Energy & Environmental Division
ASQ Excellence Through Quality™

SUMMER 2020 | VOLUME 4, ISSUE 3

ENERGY & ENVIRONMENTAL DIVISION NEWSLETTER

Inside This Issue

FEATURED ARTICLES:

Chair's Message | Karen M. Douglas

EED Members and Officers anxiously await the opportunity to meet in person, however, ASQ guidance continues with Virtual meetings – EED monthly Council meetings are now conducted via Zoom. EED is assigned to ASQ Product Segments and the planned November 7-8, 2020 TCC meeting will be virtual and but in prior years encouraged personal attendance and a greater opportunity to share experience and knowledge from other ASQ Divisions. Virtual meetings may be continued for all ASQ involvement through December 2020.

ASQ EED is proud to announce our new Environmental Management Committee Chair, Barbara LaBarge (see separate article) and currently is considering candidates for the Body of Knowledge Chair and Education/Programs & Learning Committees. Another EED Committee Chair to fill the Oil & Gas portfolio is also still needed.

The ASQ E5 Standard is currently undergoing public review with public comment submission to EED authors Ben Marguglio and Greg Lilly due 7/15/20. EED anticipates publication of the E5 Standard fall 2020.

The ASQ EED Nuclear Quality Assurance Auditor Training Handbook nears 2020 publication by ASQ Quality Press. Following manuscript submission later this month Quality Press staff will evaluate the document and advise prior to submitting to the team of ASQ Peer Reviewers. This multi-year effort involved contributions by 8 EED Authors, 13 Reviewers and four Editors. Extensive collaboration and discussions since 2017 have resulted in a product valuable both to current energy management professionals as well as auditors in other fields desiring to expand their professional opportunities.

Karen M. Douglas
Chair, ASQ Energy and Environmental Division

IAQ LAUNCHES QUALITY SUSTAINABILITY AWARD

THE INTERNATIONAL ACADEMY FOR QUALITY is launching the ***IAQ Quality Sustainability Award*** in the fall of 2020.

The award is designed to recognize organizations that have used *quality methods to solve problems* or *improve processes through projects that support sustainability.* The award focuses on *specific project activity* as opposed to recognition based on policies.

Quality professionals who might want to submit an application for their company may find more information at **iaqaward.com**. An application requires a one-page summary of the project along with a completed application form.

Contact: Dr. John Dew, **jrdew@troy.edu**

Sustainability Footprint: A Case of Perception in Two SMEs

Abstract

Critically recent research into sustainability footprint tools has focused on larger organizations with limited research into the impact of perceptions of sustainability footprint reporting in SMEs. Therefore, this paper addresses this research gap by exploring the perceptions of Sustainability Footprint methodology its context, contribution, critical success factors and challenges through the case studies of two Scottish SMEs operating in the tourism and engineering sectors respectively.

Keywords: Sustainability, CSR, SMEs

The context

Increasingly, carbon footprints are used as indicators measuring ecological and social impact of industrialisation within what is geologically defined as the *anthropocene* era (Economist, 2011) and has been the subject of recent surveys from both governmental and non-governmental sources (DEFRA, 2010; IEMA, 2010). However the use of the ecological footprint and water footprint is not yet mainstream amongst business (Rees and Wackernagel, 1996; Holland, 2003; McElroy et al., 2008).

These methodologies are described as *Sustainability Footprints* which comprise the use of carbon footprint, water footprint, ecological footprint and the emerging concept of social footprints to evaluate the present non-financial consequences and future risk implications of strategic decisions (Lash and Wellington, 2007; Hoggart, 2008; Gell, 2008; McElroy et al., 2008, James 2015). The use of sustainability footprints forms part of a wider development of sustainability and corporate social responsibility (CSR) as a concept which consists for four evolutionary transitions:

Sustainability/CSR Awareness: Fundamental research and definitions which have influenced or defined sustainability. This period is identified by the development of Environmental Reporting by practitioners (Ehrlich et al. 1971, Hart 1997) (Elkins and

Author

Dr. Lowellyne James is the Chair of the ASQ Sustainability Committee and received a PhD in management from the Edinburgh Napier University Business School in Scotland. James is author of several books, including Management Systems and Performance Frameworks for Sustainability: A Road Map for Sustainably Managed Enterprises *(Routledge, 2018).*

Max-Neef 1992) (Carroll 1979) (Beresford 1973, 1974, 1975, 1976) (Sethi 1975).

Sustainability/CSR Aspect Management: Definitions and research which reviewed sustainability in terms of its components the social, economic and environmental (Hart 1997) (Elkington 1999).

Sustainability/CSR Adoption: Research and definitions explored implementation initiatives encapsulated in the context of Environmental Social Governance (ESG). Within this period business began focusing their efforts on using voluntary reporting schemes to confirm their commitment to ESG principles amongst their various stakeholder groups (McDonough and Braungart 2002) (Pridahm 2001) (Skerratt 2003).

Sustainability/CSR Strategic Integration: Research and definitions focused on the integration of economic, finance and risk management theory to name a few in order to provide a strategic view as *Sustainability* as a concept moves from the periphery of best practice to the realm of corporate strategy. This period is benchmarked by the introduction of the ISO26000 standard (Villalonga 2004) (Charter & Clark 2007) (Krysiak 2009).

Generally, sustainability footprint reporting is voluntary initiative of which its implementation costs are considered prohibitive except for those firms with near monopolistic profits (Hicks, 2010). Studies also reveal that footprints by nature record historical impact and do not incorporate the views of future generations (Holland, 2003). The lack of utility of sustainability indices such as the Global Reporting Index as an indicator of an organization's state of sustainability or unsustainability and the difficulty in quantifying the benefits of sustainability footprints has seen its limited adoption by SMEs (Gray and Bebbington, 2005; Demos, 2006). Critically recent research into sustainability footprint tools has focused on larger organizations with limited research into sustainability footprint reporting in Small and medium-sized enterprises (SMEs) (Carbon Disclosure Project, 2010; FTSE Carbon Disclosure Project Index, 2010). Contemporary research reveals that the success of best practice initiatives e.g. carbon footprint measurement seems to benefit from the organization having capability (Done et. al. 2011). SMEs are also faced with a conundrum of short term versus long term aims within the constraints of limited resources when adopting best practice initiatives; the value of which must be judged by the achievement, deployment and sustainability of the capability generated by the initiative (Done et. al. 2011). However, the long term success of best practice initiatives requires ongoing support (Done et. al. 2011). Therefore, this seeks to fill this research gap by exploring perceptions of sustainability footprint methodology by critically analyzing its context, contributions to growth, critical success factors and challenges in its use by SMEs.

Methodology

Philosophically, an Interpretivist approach was adopted, whereby sustainability footprint data in itself may be useful, but its true value is derived when individuals interpret sustainability footprint data and adopt behaviours or make decisions which are inherently sustainable (Ackerman, 2011).

The ontological stance of constructionism complements the epistemological position acknowledging sustainability footprints and its application is evolving with its interpretation being influenced by individual perspective (Papert, 1980). Therefore in this context the observation and interpretations of the actions of decision-makers are as important as the phenomena being studied. Perceptions of sustainability footprints are evaluated in this research through the case studies of two Scottish SMEs operating in the tourism and engineering sectors respectively. Interviews of a 45-minute duration with 13 individuals were analyzed; comprising 12 employees of an engineering firm in roles ranging from Logistics Manager to Administrator; and the Managing Director of a tourism sector company whose responses was solicited by email. Perceptions of sustainability footprint measurement were presented in four main enquiry themes (Ellram, 1996; Yin, 2003):

- **Innovation Impact** - Product Innovation and Process Innovation (Lash and Wellington, 2007; Porter, 2006)
- **Cost Impact** - Risk and Financial Capital Resource allocation (Lash and Wellington, 2007; Porter, 2006; Krysiak, 2009; Teece, 1987; Winter, 1987; Hart 1995)

- **Environmental Impact** - Energy & Water Usage and Emissions and waste(Lash and Wellington, 2007; Porter, 2006; Hart, 1995)
- **Stakeholder Impact** - Anthro capital Resource Allocation (McElroy et al., 2008; Porter, 2011)

The triangulation of secondary data such as Corporate Social Responsibility Reports and Environmental Audits is used to corroborate whether perceptions Sustainability Footprint contributes to improved business performance to create a picture in words of SME perceptions (Murillo and Lozano, 2006; Arenas et. al., 2009; Amaratunga et. al., 2001). The conceptual framework within which sustainability footprints have evolved is illustrated above (**Figure 1**).

Figure 1: Conceptual framework and philosophical position of Sustainability Footprint Methodology

Background

Capital Cooling Ltd – Sustainable Refrigeration and Air Conditioning Engineering

Capital Cooling Ltd — formerly a family-owned company operating within the refrigeration and air conditioning sector — was recently purchased by the London-based group Rcapital Partners LLP (Cooling Post 2017). Ranked #63 on the RAC News HVACR Index the company achieved a turnover of £20 million in 2010. The organization's founder Alister McLean reveals his motivations for starting the company:

"What led me to establish Capital Cooling…basically having a passion for refrigeration once I completed my apprenticeship, once I learnt the industry. Just having a passion for the commercial refrigeration industry."

This passion for refrigeration has seen the company win accolades such as the Scottish Green Award for Best Green SME and the ACR News Contractor of the year. Instrumental to the Capital Cooling's success has been its management team, most of which have been with the company since its inception. Prior to the company's sale to investors, it employed over 150 support and engineering staff with 47% of the staff under age 40, 5% of the staff being from ethnic minority backgrounds and 9% being female managers. Their perceptions were then collated under four thematic headings of cost impact, environmental impact, innovation impact, stakeholder impact and then triangulated with secondary data to corroborate their expressed opinions.

Rabbie's Travel – Sustainable Tourism Pioneer

Rabbie's Travel is an award-winning SME in the tourism sector culminating with achieving the VIBES Award in 2011, Scotland's highest environmental accolade, as well as consecutive British Travel Awards in 2018 and 2019. The company has been operating small tours initially for elderly visitors with a maximum of 16 individuals per coach trip. In 2011, with 13 full-time staff the company achieved £3.4 million turnover with 40,000 satisfied customers choosing the company to provide unique holiday experiences. Within 7 years the company reported a £15.38 million turnover. This approach which has yielded dividends was borne of desperation rather than planning, as the company's founder Robin Worsnop explains:

> *"It was a trying time because I didn't have any money - I made about £4000 profit that was what I lived on."*

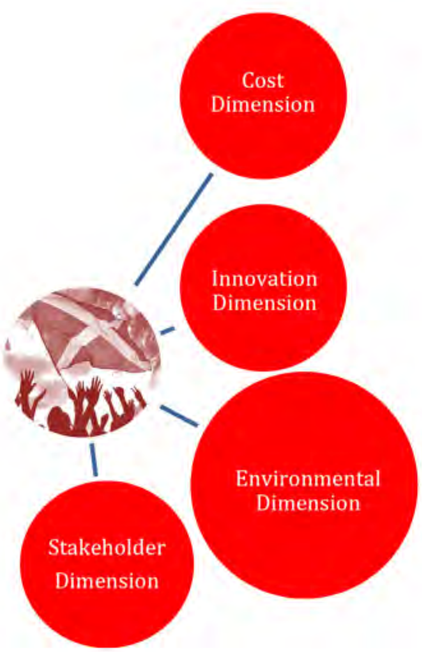
(Herald Scotland 2012)

From the company's staffing complement of 13 individuals, only one employee, the Managing Director — who was responsible for carbon footprint measurement initiatives — opted to participate in the research by email, rather than a "face to face" interview.

