity.

With respect to workforce development, a key lever will be to double down on efforts to improve the participation of underrepresented groups in the workforce for megaprojects, particularly women and Indigenous Peoples. Women represent a significant potential talent pool for megaprojects. Progress is being made toward increased representation, but there is a need to accelerate efforts in this area to deliver much better outcomes. There are many examples of creative approaches to partnerships and other relationships with Indigenous groups in Canada, which need to be shared and implemented on a broader scale. Fast-tracking immigration to Canada for people with relevant skills and addressing accreditation barriers to enable qualified immigrants to make a greater contribution in a more timely manner will be important considerations in addressing the skills gap.

It will be important to attract, develop, and retain skilled professionals in the megaprojects space. Universities and colleges will play a key role in the initial education and training, with a recognized need to expand relevant education programs. This will need to be complemented with ongoing training, both on the job (e.g., mentorship, apprenticeships) and off the job. Given the large number of concurrent megaprojects anticipated in Canada, “learning curve” opportunities will be more limited, and new approaches to training, such as the use of simulator-based training, will be required. It is important that training for megaprojects be extended beyond engineers and technical professionals to others whose actions impact the outcomes of megaprojects (e.g., finance professionals, regulators, suppliers).

With respect to workforce productivity, the feedback from the workshops was that we must look to technology as a key enabler. In some areas, we have many technological tools and best practices that could (and should) be applied much more extensively than is currently the case. In this regard, there is an opportunity to work toward standardizing and sharing these practices to realize greater impact.

Leveraging technology is a critical success factor for megaprojects going forward in both engineering and construction. Areas of opportunity discussed at the MLF included standardizing digital tools and models for project assessment and prediction, developing AI-driven solutions for lower-level design tasks, and utilizing virtual reality for training and design reviews. Canada continues to lag in investment in technology, and the funding of research related to megaprojects is small relative to their national importance. In addition, sectors such as construction have limited capacity and experience with onboarding innovations. There is an opportunity to increase investment in innovative engineering processes and to invest in centres for technology development with a specific orientation toward megaprojects.

The supply chain is an essential component of megaprojects delivery, and there are some very real challenges in Canada that need to be addressed. A number of opportunities were identified at the MLF, including:

- Evaluating and optimizing supply vs. demand for critical materials and resources.

- Standardizing supplier information requirements and streamlining reporting.
- Building stronger relationships with suppliers to reduce wait times and costs.
- Implementing state-of-the-art supply management tools for estimating and forecasting.

The fifth theme follows directly from the four themes outlined above and focuses specifically on the importance of Canada’s “brand” in enabling Canadian firms to play a meaningful role in opportunities as they relate to megaprojects in the global arena, particularly with our key allies.

Enhancing Canada’s Megaprojects “Brand”

Discussion at the MLF regarding how Canada is perceived from an external perspective strongly reinforced the need to think about Canada’s brand in a holistic manner. In the first instance, and with respect to megaprojects, the demonstrated ability to get things done at home enhances our ability to establish partnerships and provide technology and services outside Canada. The outcomes arising from the MLF provide numerous opportunities to improve our megaprojects performance. Additionally, there will be consequential collateral benefit to Canada’s opportunities as they relate to megaprojects if we are seen to be pulling our weight, and there is mutual benefit in a broader context in relationships with key partners such as the US, the UK, and Australia.

Finally, the MLF highlighted four broad and important considerations:

- Mindset is important—we need to think about these challenges from the perspective of “what would it take” rather than “why it can’t be done.”
- In many respects, the next 10 years on the journey to net zero is the low-hanging fruit. It will continue to get more difficult over time, which is the reason to initiate the actions today that will be necessary to achieve results over the medium to longer term.
- Broader societal acceptance and support of megaprojects is increasingly important, particularly in regions where megaprojects are more frequently implemented. This necessitates a stronger engineering focus on addressing social issues (real or perceived) by engaging and building the trust and confidence of key stakeholders. This is an area where all three levels of government can have a significant influence on outcomes.
- Canada has a wealth of experience and expertise related to megaprojects that provides a platform upon which to build and the basis for a sense of optimism regarding megaproject planning and delivery going forward.

5. Next Steps

The MLF is intended to be a starting point, rather than an endpoint, for the CAE's leadership and engagement on this important topic.

This CAE report will be shared with the federal government via Natural Resources Canada. In addition, we anticipate that the report will also provide the foundation for dialogue with other governments, Indigenous groups, and interested stakeholders.

We encourage everyone involved in the MLF to share the results with their networks and, in doing so, reinforce the sense of urgency, create further impetus for action, and accelerate progress toward addressing the issues and advancing the opportunities identified during the MLF. This cannot be done by the CAE alone.

This report is intended to summarize the outcomes of the MLF and the key themes arising from the discussion, all of which lend themselves to action to better position Canada to address the megaprojects challenge. Some of these potential actions are more complex and have a longer-term time horizon, whereas others are more immediate. That said, complexity and longer time frames should not obviate the need to get started without delay.

In addition, some of the potential actions outlined in this report will necessarily fall to government to lead. However, it is important to recognize that it is not the role of government alone to address these issues and establish a path forward. This is a complex and daunting challenge that will require collaborative solutions involving many players. The CAE is a willing partner for the longer term and is well positioned to contribute to areas where it has the expertise and capacity to do so.

With respect to areas where the CAE might take a lead role, the following priority areas will be given consideration:

- Working with partner academies (specifically in the US, the UK, and Australia) to advance the formation of an independent entity to identify, codify, and promote best practice as it relates to megaprojects, and to provide objective and impartial advice to governments and others regarding delivery of megaprojects throughout their life cycle.
- Identifying and sharing best practices as they relate to the application of technology to improve engineering productivity for megaprojects.
- Identifying and sharing best practices as they relate to increasing the participation of underrepresented groups in the megaprojects labour force, with particular focus on increasing the representation of women and Indigenous Peoples.
- Enhancing communications, engagement, and influence to bring the engineering voice to bear on the dialogue regarding megaprojects and pathways to net zero in Canada.

With respect to areas where the CAE might participate or act as a catalyst for action, the following will be prioritized for consideration:

- Contributing to establishing an industrial strategy and roadmap framework for net zero, with the CAE specifically providing engineering systems and risk assessment perspectives.
- Contributing to the development of strategy specific to net-zero megaprojects, potentially as a subset of the above or as a near-term alternative option, with the CAE specifically providing engineering systems and risk assessment perspectives.

- Contributing to the dialogue regarding regulatory reform as it relates to enabling megaprojects in Canada, collaborating with like-minded interests active in this area.
- Assessing the magnitude and timing of the megaprojects engineering skills and capacity gap over the period at least to 2030, along with further work on potential solutions to address this gap (e.g., increasing the emphasis on the use of computer-based simulation as a training vehicle for megaprojects, taking deliberate measures to transfer experience from one megaproject to the next).
- Working with accreditation bodies and others to better leverage the capabilities of immigrants to Canada with requisite engineering skills and experience.
- Developing a comprehensive research and development and prototyping strategy for megaprojects, aligned with the key requirements of the strategy and roadmap framework.
- Identifying areas where Canada has competitive strengths as they relate to megaprojects and working with others to promote economic opportunities and partnerships in global markets, and in doing so, strengthening the Canadian “brand.”
- Coordinating with other groups in a collaborative manner, potentially via a “coalition strategy” or centres of excellence, to advance shared interests and accelerate the impact of CAE-led initiatives.

The above will involve coordination and partnerships with governments, Indigenous groups, regulators, academia, and the engineering and construction industry.

The CAE intends to use the MLF to provide further impetus for engagement on the megaprojects challenge, as the basis for further work on this topic, and as a platform to enhance the CAE’s profile and influence as a trusted advisor, particularly to government. As a near-term action, the CAE plans to meet with governments and key stakeholders to discuss the above potential actions, to determine where the CAE can best contribute, and to prioritize those areas where it has the capacity and expertise to make a meaningful contribution. The path forward for megaprojects in Canada must be a collaborative undertaking among diverse interests, with industry playing a key role and governments at all levels playing an important enabling role.