Key Findings

The results of the pilot case studies indicate that sustainability footprint measurement, specifically the carbon footprint, can contribute the following benefits to SME firms:

- a good investment of the firm's resources
- a proxy for good financial performance
- **market leadership** – firms gain brand recognition for their "green credentials"
- **product innovation** such as use of low carbon, energy efficient technology, zero ozone depleting refrigerant and efficient journey planning
- process improvement



Cost Dimension

– Risk Management (Environmental/Financial/Legal)
– Customer Requirement
– Link between future survival of the business & planet
– Market Leadership
– Cost Reduction
– Sustainability Footprint a proxy for good financial performance

Innovation Dimension

– Benchmarking
– Process Improvement
– Waste Recycling
– Product Innovations such as energy efficient components and refrigeration equipment using zero ODP hydrocarbon refrigerants

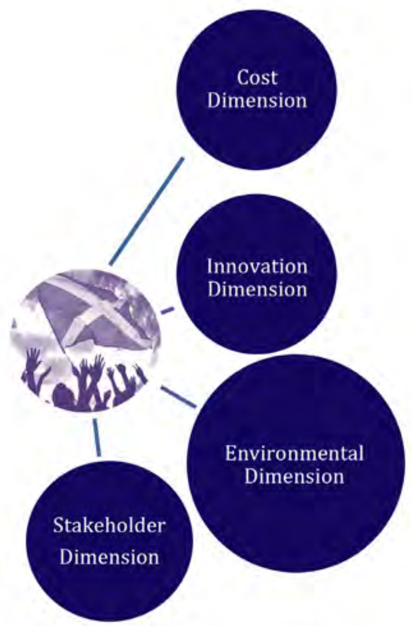
Environmental Dimension

– Carbon footprint is considered a KPI
– Positive link between carbon footprint & climate change
– Water Usage in products and processes being considered
– Lower carbon footprint = higher business growth
– Striving for market leadership in terms of its carbon footprint
– Positive link between recycling and carbon emissions
– Improved awareness of Environmental aspects and its impact

Stakeholder Dimension

– Internalization of their contribution to reducing the carbon footprint based on their job role, purchasing or life style decisions
– Aligned with Employee Satisfaction
– "Caring organization"

Figure 2: Capital Cooling Ltd interviewee responses and the relationship to the research themes



Cost Dimension

– Carbon footprint measurement important to the business

– Cost not calculated as carbon footprint measurement is conducted on a regular basis

Innovation Dimension

– Carbon Footprint reduction considered a key issue by management

– USP small group tours as an alternative to using individual private cars

– Engine tuning to improve vehicle fuel efficiency

– Self-imposed "carbon tax" of £10 for every tonne of CO2e to fund environmental projects

Environmental Dimension

– Presently measuring water consumption with interest to measure water footprint

– Positive link between carbon footprint and climate change

– Sustainability footprint measurement aligned with sustainable development

– Carbon footprint considered a KPI

– Target of less than 0.99 litres of fuel per customer for every 100km traveled

Stakeholder Dimension

– Carbon footprint measurement perceived as a critical value added initiative

– Carbon footprint measurement perceived as a good investment of organizational resources

Figure 3: Rabbie's Travel Ltd interviewee responses and the relationship to the research themes

- **cost reduction** – waste previously viewed as a cost centre is now considered a profit centre
- employee satisfaction
- **"caring organization"**- an underlying benefit of carbon footprint measurement implying that an organization adopting this strategy acts as a steward of the environment for future generations as opposed to a custodian:

"The point is twofold as I have already said, the point is to satisfy Capital Cooling and Capital Cooling's employees that we are doing our part to (save) the environment. The return that comes back from that is additional but I think we didn't start out to actually to gain financial reward immediately from that we never start out to be at the top of somebody's list because we are doing something we did it because we care I think that is the important part we cannot forget that we are doing it because we care and that is the important part."

Logistics Manager, Capital Cooling Ltd.

Interviewees equate sustainability footprint tools with business growth and operational risk management. However interviewees also perceive costs, time and resource constraints in the adoption of sustainability footprint methodology which may be mitigated if tax incentives were initiated by policy makers. The role of government policy in ameliorating the perception of sustainability footprints as being an option for firms achieving near monopolistic profits through the creation of a fair marketplace cannot be underestimated:

"Because Capital Cooling is so committed to it and there is always a cost implication when you are so committed to it…. It (government) should be ensuring that all other companies in our field of business are doing what's required as well to make it a fair marketplace type thing."

Engineering Manager, Capital Cooling Ltd

Importantly employees perceive similar benefits of sustainability footprint methodology identified in larger organisations such as *reduced risk, reduced energy consumption, market segregation,* *environmental impact indicator* and *value indicator* also accrue to the company as illustrated in (**Figure 2**) and (**Figure 3**). (Carbon Trust 2005) (Walker Crisps 2010) (Edwards-Jones et al. 2009)

Sustainability footprint tools provide benchmarks, which although do not predict the future, but enlighten the path towards sustainable innovation within business. The carbon footprint is one such tool that has provided a uniform measure to engage stakeholders in emissions reduction. Capital Cooling has used carbon footprint measurement to reduce its greenhouse gas emissions by 38.5% through its waste recycling policy has diverted 238.454 tonnes of CO2e from landfill during the period 2010 – 2011. In addition to mitigation, Rabbie's Travel has adopted a self-imposed carbon tax of £10 for every tonne of CO2e emission generated by its operation, proceeds of this initiative are distributed to charitable organizations on a selective basis.

Although both businesses operate in different economic sectors each is faced with fuel emissions being the largest proportion of greenhouse gas emissions. Each company has adopted green fleet policies such as the purchase of low emissions vehicles and the use of fuel additives in case of Capital Cooling to Rabbie's Travel Ltd's engine maintenance and tyre threading depth monitoring.

These key findings highlight opportunities to influence SME perceptions of sustainability footprint tools and consequently the adoption of inherently sustainable behavior by individuals, potentially changing consumption patterns but also products and processes.

Conclusion

SMEs are burdened by resource constraints such as limited finance or access to funding. These case studies illustrate two critical success factors that ensured the success of each carbon footprint measurement initiative despite these resource constraints;

- the catalytic role entrepreneur/founder and senior management
- a penchant for continuous improvement; thus forming the core ethos in each organization.

Although perceptions differ, the interviewees generally agree that legislation, waste reduction, senior management commitment, operational requirements and cost reduction are key driving forces for the firm to pursue carbon footprint measurement. An SME is a transnational organization in embryonic form, therefore, is less able to adapt with environmental, social and economic risk arising from climate change. In addition to this challenge, SMEs struggle to decouple carbon emissions from growth, as well as manage their water footprint and social obligations to the wider society. These case studies also demonstrate the unique roles SMEs can play in national emissions reduction whilst enhancing the traditional "bottom-line." Constraints arising from limited finance, access to funding and cashflow materialization made Capital Cooling a prime target for takeover despite good environmental and social governance. Therefore, senior management must adopt a balance approach in managing the economic, social and environmental risks to secure the long-term viability of the firm.

It is critical that policy-makers understand perceptions of sustainability footprint methodology amongst SMEs and how they can influence SME decision-maker perceptions to adopt more sustainable behaviours. For quality, safety and environmental management professionals and business leaders, it is important to know the critical success factors and whether perceptions are homogenous across sectors, departments or managerial levels using best practice organizations. Knowledge of these perceptions ensures operations management professionals take a leadership role supporting the adoption of sustainability footprint methodology within SMEs.

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EED OPEN POSITIONS

Oil & Gas Committee Chair (open)

MISSION:

1. Provide EED members with education, training, and networking opportunities specifically relating to the quality of production, safety, risk management, environmental protection and related topics as it applies to the oil and gas industry.

2. Actively grow the membership base and increase the "brand recognition" of the EED, Oil & Gas Committee in the Oil & Gas industry.

3. Provide the ASQ EED perspective for quality-related documents prepared for the oil and gas industry.

IMPLEMENTATION PLAN:

1. To the extent legally permissible, provide to EED members copies of quality-related standards, protocols, good practices similar documents originated by the COS and API Subcommittee 18.

2. Within budget limitations, attend live and teleconference meetings and submit suggestions and comments to the COS and the API Subcommittee 18 relative to the development and maintenance of quality-related standards, protocols, good practices similar documents.

3. For conferences in which EED participates, provide speakers from the oil and gas industry.

4. Without the expenditure of any out-of-pocket cost, offer to EED members free and for-fee webinars and for-fee seminars on quality-related topics as they apply to the oil and gas industry.

If you are interested in becoming the chair of one of these committees, Send your resume with a three sentence brief to Karen Douglas Chair of the Energy and Environmental Division (EED) at douglaskm@alumni.standford.edu and current chair of one of these committees Benjamin Marguglio ben@HighTechnologySeminars.com

More open positions listed on next page.

EED OPEN POSITIONS

Student Intern (open)

Do you want an ever-expanding space of learning from mentors leading the way in the energy and environmental domain? Volunteer to complement your formal learning with practical partnering in:

- Programs and Learning
- EED Standards
- E-Standards
- Communications and Newsletter
- My ASQ
- Body of Knowledge
- Membership

Excited about making a difference to your career; passionate about Quality 4.0 and determined to leave your unique mark on future generations by leveraging technology to transform energy and environmental impacts in a connected world?

> **Send your resume with a three sentence brief to Karen Douglas Chair of the Energy and Environmental Division (EED) at douglaskm@alumni.standford.edu and and Abhijit Sengupta, communications chair, at senguptaa@hotmail.com for consideration.**

More open positions listed on next page.

EED OPEN POSITION

Member Leader Position—Body of Knowledge (open)

Work with Division leadership committee to determine, maintain, and leverage division Body of Knowledge for refreshed content, events, and programs that will add value to members.

Specific Duties & Responsibilities

- Work with the division leadership committee to set goals/metrics to support the division's management process as they relate to the Body of Knowledge (BoK).
- Communicate/report to division leadership committee activities performed and status of performance against goals/metrics set.
- Solicit content from community authors, webinar/event speakers.
- Work with division leadership committee, committee, and sub-committee chairs, if applicable, to provide/receive appropriate content for consumer need.
- Work with newsletter editor and the myASQ website coordinator to publish/socialize updates.
- Attend division leadership committee and general membership meetings to collect and analyze feedback from attendees for content enhancement.

Qualifications

- Be a Full, Senior, or Fellow ASQ member in good standing and associated with the relevant division.
- Strong organization, communication, delegation, and negotiation skills.
- Preferably will have understanding of needs assessment tools.
- Preferably will have some digital platform analytics experience.

Time Commitment

Average three hours per month (outside division & executive committee meetings).

Resources

The following resources can be found on www.asq.org (login required).

- ASQ Bylaws, Policies, and Procedures.
- Member Leader Community of Practice.
- Member Unit Operating Agreement (MUOA)

Send your resume with a three sentence brief to Karen Douglas Chair of the Energy and Environmental Division (EED) at douglaskm@alumni.standford.edu and arichard365@gmail.com for consideration.

More open positions listed on next page.

EED OPEN POSITIONS

Programs & Learning Chair (open)

Specific Duties & Responsibilities

- Work with the division leadership committee to set goals/metrics to support the division's management process as they relate to programs and activities development.
- Communicate/report to division leadership committee activities performed, status of performance against goals/ metrics set, etc. for division programs and activities development.
- Solicit speakers to match topics.
- Work with arrangements chair, if applicable, to coordinate speaker needs.
- Work with newsletter editor to publish events in a timely manner.
- Attend division leadership committee and general membership meetings to collect and analyze feedback from program attendees for improvements.
- Uphold society bylaws, policies and procedures, and division management agreement.

Qualifications

- Be a Full, Senior, or Fellow ASQ member in good standing and associated with the relevant division.
- Strong organization, communication, delegation, and negotiation skills.
- Preferably will have understanding of needs assessment tools.
- Preferably will have some event planning experience.

Time Commitment

Approx three to five hours per month (outside division & executive committee meetings).

Resources

The following resources can be found on www.asq.org (login required).

- ASQ Bylaws, Policies, and Procedures.
- Society Policies and Procedures (A20: Conference Scheduling Policy; G41: Society Involvement with Other Organizations and Use of Logo; G42: Joint Activities of Society and Member Units).
- Member Leader Community of Practice.
- Division Management Agreement (DMA) / Division Minimum Requirements

Send your resume with a three sentence brief to Karen Douglas Chair of the Energy and Environmental Division (EED) at douglaskm@alumni.standford.edu and arichard365@gmail.com for consideration.

ASQ EED Sustainability Committee Strategic Plan

"A customer is the most important visitor on our premises.
He is not dependent on us.
We are dependent on him.
He is not an interruption of our work.
He is the purpose of it.
He is not an outsider of our business.
He is part of it.
We are not doing him a favour by serving him.
He is doing us a favour by giving us the opportunity to do so."

Mahatma Gandhi

Executive Summary

Strategy is defined as a *pattern in a stream of decisions*. These decisions may be consciously undertaken, but can emerge overtime, sometimes unintentionally. Existing strategic intent has not been fully realised due to transition and succession from previous post holders.

However, there is a requirement to demonstrate the effectiveness of communication and engagement initiatives and manage data collected and report performance to ASQ Energy & Environmental Division (EED) Leadership. An *ASQ EED Sustainability Committee Strategic Plan* has been outlined, within which key stakeholders, risks and costs have been identified that may impact the project. A high-level project plan and work breakdown structure has been outlined in this document to ensure project aims and objectives are achieved.

The *ASQ EED Sustainability Committee Strategic Plan* is influenced by the concept of *Absolute Zero:* the point at which an organisation's processes, products/services and people have no adverse impact on the society and planet. Our *Absolute Zero* strategy is underpinned by the principles of *do no harm, continuous improvement, engage* and *listen to all stakeholders* (James 2018).

Author

Dr. Lowellyne James is the Chair of the ASQ Sustainability Committee and received a PhD in management from the Edinburgh Napier University Business School in Scotland. James is author of several books, including Management Systems and Performance Frameworks for Sustainability: A Road Map for Sustainably Managed Enterprises *(Routledge, 2018).*

The proposed *Absolute Zero* strategy is expressed in five steps **Learn** – *Communication Preparedness* and *Sustainability Knowledge*; **Develop** – *Communication Planning*; **Implement** – *Right First Time, Assess Risks* and *Challenges*; **Optimise** – *Continuous Improvement* and *Share Good Practices*; **Sustain** – *Celebrate Excellence* and *Care for people and environment.*

Purpose

To make evaluation of *ASQ EED Sustainability Committee* activities and continued engagement to all relevant stakeholders both internal and external. Effective communication with stakeholders throughout the communication process and dissemination of the evaluation results will help ensure consistent delivery of sustainability management knowledge used for decision-making. These values are incorporated within the *ASQ Sustainability Committee Strategic Plan* to ensure alignment with ASQ corporate objectives.

Objectives

Objective 1 Provide relevant and timely information on environmental sustainability management.

Objective 2 Improve member engagement on environmental sustainability management.

Objective 3 Promote sustainability management within the ASQ events.

Objective 4 Improve understanding of the relationship between quality and environmental sustainability.

Scope

The project will seek to implement effective communication of sustainability management tools, techniques and improvement culture.

Constraints

Typical project constraints revolve around quality, cost and time. Members of the *ASQ EED* are focused on the effective implementation ISO 14001 management systems and energy compliance obligations, consideration must be given to the relocation of resources to achieve project objectives and deliverables within agreed timescales.

Context

The mission of the *ASQ EED Sustainability Committee* is to provide its members with knowledge and tools that will enable them to be leaders in their organizations and their industries with regard to the strategic integration of quality and sustainability. Quality professionals are well suited to provide skills and expertise, including leading change, continual process improvement, lean principles and analytical skills all of which are needed to improve sustainability performance. In addition, energy and environmental professionals are located within industries that are at the centre of high-visibility sustainability issues and can therefore provide leadership that benefits their organizations and society at large.

Despite these achievements, the company is striving to adopt a holistic approach to the management of its non-financial risks to achieve consistent sustainable outcomes for both the business and society. However, the organisation is faced by the following three challenges:

- **Cultural**
- **Philosophical**
- **Strategic**

Cultural Challenge

The *Cultural Challenge* is defined as a *framework of norms, values that are either nurtured or assimilated, which manifests itself in the public sphere as societal norms or within businesses as the organisational culture*. Leaders within the organisation are influenced by wider societal norms thereby affecting the integration of both sustainability and quality within the organisational culture.

Philosophical Challenge

The *Philosophical Challenge* is defined as an *ethical framework within which we justify sustainable action or inaction*. The philosophical challenge has arisen as the result of the following conditions:

- Ascription of rights on non-human species
- Growing environmental awareness
- Disconnection of society from the sources of food and water

As a result, the role of the individual and by extension the organisation is to define organisation its purpose and fulfill its corporate citizenship and other compliance obligations due to the cross-border nature of global business. By exercising good corporate citizenship, the company will take actions for the greater good and develop an ethical construct in terms of values and identity. ASQ EED has begun its journey towards corporate citizenship excellence by defining its core values. Despite good practices, these efforts must be bolstered by a framework that translates values into strategically meaningful action.

Strategic Challenge

The *Strategic Challenge* is the *interpretation of an organisation's goals to incorporate both the philosophical and cultural values to yield sustainable business growth.*

Any interpretation of organisational goals/objectives is affected by the internal and external risks within its operating environment. ISO 31000 defines risk as the *effect of uncertainty on objectives. The risks identified for this project are categorised in terms of* **external risk** *i.e.* Political, Economic, Social, Technological, Environmental, Legal (PESTEL) *and* **internal risk** *i.e.* strategy, style, systems, structure, staff, shared value and skills. *Each identified risk has been analysed using a 5x5 matrix with appropriate mitigation actions to reduce the negative impacts on the achievement of project deliverables.* (**Figure 1**).

External Risks

Political Risk

Negative perceptions of sustainability linked to increased environmental regulation (James 2015).

Economic Risk

Recession created by COVID-19 Pandemic - *Large-scale quarantines, travel restrictions, and social-distancing measures drive a sharp fall in consumer and business spending until the end of Q2, producing a recession. Although the outbreak comes under control in most parts of the world by late in Q2, the self-reinforcing dynamics of a recession kick in and prolong the slump until the end of Q3. Consumers stay home, businesses lose revenue and lay off workers, and unemployment levels rise sharply. Business investment contracts, and corporate bankruptcies soar, putting significant pressure on the banking and financial system* (McKinsey 2020).

Social Risk

Perceived lack of transparency within the organisation.

Technological Risk

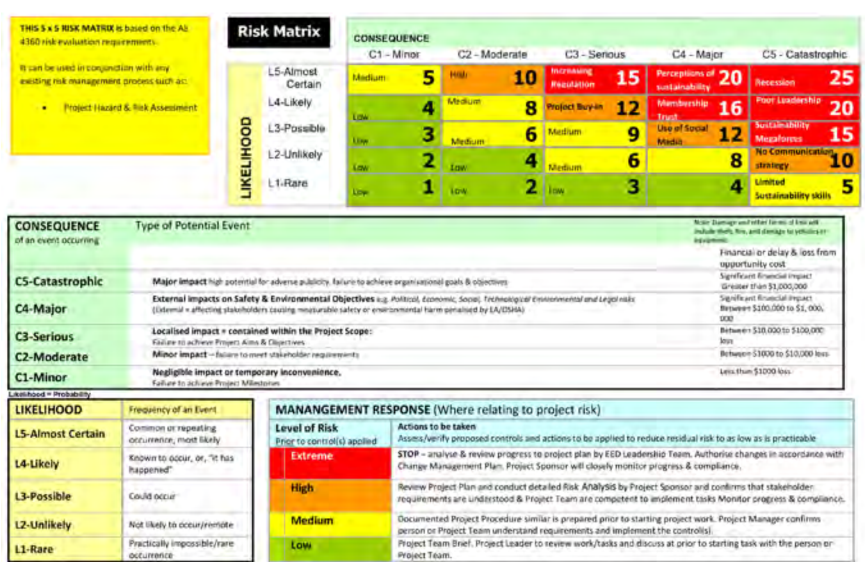
Increasing adoption of social media to communicate both ASQ Member dissatisfaction.

Environmental Risk

Impact of Sustainability Megaforces e.g. climate change (James 2015).

Legal Risk

Increasing environmental legislation to encourage a transition towards a circular economy.



THIS 5 x 5 RISK MATRIX is based on the AS 4360 risk evaluation requirements.

It can be used in conjunction with any existing risk management process such as:

- Project Hazard & Risk Assessment

Risk Matrix

LIKELIHOOD	CONSEQUENCE C1 - Minor	C2 - Moderate	C3 - Serious	C4 - Major	C5 - Catastrophic
L5-Almost Certain	Medium 5	High 10	Increasing Regulation 15	Perceptions of sustainability 20	Recession 25
L4-Likely	Low 4	Medium 8	Project Buy-in 12	Membership Trust 16	Poor Leadership 20
L3-Possible	Low 3	Medium 6	Medium 9	Use of Social Media 12	Sustainability Megaforces 15
L2-Unlikely	Low 2	Low 4	Medium 6	8	No Communication strategy 10
L1-Rare	Low 1	Low 2	Low 3	4	Limited Sustainability skills 5

CONSEQUENCE of an event occurring	Type of Potential Event	Note: Damage and other forms of loss will include theft, fire, and damage to vehicles or equipment. Financial or delay & loss from opportunity cost
C5-Catastrophic	**Major impact** high potential for adverse publicity, failure to achieve organisational goals & objectives	Significant financial impact Greater than $1,000,000
C4-Major	**External impacts on Safety & Environmental Objectives** e.g. *Political, Economic, Social, Technological Environmental and Legal risks* (External = affecting stakeholders causing measurable safety or environmental harm penalised by LA/OSHA)	Significant financial impact Between $100,000 to $1,000,000
C3-Serious	**Localised impact = contained within the Project Scope:** Failure to achieve Project Aims & Objectives	Between $10,000 to $100,000 loss
C2-Moderate	**Minor impact** – failure to meet stakeholder requirements	Between $1000 to $10,000 loss
C1-Minor	**Negligible impact or temporary inconvenience.** Failure to achieve Project Milestones	Less than $1000 loss

Likelihood = Probability

LIKELIHOOD	Frequency of an Event
L5-Almost Certain	Common or repeating occurrence, most likely
L4-Likely	Known to occur, or, "it has happened"
L3-Possible	Could occur
L2-Unlikely	Not likely to occur/remote
L1-Rare	Practically impossible/rare occurrence

MANANGEMENT RESPONSE (Where relating to project risk)

Level of Risk Prior to control(s) applied	Actions to be taken Assess/verify proposed controls and actions to be applied to reduce residual risk to as low as is practicable
Extreme	STOP – analyse & review progress to project plan by EED Leadership Team. Authorise changes in accordance with Change Management Plan. Project Sponsor will closely monitor progress & compliance.
High	Review Project Plan and conduct detailed Risk Analysis by Project Sponsor and confirms that stakeholder requirements are understood & Project Team are competent to implement tasks Monitor progress & compliance.
Medium	Documented Project Procedure similar is prepared prior to starting project work. Project Manager confirms person or Project Team understand requirements and implement the control(s).
Low	Project Team Brief. Project Leader to review work/tasks and discuss at prior to starting task with the person or Project Team.

Figure 1: ASQ EED Risk Analysis

Internal Risks

In addition to impacts arising from time constraints, projects are affected by internal risks and opportunities outlined in (**Figure 2**). Key internal risks include an absence of a holistic communication strategy, level of trust in the organisation, sustainability — specifically an understanding of environmental impacts — are not a core competence or a prerequisite for leadership. Notwithstanding delays created by succession and reorganisation, as well as negative impacts arising from limited resource allocation.

For clarity, key internal and external risks have been qualitatively analysed, notably recession as a potential event whether precipitated by the COVID-19 pandemic and particularly perceptions of sustainability as being linked to increased environmental regulation was given the higher risk scores. Increasing regulatory and legal pressures will be an ongoing facet of the external operating environment as countries attempt to reduce the effects of pollution and climate change. The visionary leadership exhibited by the senior management of the organisation has enabled the EED to champion environmental sustainability management within the ASQ. Despite this there is a perceived low level of trust amongst some ASQ members regarding the transparency of recentre structuring decisions, a siloed approach to quality management and critically sustainability management skills are not a core competency nonetheless a corporate value.

The limited availability of social media communication metrics e.g. *click-through rate* prevents the effective management of these important non-financial risks. Generally, the absence of monitoring of metrics and feedback from communication activities can contribute to sub-optimal decisions.

Absolute Zero Concept

To surmount the **Cultural**, **Philosophical** and **Strategic** challenges, the *ASQ EED Sustainability Committee Chair* must combine the quality outcomes of "*zero errors*", environmental outcomes "*zero emissions*" and safety outcomes "*zero harm*" into the pursuit of a singular strategic goal of "*Absolute Zero*" the point at which no more adverse risk can be removed from a system, which is a benchmark upon which sustained customer satisfaction both internal and external can be achieved (James 2018).

This new definition of sustainability is given operational expression using a five-stage model (**Figure 3**):

Learn consists of two key constructs: *acquire **sustainability knowledge*** *build capability* and ***communication preparedness.***

Develop a ***communication plan*** to disseminate sustainable business practices with strategic goals involving adoption amongst ASQ Members.