As the above potential action items are better defined, further prioritized, and communicated by the CAE, there will be opportunities for interested CAE Fellows to contribute their expertise toward the goal of Canadian leadership in the planning, design, and execution of megaprojects. In doing so, there is an opportunity for Fellows to make a significant contribution toward creative solutions to one of Canada’s key challenges—the successful delivery of megaprojects on a scale and timeline that are unprecedented in this country.

Appendix A

Megaprojects Leadership Forum
Program



**Megaprojects Leadership Forum Program
Ottawa, ON
Lord Elgin Hotel**

Tuesday, March 5th, 2024

<p>6:45pm – 8:30pm</p>	<p>Dinner – Lady Elgin Room</p> <ul style="list-style-type: none"> • Greeting – Robert Crawhall, FCAE, Executive Director, CAE • Welcome Remarks – Dr. Soheil Asgarpour, FCAE, President of CAE and President and CEO at PTAC • Forum; Purpose and Expectations – Dave Collyer, FCAE, Corporate Director • Keynote address: Framing the Challenge – Dr. Monica Gattinger, Director of the Institute for Science, Society and Policy, Chair of Positive Energy, Professor at the University of Ottawa’s School of Political Studies
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Wednesday, March 6th, 2024

<p>9:00am – 10:15am</p>	<p>Opening Remarks</p> <ul style="list-style-type: none"> • Dr. Soheil Asgarpour, FCAE, President of CAE and President and CEO at PTAC Canadian Priorities • Drew Leyburne, Assistant Deputy Minister, Energy Technology, Natural Resources Canada (NRCan) • Colette Kaminsky, Senior Assistant Deputy Minister, Skills and Employment Branch Employment and Social Development Canada Global Perspectives • Don Winter, Chair, US National Academy of Engineering
<p>10:15am – 10:30am</p>	<p>Break</p>
<p>10:30am – 12:00pm</p>	<p>Parallel Workshops</p> <ul style="list-style-type: none"> • Workshop #1 – Best Practices; Rapporteur; James Marzocca, Global Managing Director, Hatch • Workshop #2 – Meeting the Capacity Challenge; Rapporteur; Samantha Espley, FCAE, President-Elect CAE, Senior Advisor, Stantec, Board Member of Northern Graphite, and Paramount Gold Nevada • Workshop #3– Global Competitiveness; Rapporteur; Dave Collyer, FCAE, Corporate Director
<p>12:00pm – 12:45pm</p>	<p>Lunch</p>
<p>12:45pm – 1:30pm</p>	<p>Parallel Workshops (continued)</p>
<p>1:30pm – 1:45pm</p>	<p>Break</p>

<p>1:45pm – 4:00pm</p>	<p>Workshop Presentations</p> <p>Workshop #1</p> <ul style="list-style-type: none"> • Presentation – James Marzocca – 1:45 to 2:00 • General Discussion – 2:00 to 2:30 <p>Workshop #2</p> <ul style="list-style-type: none"> • Presentation – Samantha Espley – 2:30 to 2:45 • General Discussion – 2:45 to 3:15 <p>Workshop #3</p> <ul style="list-style-type: none"> • Presentation – Dave Collyer – 3:15 to 3:30 • General Discussion – 3:30 to 4:00
<p>4:00pm – 4:30pm</p>	<p>Closing Remarks</p> <ul style="list-style-type: none"> • Dave Collyer • Soheil Asgarpour