Figure 2: McKinsey 7S Analysis – Energy & Environment Division

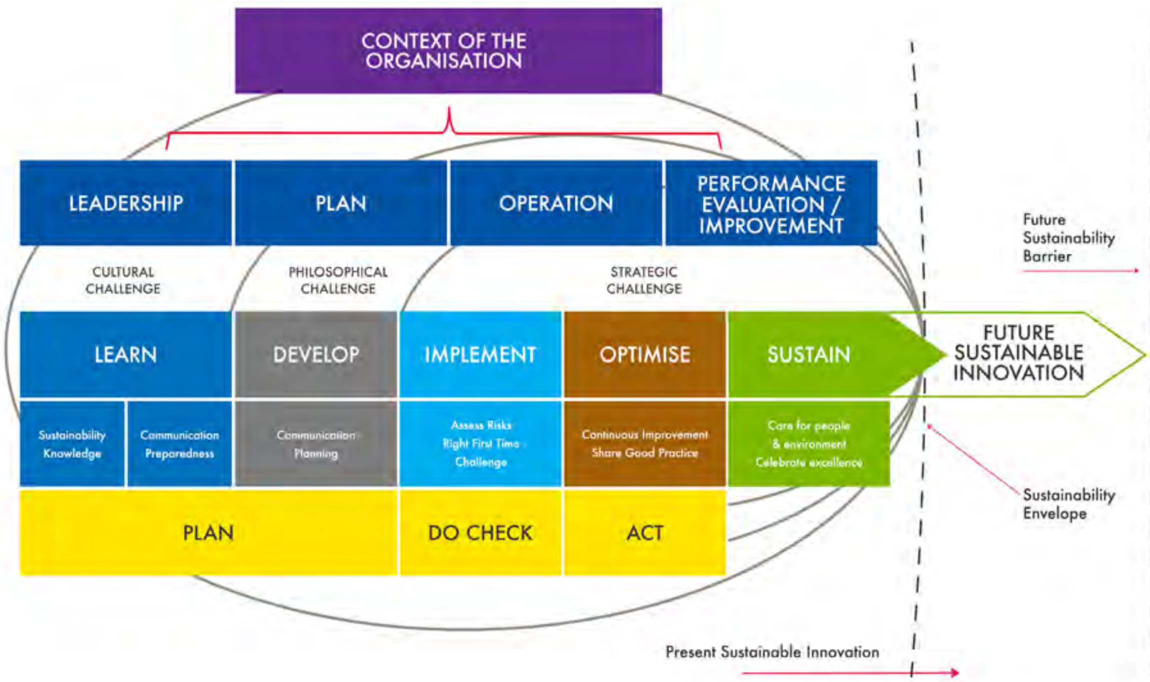


Figure 3: Application of the SSG Model to Sustainability Committee

Implement involves the commitment of EED leadership to engage stakeholders in embedding sustainability by staff presenting a *challenge* to sustainability perceptions: ***assess risks*** and doing each task ***right the first time***.

Optimise the use of resources to disseminate sustainable business practices through ***continuous improvement*** and ***sharing best practice***.

Sustain value creation through rewarding and supporting sustainable behavior. Taking time to ***celebrate excellence*** and exhibiting ***care for people and environment*** (James 2018).

Using this model, as the maximum economic, social and environmental returns achievable by the organisation from a given strategy using existing technology and resources, the firm approaches a *Sustainability Barrier* (**Figure 3**).

Beyond which further sustainable growth can be achieved by reinvigorating members to participate in new low carbon initiatives, supported by investment in training, new technology e.g. processes, systems e.g. IT video conferencing facilities and R&D. At this stage creative destruction must occur as EED leadership and stakeholders review and implement each stage. Therefore, the purpose of *ASQ Sustainability Committee* is the development of strategy that continually moves beyond the *Sustainability Barrier* to realize the benefits of future growth ensuring the survival of the organisation and maintain both its economic and social value. Use of the model is compatible with the Annex SL layout of the ISO 9001, ISO 14001 and ISO 45001 and the **Plan**, **Do**, **Check & Act** cycle.

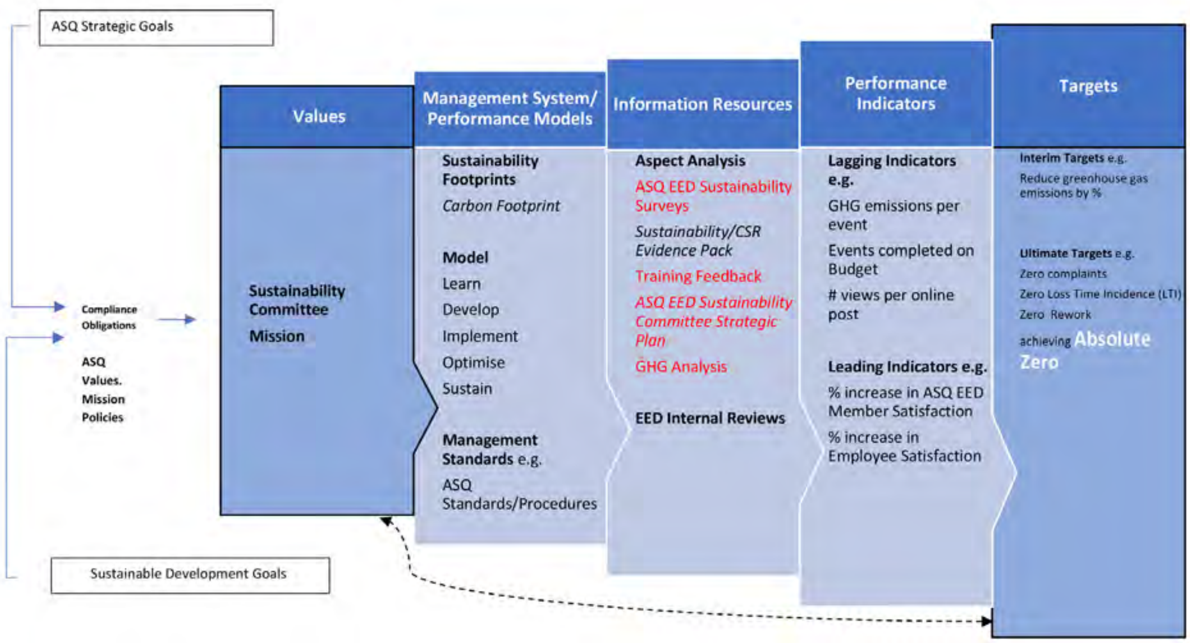


Figure 4: Sustainability Performance Framework

Performance Framework

Sustainability performance is the management of individual and organisational activities that contribute to the achievement of sustainable development goals with *sustainability performance* measurement being the collation and analysis of socioeconomic and environmental performance for effective decision making (James 2018).

The *Sustainability Performance Framework* (**Figure 4**) provides a structure that assists leadership in disseminating strategy to other functions within the EED by providing the *policy, principles, management systems, information resources, key performance indicators* and *targets* to achieve objectives to create shared value and meet societal obligations for responsible business activity. The framework incorporates strategic goals. Compliance obligations are organisational performance conditions created by regulatory compulsion e.g. *Environmental Protection Act*, contractual e.g. *customer requirements* or other voluntary commitments such ASQ Vision, Mission and values and *Sustainable Development Goals* (SDGs). The *ASQ Sustainability Committee Strategic Plan* is framed with an understanding of the business implications of compliance obligations as well as *Sustainable Development Goals* (SDGs) i.e. *good health and wellbeing, decent work and economic growth, industry innovation and infrastructure, sustainable cities and communities, responsible consumption and production and climate action.* (**Figure 5**)

Although ASQ has outlined a set of values, further review and alignment with existing EED objectives, *ASQ Sustainability Committee Strategic Plan* and future targets are required. The proposed model of *Learn, Develop, Implement, Optimise* and *Sustain* will be disseminated along with carbon footprint measurement, reinforced by training webinars accredited by ASQ.

Figure 5: The key components of ASQ EED Sustainability Committee communication plan

Effective decision-making regarding non-financial risk is supported by the use of information sources viz:

- ASQ EED Sustainability Survey
- Training Feedback
- ASQ EED Sustainability Committee Strategic Plan
- Carbon Footprint

Data for inclusion at EED leadership meeting deliberations will consist of the following environmental performance indicators with reporting accountability assigned to specific functions/roles within the organisation:

Quality Performance Indicators

– *Page Load Time*

– *Bounce Tate*

– *# Views per Online Post*

– *# Member Complaints*

– *# Webinar Participants*

– *Click-through Rate*

– *Attendee Ratio*

The nature and category of interim targets is the domain of EED Leadership but aimed at the ultimate target of achieving Absolute Zero the point at which *"zero errors"*, *"zero emissions"* and *"zero harm"* is actualised within the organisation.

Communication Plan

Figure 5 shows the key components of a communication plan. The basic principle is to reflect on the products and information from each phase of the evaluation, the most relevant target audience (to whom) and the most appropriate communication means (how/by what ways).

Careful review of the interests of various stakeholder groups ensures the success of any project. The communication plan will be established to incorporate the concerns of key stakeholders and implementation of the *ASQ EED Sustainability Committee Strategic Plan* (**Figure 6, page 21**).

For each defined stakeholder group, a pertinent communication approach will be developed to ensure information relevant to project success is shared and internal stakeholder concerns are incorporated into the *ASQ EED Sustainability Committee Strategic Plan*.

Specifically, feedback will be solicited from a wider ASQ EED Membership to ascertain performance requirements for the Sustainability Committee at the initiation phase and after the execution phase of the project. Thereby allowing for objective analysis in the determination of options available to effectively disseminating sustainability management within the EED.

To increase interest in Sustainable Development accredited training programs detailing the relationship between quality and sustainability

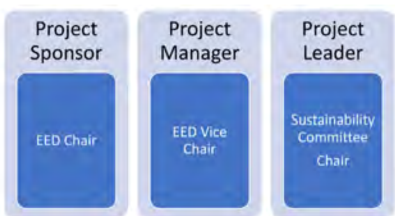


Figure 7: Project Structure

awareness will be delivered by the Sustainability Committee Chair, ASQ Members and other volunteer practitioners.

A final report containing all findings arising from this project and will be communicated to *EED Chair* for review and comment.

Change Management

Change control and management of change are critical factors in successfully managed projects. The *EED Leadership Team* (**Figure 7**) provides governance and oversight for all changes to the strategic elements of the project such as:

- Aims
- Objectives
- Scope

The *Project Sponsor* authorises any changes to operational elements of the project in terms of resource allocation, project controls, quality, safety and environmental systems development. Notwithstanding completion of project objectives, the following management structure is adopted to support management accountability and ease of communication. The **EED Chair** is typically responsible for initiating, ensuring, approving, and establishing a series of key aspects in relation to the project, which can be summed up under categories of vision, governance, and value/benefits realization.

Project Manager – **EED Vice Chair** will be responsible for developing trust and communication among all project stakeholder, i.e. *Project Sponsor*, those who will make use of the project's results, those who command the resources needed and the project team members.

Project Leader – **Sustainability Committee Chair** will utilise the tactical skills and competencies to deliver aims and objectives within the constraints of cost, time and quality.

These three functions are critical to the allocation of organisational resources to achieve project deliverables. Project Team members are selected by the *Project Manager* based on their skill, qualifications and experience in relation to realisation of project deliverables.

Project Plan

The project plan is a formal, approved document used to guide both project execution and project control. This *Project Initiation Document* (PID) is important in the project planning framework which includes both a high-level work breakdown structure and *Project Gantt Chart*, (**Figure 8, page 21**) detailing key tasks, developed by the *Project Sponsor, Project Manager* and *Project Leader* for review and approval by the EED Leadership prior to the execution phase of the project. Key tasks will be annotated in Asana for subsequent allocation to Project Team members. A total of 420 project days have been allocated for successful completion of the project.

Project Costs

Budgets are an important mechanism in the control and successful achievement of project aims and objectives. The following assumptions dictate the cost calculations in relation to this project:

1. IT costs are sunk as equipment and software were not specifically purchased for the project.

2. Opportunity costs cannot be reasonably calculated nonetheless is a consideration.

Travel, accommodation and subsistence costs for attending ASQ Conferences and engaging with other practitioner bodies e.g. ISSP, IEMA is within the scope of existing budgeting arrangements if approved by EED leadership.

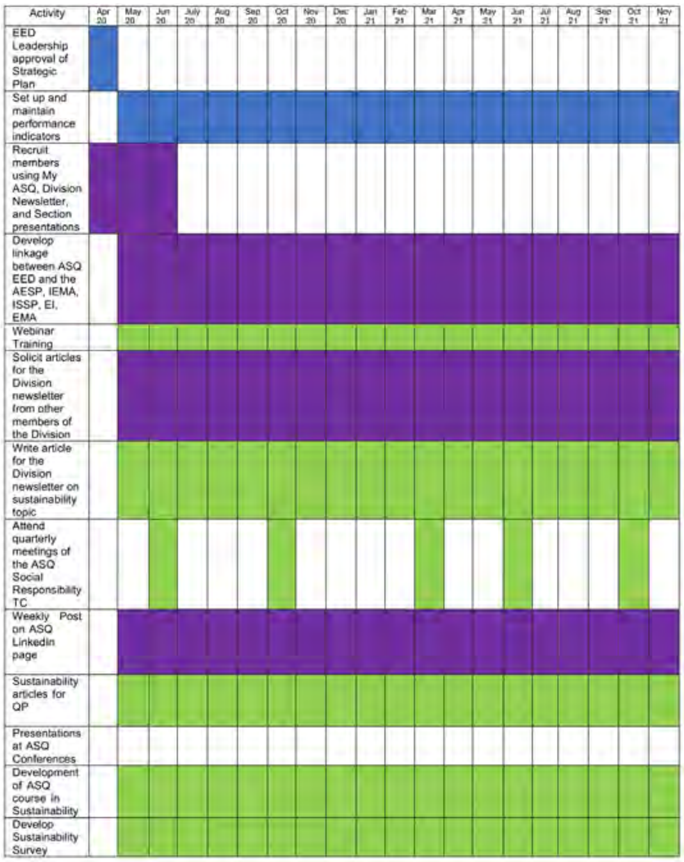


Figure 8: ASQ EED Sustainability Committee Project Gantt Chart

When *Evaluation phase*	**What-** *Communication product/ information*	**To whom** *Target group or individuals / position*	**What level** *Organizational level of communication*	**From whom**	**How (in what way)** *Communication means (e.g. meeting, interaction, written report, email etc.)*	**Why**-*Purpose of communication (e.g. solicit comments, seek approval, share findings for organizational learning)*
Planning	Tentative time and scope of activities	ASQ EED leadership	Strategic	Sustainability Committee Chair	Strategic Plan. During the annual performance planning session or other regular forum	To solicit comments and seek approval
Preparation/ Strategic Plan	Draft Strategic Plan	Key stakeholders	ASQ Members, ASQ management and technical level depending on subject matter	Sustainability Committee Chair	Email, the ASQ EEDwebpage, social media	To get comments
	Final Strategic Plan	Key stakeholders -relevant support staff	ASQ Members, ASQ management and technical level depending on subject matter	EED Chair	Email, the ASQ EEDwebpage, social media	-Inform the relevant staff of the overall plan, including critical dates and milestones. -informs the support staff on the selected strategic options and program of work
Inception/Project schedule	Draft Project schedule/key milestones	Key stakeholders -relevant support staff	ASQ Members, ASQ management and technical level depending on subject matter	Sustainability Committee Chair	Email, the ASQ EEDwebpage, social media	To get comments
	FinalProject schedule/key milestones	Key stakeholders -relevant support staff	ASQ Members, ASQ management and technical level depending on subject matter -operations staff	Sustainability Committee Chair	Email, the ASQ EEDwebpage, social media	Inform the relevant staff of the detailed project schedule, including critical dates and milestones; sites to be visited; stakeholders to be engaged etc. -informs the support staff (especially administration) of required logistical support
Data collection	Debriefing power-point	Key stakeholders -relevant support staff	ASQ EED Leadership management and technical level depending on subject matter -operations staff	Sustainability Committee Chair	Email	Allow reflection on the preliminary findings before the project schedule or activity review.
Data Analysis and Reporting	Draft Evaluation report	Key stakeholders -relevant support staff	ASQ EED Leadership management and technical level	Sustainability Committee Chair	Email	Request for comments on the draft report
	Final evaluation Report	Key stakeholders -relevant support staff	ASQ Members, ASQ management and technical level depending on subject matter	EED Chair	Email, the ASQ EEDwebpage, social media	Informing internal stakeholders of the final main product from the evaluation -Making the report available publicly
Dissemination & Follow-up	Draft Management Response to the evaluation recommendations	Key stakeholders -relevant support staff	ASQ Members	Sustainability Committee Chair	Webinar,/or an organized face-to-face session/conference	-communicate the suggested actions on recommendations and elicit comments -discuss the ASQ Management action to address the evaluation recommendations
	Final management Response	Key stakeholders -relevant support staff	- All levels	Sustainability Committee Chair	ASQ EEDwebpage	-Ensure that all ASQ Members are informed on the commitments made on taking actions

Figure 6: ASQ Sustainability Committee Communications Plan

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Quality and Essential Element of Sustainable Development

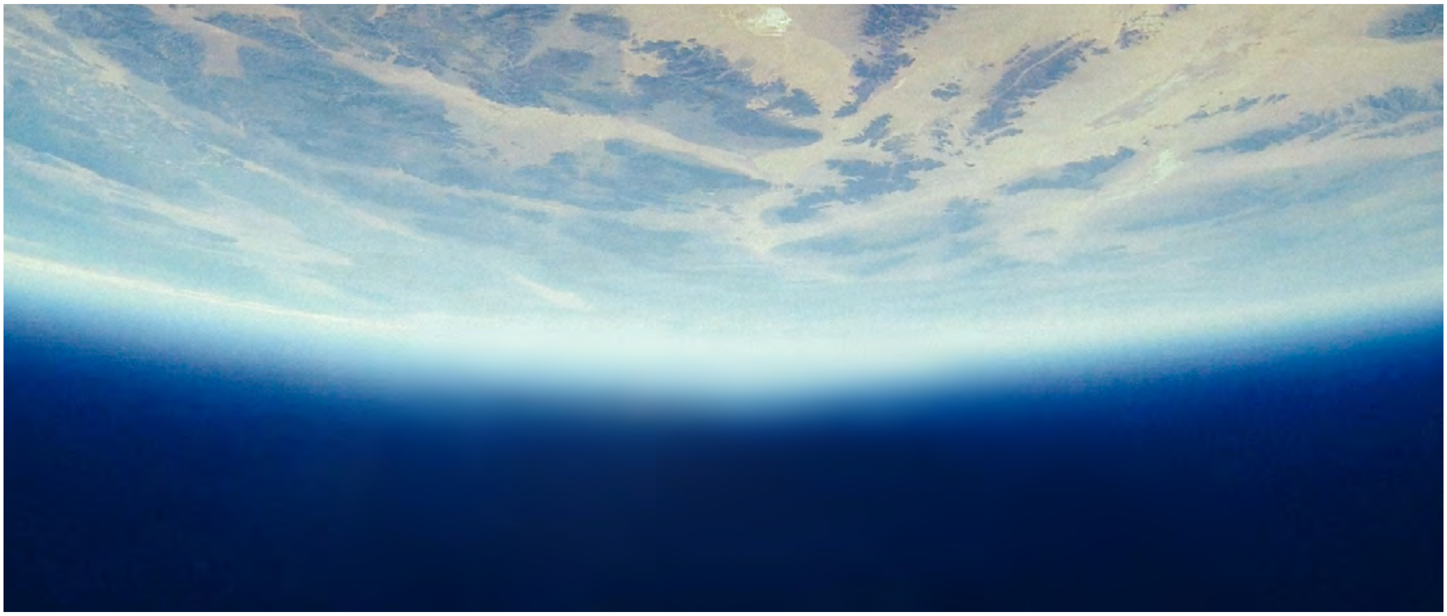
As I draft this document, global society is in the grip of the COVID-19 pandemic that has at the time of writing globally infected 20, 614,014 individuals and claiming 749,444 lives (ECDC2020). This pandemic is horrific enough when considered as a single event but when viewed from the lens of environmental sustainability and specifically climate change a new threat multiplier emerges. *Climate change* should not be considered in isolation but in relation to other global megaforces including *energy and fuel, resource scarcity, water scarcity, population growth, wealth, urbanization, food security, ecosystem decline* and *deforestation* (KPMG 2012).

At first glance there appears to be no direct relationship between COVID-19 — a zoonotic disease that can be transmitted from animals to humans — and sustainable development pillars i.e. economic, social and environmental. However, the UN Environment Program estimates that, since 2002, infectious zoonotic diseases such as Middle East Respiratory Syndrome (MERS), Severe Acute Respiratory Syndrome (SARS) and Ebola has claimed thousands of lives with Avian bird flu accounting for $20 billion in economic losses affecting *quality of life* (UNEP 2016). The increasing prevalence of zoonotic diseases are a result of the following factors: *deforestation and other land use changes, illegal and poorly regulated wildlife trade, intensified agriculture and wildlife production, antimicrobial resistance and climate change* (UNEP 2016).

Decades of environmental activism on its own can be deemed ineffective in stemming the negative impacts from unchecked human development. Businesses have been producing Environmental Reports, mainly voluntarily in some cases, as a legal require-

Author

Dr. Lowellyne James is the Chair of the ASQ Sustainability Committee and received a PhD in management from the Edinburgh Napier University Business School in Scotland. James is author of several books, including Management Systems and Performance Frameworks for Sustainability: A Road Map for Sustainably Managed Enterprises *(Routledge, 2018).*



ment. Recently Environmental reports include key performance indicators, such as carbon footprint, due to the need to mitigate greenhouse emissions and climate change risks (Kolk 2003, 2005a, 2005b) (IEMA 2010) (Environmentalist 2011).

Besides greenhouse gas measurement, there is a trend to adopt even more exotic techniques described as *ecological footprint and water footprint measured as the amount of productive land and/or water supporting human activities and required to sustain human life* (Holland 2003). The mainstreaming of these indicators is not yet apparent, even though ecological footprint measurement was developed in the 1990s (Rees and Wackernagel 1996). Tools to measure social outcomes e.g. stewardship or business contributions to building non-financial capital are rarely utilised by organisations (McElroy et al. 2008).

Quality has an all-encompassing role in the delivery of sustainability outcomes in terms of standards setting, inspection, testing and the development of a sustainability culture that directly influences quality of life. In my opinion, for the quality profession to be relevant to the strategic challenges arising from global megaforces, it requires a shift in understanding of the following three issues:

The concept of customer satisfaction

Conventional notions of the customer within quality management involves the exchange of goods or services within the confines of the traditional process model of *input-process-output* that identifies waste as a result of economic activity albeit an unavoidable externality. Waste reduction and loss have always been a focus of quality management tools and techniques, e.g. lean manufacturing and Six Sigma. However, these tools were never designed to account for the effects of externalities such as carbon emissions arising from *energy and fuel* consumption. Therefore, the concept of the customer must evolve to include global society redefining the concept of quality beyond the boundaries of product and service conformity towards sustainable development.

The decoupling of quality from sustainable development

A regularly quoted definition of sustainable development, *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs,"* has influenced approaches to sustainability within business (Brundtland 1987). Inherent in this definition is an imperative of satisfaction of the "needs" of humanity both present and future. Siloed thinking of quality as a separate and exclusive concept to sustainability must be replaced by viewing quality as the active element of sustainable development.

The inability to respond to the dilemma inherent in the principal – agent relationship

Quality gurus have stated of the dangers of a focus on short-term profits by CEOs to the detriment of the long-term prosperity of principals i.e. shareholders, investors and society. This attitude has been nourished by unsustainable business practices, such as bonuses linked to purely financial indicators. Thankfully, ASQ has taken the lead in embracing sustainability as a key aspect of the quality professional's role within the C-suite, championing change in strategic thinking at leadership levels.

ASQ Sustainability Committee Strategic Plan

The mission of the *Sustainability Committee* is to *provide its members with knowledge and tools that will enable them to be leaders in their organizations and their industries with regard to the strategic integration of quality and sustainability*. Quality professionals are well-suited to provide skills and expertise, including leading change, continual process improvement, lean principles and analytical skills, all of which are needed to improve sustainability performance. In addition, Energy and Environmental Division (EED) members are employed within industries that are at the centre of high-visibility sustainability issues and can therefore provide leadership that advances their organizations and society at large.

The *ASQ EED Sustainability Committee Strategic Plan* has been developed as a live document and seeks to incorporate this strategic intent by pursuing four objectives:

Objective 1 Provide relevant and timely information on environmental sustainability management.