Appendix B

Megaprojects Leadership Forum Participants

Participants

Dr. Soheil Asgarpour, FCAE, President CAE, President & CEO PTAC
Mr. John Beck, FCAE, Founder and Chairman, Aecon Group
Mr. Gilbert Bennett, FCAE, President, WaterPower Canada; Former VP, Nalcor Energy, Lower Churchill Project
Mr. John Bianchini, FCAE, Chairman & CEO, Hatch
Mr. Richard Boudreault, FCAE, Governor, Chair, First Nations University, Regina, Entrepreneur
Mr. Jim Carter, O.C., AOE., P.Eng., FCAE, Former President and COO Syncrude Canada Ltd., Corporate Director
Mr. David Collyer, FCAE, Corporate Director, Calgary AB
Dr. Robert Crawhall, FCAE, P.Eng., PMP, ICD.D, Executive Director, CAE
Ms. Marie-Claude Dumas, President & CEO, WSP Canada
Mr. Gerard Dunphy, VP, Churchill Falls and Muskrat Falls, Newfoundland & Labrador Hydro
Ms. Samantha Espley, FCAE, Senior Advisor, Mining, Stantec, former CTO Vale-Inco
Mr. Chris Frantz, Senior Project Manager, CAE
Dr. Monica Gattinger, Professor Monica Gattinger, Founding Chair, Positive Energy, University of Ottawa
Dr. Mark Green, FCAE, Prof. Civil Engineering, Queen's University, NSERC Scholar in Residence
Dr. Carl Haas, FCAE, Professor in Civil and Environmental Engineering at the University of Waterloo
Dr. Kevin Hall, FCAE, President and Vice Chancellor, University of Victoria
Mr. Randy Herrmann, P.Eng. FEC, FCAE, Director, Engineering Access Program, University of Manitoba
Mr. Jason Idler, Chief Operating Officer, Heavy Industrial PCL
Dr. Eddy Isaacs, FCAE, Former CEO, Alberta Innovates - Energy and Environment Solutions (AI-EES)
Dr. Brenda Kenny, FCAE, Chair, Alberta Innovates, Former President & CEO, Canadian Energy Pipeline Assoc.
Mr. Carey Kostyk, President, Valard Construction, Quanta Services Inc.
M. Réal Laporte, FCAE, Former President Hydro-Quebec Équipement & CEO, Société d'énergie de la Baie James
Dr. John Leggat, CD, FCAE, Former President CAE and CAETS, and former CEO DRDC
M. Pierre Lortie, FCAE, Senior Business Advisor, Dentons, Canada, Former President, CAE
Dr. Guru Madhavan, Norman R. Augustine Senior Scholar and Senior Director of Programs, National Academy of Engineering (US)
Mr. James Marzocca, Global Managing Director, Project Management & Construction, Hatch
Dr. Axel Meisen, FCAE, President, Fusion Energy Council of Canada, Chair CAETS Sequel Project on Low-GHG Emissions
Mr. Pierre Pichet, Executive Vice President, Project Delivery, WSP in Canada
Ms. Joy P Romero, P. Eng., MBA PM, ICD.D, FCAE, Executive Advisor Innovation, Canadian Natural Resources Ltd.
Dr. Bill Rosehart, FCAE, Dean, Schulich School of Engineering, U of Calgary
Ms. Sadie Sellars, FCAE, Former Technical Manager, Hebron Development Project, ExxonMobil
Mr. Howard Shearer, FCAE, LLM, Chief Executive Canada, Hitachi Canada
Dr. Oskar Sigvaldason, FCAE, Chair; Future of Engineering Committee; Canadian Academy of Engineering
Mr. Andy Trewick, President & CEO, Graham Construction
Mr. Robert Walker, FCAE, Former President and CEO, AECL and former CEO, DRDC
Mr. Donald C. Winter Chair of the National Academy of Engineering, former United States Secretary of the Navy and CEO TRW Systems

Observers

Ms. Colette Kaminsky Senior ADM, ESDC
Ms. Kimberly Lavoie Assistant Deputy Minister at Natural Resources Canada
Mr. Drew Leyburne ADM, Energy Efficiency & Technology Sector, Natural Resources Canada
Mr. Chris Padfield Assistant Secretary to the Cabinet Clean Growth, Privy Council Office



THE CANADIAN ACADEMY OF ENGINEERING
L'ACADÉMIE CANADIENNE DU GÉNIE

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