Objective 2 Improve member engagement on environmental sustainability management.

Objective 3 Promote sustainability management within the ASQ events.

Objective 4 Improve understanding of the relationship between quality and environmental sustainability.

To realise these strategic objectives, a few activities are scheduled for implementation e.g. sustainability training and benchmark sustainability survey. In these uncertain times the success of these initiatives relies on the support ASQ EED members. Give us feedback on any additional activities that will help us achieve our mission and tailor our strategic plan to the needs of the ASQ Membership.

On behalf of the EED Council I look forward to engaging with ASQ members to deliver benefits that will enhance careers and embed sustainability as a core value within organizations.

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INTRODUCING

The Environmental Committee Chair

| *"The biggest risk is not taking any risk."*

Mark Zuckerberg

It is challenging to describe how I got into this field. I have had many different chapters in life and yet somehow, they come together with my undeniable passion for Quality. My Enthusiasm for Quality started when I was in the Navy. Serving in the US Navy for six years is where I was first introduced to the general concept of Quality. It was easy to realize that Quality is embedded into every division, every shop, and every job, but I found that there were so many who were unaware of various Quality Management Practices. My interest in Quality quickly grew. The idea of *"How can we do a job more efficiently and effectively with higher quality results?"* fascinated me. The more I read, the more I knew this is what I wanted to do as a career.

Fast forward to 2014, where I worked as a Civil Servant at NASA Armstrong Flight Research Center out of Edwards, California, and my assignments began to include research pertaining to Safety and Quality. This is what lead me to ASQ to begin with; this is an organization that has so many resources and subject matter experts who are all passionate about the field. This is an organization that I enjoy being part of.

In 2018 I decided to move towards a career where I can focus solely on Environmental, safety, Health and Quality. I

Author

Barbara LaBarge, Environmental Committee Chair, is the Global Safety and Quality Manager at Fluence Energy out of Arlington VA

am currently the Global Safety and Quality Manager at Fluence Energy out of Arlington, Virginia. This has been one of the more exciting chapters of my life to date.

More so now than ever, protecting the environment is on every company's mind. In fact, the environment is on everyone's mind around the globe. I do not think you can open any newspaper without finding some article related to the Environment. When I saw that this committee chair was open, I was eager to apply. There are so many directions you can take with a committee like this. I hope to get others energized about Environmental Management and help spread the knowledge of various subject matter experts in the field. I am very excited to be joining the Energy and Environmental Division (EED) at ASQ as the new Environmental Committee Chair.

Due to the increasing awareness and concerns regarding environmental issues, a variety of new standards and tools related to environmental aspects are being developed. The Environmental Committee has a very ambitious plan and we will be keeping EED members updated on pertinent changes to ISO Environmental Standards such as ISO-14001 & other related standards, systems, and tools by writing articles in this newsletter.

We have an ambitious plan in writing articles and hosting various webinars throughout the year. I am also interested in engaging with the energy industry, as well as a variety of other industries to collaborate with us on our endeavors.

This committee is small but another goal that I have in the next 12 months is to grow the committee to help achieve the various goals and objectives that we have on our plate. If you are interested in joining the committee, I would love to have you on the team! Please do not hesitate to reach out.

Also, if you have concepts or ideas of what topics to cover in additional newsletters or future webinars, I would love to hear from you. You can contact me at **Babs.labarge@gmail.com**. Regardless of your life chapters and how you got into this field, I look forward to taking this journey with you.

Advanced Reactors:
State of the technology and an exploration into the fast spectrum molten salt reactor

The Department of Energy (DOE) [https://www.energy.gov/ne/articles/energy-department-launches-new-demonstration-center-advanced-nuclear-technologies] formed the National Reactor Innovation Center (NRIC) in August 2019 to develop advanced fission reactor technology in the United States (U.S.), driven by growing U.S. interest in more energy independence and reducing carbon emissions.

Nuclear reactors in the U.S. have produced more carbon-free electricity than any other power source. Historically, domestic nuclear power reactors have been large light water reactors (LWR), with power ratings on the order of 1000s MWe, which can power approximately 700,000 homes. LWRs use uranium ceramic fuel pellets held in long metal tubes called fuel rods, packaged into fuel bundles that are loaded into the reactor core. Uranium used in the fuel is enriched to include a higher percentage of fissile Uranium-235, a specific isotope that fissions easier. There are two types of LWRs: pressurized water reactors (PWRs) and boiling water reactors (BWRs). The main difference between the two is that PWRs use steam generators to produce steam for electrical generation, while BWRs use water boiled directly in the core to produce steam for that same purpose.

Deploying new LWRs of either type has been difficult since the electrical generation market currently favors cheaper alternatives, such as natural gas. However, there are some proposed advanced reactor designs that seek to improve the economics of nuclear reactors by addressing the cost of deployment through economies of scale. Small Modular

Author

Vincent Novellino is a recent graduate of North Carolina State University with his Bachelors and will be returning to NCSU to pursue a PhD in nuclear engineering. He has interned at Oak Ridge National Lab conducting research on modeling HALEU fuel with VERA and Polaris. The senior design project he worked on was to propose a design of a demonstration fast spectrum molten salt reactor. He can be reached at **vnnovell@ncsu.edu**

Reactors (SMRs) are one innovative technology that uses the same LWR technology of the traditional reactor, but shrinks the size of the reactor so it can be manufactured in a factory and shipped to the reactor site. Additionally, passive safety systems in SMRs remove the need for operator intervention during accidents, making these designs safer than current LWRs.

Other advanced reactor designs that are being investigated include non-LWR designs, which have some unique advantages. The NRIC has released a timeline to deploy several advanced reactor designs over the next decade, such as micro-reactors and non-LWR demonstration faculties. Fast spectrum Molten Salt Reactors (MSRs) are another proposed advanced reactor technology that the NRIC plans to demonstrate. The first MSR was built as part of the Aircraft Reactor Experiment (ARE) in the 1950s that aimed to test the technology for use in long-range bombers. Intercontinental Ballistic Missiles (ICBMs) development removed the need for long-range bombers and led to the abandonment of the ARE project. Another MSR was built at Oak Ridge National Lab (ORNL) in the 1960s as part of what the lab called the Molten Salt Reactor Experiment (MSRE). The MSRE was an important experiment to explore the feasibility of using MSRs for electrical generation. Both of these facilities were demonstration facilities, designed to confirm theoretical predictions of behavior and gain operational experience using the technologies. MSRs, in general, are a class of nuclear reactors that use a molten salt as a coolant and typically use uranium salts that are dissolved into a molten salt mixture to make the fuel salt. The fuel salt mixture is contained in a vessel that features a critical configuration.

Advantages of MSRs over solid fuel designs include: online refueling and isotope control, no meltdown accidents, loss of coolant accident (LOCA) protection inherent to the technology, and near atmospheric operating pressure. Online refueling is attractive since outages in LWRs are costly and the ability to refuel online means longer operating cycles and less outages. In addition, online refueling and isotope control eliminates the need to add large amounts of excess fuel to the reactor to maintain criticality during operation, thus nearly eliminating the possibility of a power excursion accident. In fact, entire classes of accident types are eliminated in MSRs because the fuel is supposed to be melted during operation! LOCAs are mitigated because of the large feedback coefficients that result from the high expansivity of liquid fuel salts. That means small increases in temperature decrease the density of the fuel salt significantly, which slows the chain reaction as distance between uranium atoms increases. Historically, the most infamous nuclear accidents were either power-excursion (Chernobyl) or LOCAs (Three Mile Island and Fukushima). Near atmospheric operating pressure of MSRs reduces both the containment building and reactor vessel costs.

Historical MSR facilities were thermal reactors that used a moderator to slow neutrons down. Neutrons that are produced from fission have lots of energy and are moving fast. Moderators act as targets for neutrons to hit and transfer energy to, slowing them down to a speed where the neutron hitting a fuel atom is more likely to cause fission. The drawback of moderators in MSRs is swelling of graphite, a common moderator material, as radiation dose increases. Operation lifetime of the reactor is limited by this phenomena in thermal MSRs. Fast spectrum MSRs removes the graphite moderator and uses fast neutrons to induce fission.

Removing the moderator also shrinks the size of the reactor vessel, improving the economics of the design. In addition, fast spectrum MSRs would use High Assay Low Enriched Uranium (HALEU) fuel, which also improves the economics. In general, fast spectrum reactors have better conversion ratios compared to thermal spectrum reactors. Conversion ratios measure the amount of fissile material — material that can fission to make power — that is produced during reactor operation. A significant reaction in reactors affecting the conversion ratio is Uranium-238, the most common isotope of uranium, absorbing a neutron to become Uranium-239, which decays immediately into Neptunium-239, which decays after about two days to Plutonium-239, which is fissile. High conversion ratios means less fuel is needed to be replaced in the reactor in order to maintain the chain reaction.

Fast spectrum MSRs have high leakage of neutrons out of the vessel due to their smaller size and higher average neutron energy. The high leakage of neutrons enables

ex-vessel control of the reactor, meaning almost all penetrations into the vessel can be eliminated. Traditional LWRs and thermal MSRs have in-core control rods that are moved to enable the reactor to start up, shut down, and change power. Eliminating vessel penetrations serves two purposes in the design: removing points of failure in the reactor vessel and reducing neutron damage to the control material, allowing longer operation without replacement. Ex-vessel control can have two different methodologies of control: absorption or reflection of neutrons that leak from the vessel. Reflection of neutrons is the preferred method since it allows smaller vessel sizes which reduces the overall cost of the reactor.

Molten salt reactors can use a variety of different salt mixtures in their design to fine tune the operating characteristics of the reactor. Fluoride salts have historically been used in MSRs designs, and in the MSRE, because there is only one naturally occurring isotope of fluorine, Fluorine-19, which has a relatively small absorption cross-section, meaning it does not typically absorb neutrons. Chloride salts are another option for MSRs and are included in many fast MSR designs. An advantage of using chloride salts in fast designs is that chlorine has a lower moderating power than fluorine, meaning neutrons do not slow down as quickly with collisions with chlorine. This means the average energy of neutrons is higher with chloride salts than fluoride salts. Higher average energy neutrons in the reactor corresponds to more neutrons being produced from fission and a greater breeding or transuranic burning potential. Transuranic burning is the transmutation of long-lived radioactive elements (transuranic) to radioactive elements with smaller half-lives. This is an advantage of fast reactors since transuranic burning reduces the long term radio-toxicity of used fuel and the number of years the used fuel needs to be stored until considered safe. A disadvantage of using chlorine is that there are two naturally occurring isotopes, Chlorine-35 and Chlorine-37 at 76% and 24% abundances, respectively. Chlorine-35 has a high absorption cross-section, meaning it absorbs neutrons readily producing Chlorine-36 which has a very long half-life, increasing radio-toxicity of used fuel salt. Proposed designs address this issue by enriching the chlorine used in the fuel salt to remove Chlorine-35. The larger relative difference between the two isotope masses makes separating the chlorine isotopes easier. Therefore, the enrichment cost is expected to be small compared to the overall cost of the fuel.

Auxiliary systems included within MSRs include salt pumps, heat-exchangers, fission gas removal systems, salt chemistry control, drain tanks with freeze plugs for emergency shutdown, and the entire electrical generation system. Each of these systems work together to keep the reactor producing electricity. A lot of these sub-systems for MSRs have been demonstrated with the MSRE for fluoride salts. To transition to chloride salt reactors, the salt chemistry control system needs to be designed and validated. In addition, exploring corrosive properties of chloride salts when used in-conjunction with different pipe and vessel materials at operating conditions is also necessary to validate designs. A majority of the research into chloride MSRs will be centered on those two tasks, which would be aided immensely by deploying a demonstration reactor.

Overall, the U.S. DOE has shown a commitment to deploying advanced reactor designs over the next decade through the NRIC. SMRs will be the first technology to be deployed, given their similarity to current LWRs and to their being the furthest along in its deployment with the NuScale design licensed by the Nuclear Regulatory Commission (NRC). Many non-LWR designs are proposed, with each technology at a different level of design maturity. The sodium fast-reactor is considered to be the most mature and quickest to deploy, due to extensive research that was performed in the 1950s-1990s. We explored the fast spectrum MSR technology in detail, comparing and contrasting the designs with previous MSR demonstrations. In addition, different design choices for fast MSRs were discussed in some detail to show why chloride salts would be advantageous to use in fast MSR designs. However, the lack of operational history means a demonstration facility is needed to confirm theoretical predictions used in the design of the auxiliary systems for fast chloride MSRs. In conclusion, it is an exciting time for those in the nuclear industry and for those researching advanced reactors as the drive to deploy low-carbon electrical production accelerates to combat climate change. The need for low-carbon base-load power means we will likely see more reactors being deployed to meet that demand.

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CFD Virtual Sensing for the Next-Generation Nuclear Systems Online Monitoring

In the last two decades, the engineering simulation has become a convenient and accessible tool for new product design and optimization, eliminating a costly and time-consuming need to build multiple prototypes before product launch. Now, with the emergence of a **Digital Twin**, simulation is expanding into operations. Advanced nuclear systems have to integrate modern design and monitoring technologies to improve components design and optimization processes along with overall system operation performance.

The Digital Twin (or virtual twin/avatar) models the current operating conditions of a physical system with a set of physics-based methods and advanced analytics. According to the GE Digital Twin report (2016), the Digital Twin model and advanced techniques of optimization, control, and forecasting, applications *"can more accurately predict outcomes along different axes of availability, performance, reliability, wear and tear, flexibility, and maintainability."* The physical models coupled with the sensor data enable prediction of the plant's performance during normal and off-normal conditions, and enhance efficiency and safety. Development and implementation of the Digital Twin are also imperative to maximize advanced nuclear power plant systems' cyber-resistance characteristics against external, intentional, and accidental compromises potentially disrupting energy delivery.[1]

Abbreviations

CFD
Computational Fluid Dynamics

FEA
Finite Element Analysis

HPC
High Performance Computing

ROM
Reduced Order Modeling

SPH
Smoothed Particle Hydrodynamics

Author

Dr. Izabela Gutowska is an Assistant Professor at Oregon State University School of Nuclear Science and Engineering. Before joining OSU, she was an Advanced CFD Engineer at GE Power. Her main expertise scopes scaling, heat transfer, thermal design, computational fluid dynamics, and nuclear safety analyses of HTGRs. A longer bio version is available at

https://ne.oregonstate.edu/izabela-gutowska

There is a dataflow between the twin and its real-life counterpart, and, via sensors on the real-life system, the twin is updated so that the system's status can be monitored, virtually, in real-time. And this process is not just for status updates of the real-life system. The twin can be programmed to run what-if scenarios, and optimal parameters can be determined for functionality. A comprehensive Digital Twin can comprise of different segments. Each virtual segment represents an equivalent physical layer. These layers scope physics, materials, structures, electronics, fluids, and other physical characteristics of the system. A one-to-one mapping between the Digital Twin and real model should allow engineers to make immediate corrections to their systems, optimize performance and rapidly accelerate the design.

Along with the recent developments in the Digital Twin, Machine Learning, Virtual Reality, Artificial Intelligence, and Internet of Things, the availability of high-resolution Computational Fluid Dynamics (CFD) and affordable computing power have advanced considerably in recent years. CFD is a powerful tool for simulating fluid flow, heat transfer, and combustion processes in almost any kind of engineering system.

CFD analyses enable a rich set of capabilities, ranging from evaluating pressure drops, mass flow rates, and stagnation zones, to monitoring mixing and heat transfer efficiency, turbulent regime formation, wall erosion and even predicting aerodynamically generated noise. Even further, the CFD simulation can be coupled with an FEA model in a Fluid-Structure interaction simulation to evaluate flow-induced vibration

CFD techniques have the potential to be used as a virtual sensor for an active, operational thermal-hydraulic management and the 'fluid analysis' layer of the Digital Twin model of a real nuclear system. Virtual sensing, also known as soft sensing, has been successfully applied to various processes to provide feasible and economical alternatives when physical measuring instruments are not available or feasible [2, 3, 4, 5, 6, 7]. The principle upon which soft sensors work is based on the real-time analysis that utilizes input from all available hardware sensors (flow meters, thermocouples, pressure transducers, etc.). CFD virtual sensing concept is presented in **Figure 1**.

If CFD is used as a virtual sensor, then interpolation between data from limited physical instruments will be no longer needed and fluid flow properties will be available

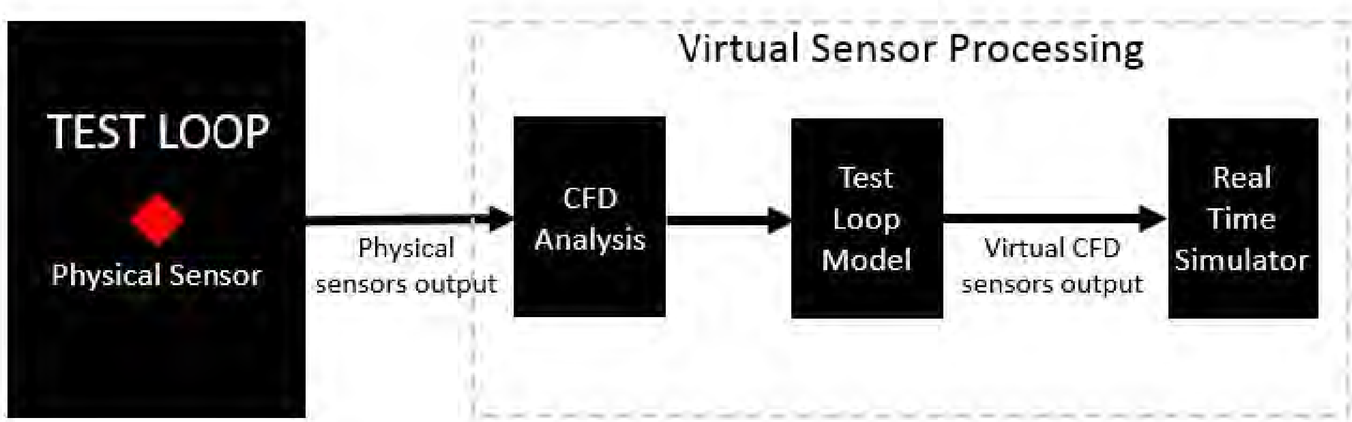

Figure 1: Virtual sensing system concept

at any location that was modeled. Ultimately, the CFD virtual sensing, if applied to various nuclear systems, can serve for components design, optimization driven by simulation, demonstration of safe performance, or active systems monitoring.

On the other hand, simulating real-world processes in real-time using CFD is very challenging due to the complexity involved in the physical phenomena studied. Traditional CFD simulation typically takes hours on large HPC clusters to produce a meaningful, highly accurate, results. Therefore, the development and implementation of a robust virtual CFD sensor are characterized by conflicting demands imposed on the concept. In particular, it should provide an accurate results, using limited computing resources (which implies coarser grids) during the real-time test run[8].

The current typical mesh-based CFD simulation process is presented in **Figure 2**. The first step in the analysis involves the preparation of the geometry for meshing. Complex geometries of nuclear systems components require hours of manual effort to 'clean-up' the model and then generate the mesh. The adequate grid resolution is currently the most difficult and time-consuming aspect in determining an accurate solution on a complicated domain. A relatively large amount of total CFD process time (~73%) is devoted to steps 1-6 (**Figure 2**). Moreover, often due to technical limitations, the user has to reduce the number of mesh cells to be able to perform analysis but does not have enough

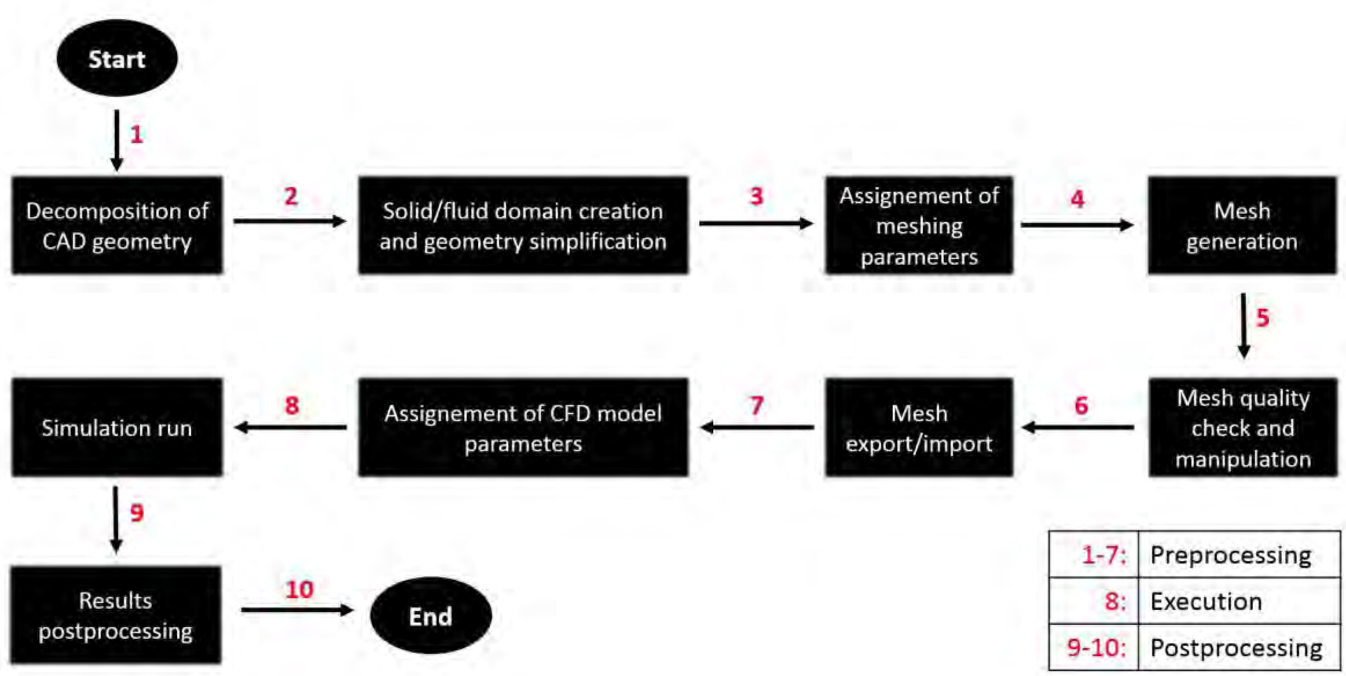

Figure 2: Standard CFD process

computational resources and physical time to produce practical solutions (verification procedures). This is detrimental to the fidelity and accuracy of CFD results. What is more, stationary mesh, generated before the solution of the flow field is calculated, precludes the possibility to capture certain physical phenomena in locations where a-priori grid refinement was not applied. Presumptive spatial discretization has to be set up each time-analyzed geometry is iterated towards optimized design.

The alternatives to the mesh-based CFD simulation methods that can provide significant speed-up for online use and soft sensing. This includes mesh-based methods such as Reduced Order Modeling (ROM) or mesh-free approach based on for instance Smoothed Particle Hydrodynamics (SPH) among others [9].

New technologies such as virtual sensing and Digital Twin can complement the standard field observations and laboratory experiments. Despite the execution difficulties, the need for online CFD monitoring in advanced nuclear reactors will become more and more transparent and critical for assessing fluids parameters at any given location during normal and abnormal system conditions. Therefore, knowing the critical need to feed the CFD input by real-time monitoring information to allow for continuous improvements of various thermal-hydraulic nuclear reactor systems and immediate response in case of system failure, the remaining question is whether an instantaneous prediction from current conditions is even possible. CFD and nuclear engineers are currently working on enabling the soft sensing concept by developing time-efficient online CFD analyses coupled with integrated sensing technologies.

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Braving the Energy Future of Canada

This article presents both the energy status and outlook in Canada. There is a special interest in nuclear energy, especially Small Modular Reactors (SMR). SMRs are a topic of global conversation, including Canada. Besides myself, Professor Dan Hoornweg, with expertise in analyses of three types – energy, sustainability and cities versus regional areas, and recent graduate, Jordan Crowell, are contributing authors.

I. Energy in Canada: Contrasts and Connectivity

Energy is a major theme in Canada's economy, politics and social structures. On a per capita basis, Canadians use more energy and generate more greenhouse gas emissions than almost any country in the world (recently surpassing the U.S. and Australia). Canada's largest export is oil and gas; about 25 percent of the country's total exports.

Canada's unique federation gives custody of energy resources, and electricity generation to the provinces. Oil development, especially now from oil sands, is Alberta's largest share of the economy. In Quebec, hydroelectric production, including sale to U.S. states, underpins the economy.

The hydro contribution to electricity in most of Canada is considerable. In the provinces of British Colombia, Manitoba, Ontario, Quebec and Newfoundland, hydro is such a large and original part of electricity generation that 'hydro' and electricity are used synonymously. Electricity companies emerged as utilities such as BC Hydro, Ontario Hydro, and Hydro-Quebec. In Ontario, the public still refers to 'hydro' as electricity, even though hydro now only makes up 20 percent of Ontario's generation.

Authors

Dr Akira Tokuhiro: Dean and Professor, Faculty of Energy Systems and Nuclear Science, Ontario Tech University. He has diverse interests in nuclear energy; most recently in small modular reactor

Dr. Dan Hoornweg: Associate Dean and Professor and Richard Marceau Research Chair in Faculty of Energy Systems and Nuclear Science at Ontario Tech University

Jordan Crowell: Junior Engineer at X-energy; BS Nuclear Engineering University of Ontario Institute of Technology

Canadian provinces, especially BC, Ontario and Quebec, used low electricity rates to attract businesses. Manufacturing was anchored in Ontario and Quebec, especially automobile manufacturing. Today, Ontario, for example provides a $6 billion subsidy to electricity (the billed cost of about 11 cents/kWh covering less than half the total cost). Provincial governments are routinely voted in and out of power based on electricity prices. As prices received greater focus than costs, Canadians emerged as the world's largest per capita electricity consumers.

Canadian households have among the lowest total budget allocation to energy costs (less than 1.5%) and even though energy in Germany is more than twice the cost as in Canada, household budget allocations are similar as German households use about half the total energy of Canadian households. Conservation is not yet seriously pursued in most Canadian provinces. The recent application of a national carbon tax will not likely have much impact on electricity pricing in most provinces as electricity is relative low-carbon.

Alberta and Saskatchewan differ from most provinces as electricity generation remains mostly coal-fired.

Canada, similar to other high-income countries, has three broad parts to its energy system. Transportation is the largest part ($17 - $23/GJ, or $0.65 - $0.80 L for gasoline, diesel and jet-fuel), followed by heating ($2 - $8/GJ, mainly natural gas), with electricity the smallest third but typically the most costly form of energy($8 - $28/GJ, or $30 - $100/MWh)[1]. Canada's overall electricity generation is about 60 percent hydro, 15 percent nuclear, 19 percent fossil fuels, and 7 percent renewables other than hydro. Grid supplied electricity is relatively low carbon intensity, about 140 gCo2/kWh, compared to 450 gCO2 in the USA[2], and a global average of 475 gCO2[3].

Canada exports about 50 TWh of low-carbon electricity to the U.S. every year, saving the U.S. about 20 Mt of CO2 (with a $600 million implicit subsidy at a carbon price of $30/t, with a net difference in electricity of 400 gCO2/kwh).

Nuclear energy is provided from Canadian-designed CANada Deuterium Uranium (CANDU) power plants (18 reactors in Ontario and 1 in New Brunswick).

Canada's overall energy system is undergoing a fundamental transition as efforts to de-carbonize take hold. Similar to strategies in other countries, Canada intends to electrify transportation (including hydrogen to largely replace vehicles currently powered by diesel) and apply ground source heating and cooling systems. Electricity demand may well increase by up to 75 percent by 2050.

Nuclear power is expected to remain central to electricity production, especially in Ontario, where the share of nuclear power is not expected to fall below 50 percent. Any new generation, however is expected to be delivered through new small modular reactors (SMRs). The existing Darlington and Bruce nuclear power plants are undergoing major life-extension works, with operation of both plants expected beyond 2050.

The great standards war – between AC or DC transmission of electricity – was waged most forcefully over the enormous flow of the Niagara River and the 99-meter drop in elevation from Lake Erie to Lake Ontario. Nikola Tesla and George Westinghouse on one side; Thomas Edison and his stack of DC-lightbulb patents on the other. The battle was decided when Tesla and Westinghouse won the contract to light up the 1893 Chicago Worlds Fair.

Hydro-electric power plants along the Niagara River started in 1882, with the Niagara Falls Hydraulic Power and Manufacturing Company of Niagara Falls, NY, which entered into bankruptcy two years later. Several private-sector power plants on both sides of the River were built. Angst grew as municipalities worried about access to electricity.

During the 1905 Ontario provincial election campaign, James Whitney (who would become Premier) arguing for the creation of a public utility declared: *"The water power of Niagara should be as free as the air."*

Work began to establish a public utility (Hydro-Electric Power Commission of Ontario, HEPCO), initially to provide transmission services to municipalities. In 1921, HEPCO acquired the Toronto Electric Light Company and various electric railways, making it the largest electric power system in the world. HEPCO was charged with rural electrification for Ontario in the early 1920s.

HEPCO, renamed Ontario Hydro in 1974, grew quickly, fully entwined within provincial politics, and significantly increased generation capacity. The Adam Beck I hydro-power plant was the world's largest civil works project at the time (1922). The 4,000 MW Nanticoke coal-fired station, that started in 1972, was the largest fossil-fuel plant in North America. Ontario Hydro, exhausting hydro capacity, and fossil fuels, aggressively developed nuclear generation capacity (about 13,000 MW in three plants, including in 2011, the world's largest nuclear power plant at Bruce County).

The Province of Quebec had a similar aggressive expansion of electricity generation, beginning in 1944, when several private firms were expropriated by the provincial utility. In 1963, the utility consolidated its provincial power base when it purchased all but one of the remaining private distribution companies.

The province resisted the federal government's lobbying for expansion of nuclear power, and decided to develop the massive hydro-potential in the province's north[4]. The James Bay hydroelectric development (Phase I and II) provides up to 27,000 MW and impacted watersheds of 177,000 km^2 (larger in extant than Florida). The initiative was the key plank of Robert Bourassa's political campaign for Premier. The crown corporation now provides annual dividends to the province in excess of $4 billion.

Canada's large electricity utilities are provincially owned. British Columbia, Manitoba, Ontario, Quebec and Newfoundland 'Hydro' utilities are among the largest companies in their respective province. Many developed international subsidiaries, however these efforts were minimal. Unlike, for example, Engie in France (nationally owned utility).

In Alberta, no large-scale electricity utility developed as electricity generation was left to private sector companies and municipalities. EPCOR the largest utility in Alberta (electricity transmission, wastewater, water and gas distribution) is owned entirely by the City of Edmonton operates in three provinces and three U.S. states.

The future of energy development in Canada is likely to see history repeat as the federal government attempts to coordinate activities, from nuclear to hydrogen, while provinces, work to limit federal involvement in their local energy systems. Cities, especially in Ontario, are largely divesting local distribution companies as they consolidate to larger scales of service areas and finance.

Natural gas is provided and distributed mostly by the private sector in Canada. Federal oversight is limited to pipeline transmission where pipelines cross provincial borders. Each province also regulates pricing and safety of natural gas transmission.

Coordination of electricity markets in Canada is likely to remain difficult as each province prioritizes the shift to electrifying transportation (with hydrogen) and space heating (replacing natural gas). Trust and cooperation between provinces is weak. The acrimony in Newfoundland over the transmission fees charged by Hydro-Quebec from Churchill Falls, and the friction between Alberta and British Columbia, over access to (hydrocarbon) pipelines (and resulting reluctance by Alberta to buy BC's hydro-electricity) are illustrative.

Canada's overall energy system is reflective of a weak federation where key local parts are optimized, often at the expense of the overall system efficiency. This 'province-first' approach to energy development challenges the fungibility of energy types. Hydrogen, for example, may well emerge as a key energy carrier, well-suited to production of non-peak demand electricity and subsequent use for transportation or space heating. However, this then requires a common regulatory and usage approach – with corresponding development of businesses. Will Ontario and Quebec again want to drive the development of hydrogen energy systems?

Will the Government of Canada again attempt to coordinate development of nuclear programs? Will Canada, and Canadian provinces, develop new energy systems with a view to export that capacity internationally?

In Canada energy remains entwined between political, technical and geographic considerations.

II. Canadian Nuclear Energy's Legacy and Future

History of (civilian) nuclear power goes back to the early 1940s under a British-Canadian partnership and administration of the National Research Council of Canada. One of the first experimental (research) reactor designs was a heavy-water moderated, natural uranium fueled reactor called the National Research Experimental (NRX). The NRX and the ZEEP – Zero Energy Experimental Pile, were constructed at the Chalk River Nuclear Laboratory all before 1950. It is worth noting that the Canadian uranium mining industry is distinct and independent to national nuclear reactor developments.

The Chalk River site is also home to the present day Canadian Nuclear Laboratory (CNL). CNL plans to host either Micro or Small Modular (demonstration) Reactors on its site. *(More on new builds, including SMRs below).*

In the early 1950s, the Canadian government formed the Atomic Energy Canada Limited (AECL) as a Crown corporation, and in a subsequent partnership with Ontario Hydro and Canadian General Electric built its first nuclear power plant. The 20 MWe Nuclear Power Demonstration (NPD) that started operation in 1962, formed the basis of what is known to this day as the CANDU reactor. AECL set a goal to build 24 CANDU power plants, starting in 1961, in the Provinces of Ontario, Quebec and New Brunswick. Additional details on the history of nuclear power is given in the Wikipedia article, "Nuclear Power in Canada"[5].

Alberta, Saskatchewan, and New Brunswick have all initiated activity or expressed interest in next generation nuclear. As noted, British Columbia predominantly relies on hydroelectric power and hosts General Fusion, a fusion reactor startup.

The regulatory authority in Canada is the Canadian Nuclear Safety Commission (CNSC). The CNSC, headquartered in Ottawa, regulates power plants, nuclear research facilities and the use of nuclear materials, including radionuclides. In terms of operating plants, Ontario has 18 of the 19 plants, with one additional plant in New Brunswick. The oldest plant started commercial operations in 1971, and the newest in 1993. Both Ontario Power Generation and Bruce Power have started on "refurbishment" of some 10 units, at a planned cost of CA$26B, with the last unit completing refurbishment in 2032. The planned additional year of operations beyond major component replacement is 30 years. Thus, OPG/BP have already declared an intent to operate the existing plants to years, 2055 - 2065, depending on the unit.

Equally, the Pickering site, only 45 km (28 mi) east from downtown Toronto, and adjacent to Lake Ontario, currently has 5 units in operation (total, 2.5GW). The growth of suburbs east stretches another 30 miles. Operations of this facility was extended with licenses granted for the 6 remaining units to 2022, and four to 2024.

The GridWatch (Ontario Edition)[6] application for cell-phones and per website provides live generation data of all energy sources in Ontario, including the nuclear generation stations. It also provides live data on the carbon content, in grams per kilowatt-hours, of electricity generation. Viewing this data highlights that Ontario has very low carbon intensity – one of the world's lowest, based typically on 60% nuclear, 25-30% hydroelectric and 10-15% on renewable and natural gas generation sources. Of note is Ontario's closure of its coal-fired plants.

Young Canadian Generation in Nuclear

There is ongoing enthusiasm in Canadian stakeholder institutions regarding nuclear's future. This enthusiasm is primarily to host a Small Modular Reactors or construction of a new plant – possibly an evolutionary design of the CANDU concept. Ontario Power Generation's Darlington site, currently with 4 operating units, has a completed environmental assessment for a new build nuclear plant. OPG is engaged in a selection process for new build options, which include a declared interest in SMR. Enthusiasm for SMRs was partially provided by Natural Resources Canada's (NRCan) SMR Roadmap issued in November 2018. "NRCan" oversees the federal government's interests in nuclear technologies and facilities. In Canada, nuclear engineering, as an undergraduate level university degree program, exists only at Ontario Tech University. The program began in 2003. With the first graduate in 2007, the program, along with graduate degrees (MS, M.Eng., PhD) has produced about 1000 graduates. Over the past 6-years at the Bachelor level, it has produced the third most graduates in North America (cf. USDOE Sourcebook).

Currently, there are more than 10 potential SMR concepts undergoing a three Phase "Vendor Design Review" process with the CNSC. Many of the SMR startups (NuScale, Terrestrial Energy, Moltex, ARC, X-Energy, UltraSafe, Global First Power), as well as concepts proposed by Westinghouse and GEH (eVinci, BWRX-300), have filed/completed CNSC's Phase 1 and/or Phase 2. Many, but not all the startups have incorporated in Canada or have partnership with one of the larger Canadian engineering and/or A&E firms. It is important to note that the Canadian regulatory review process is different, relative to the 'prescriptive approach' that the USNRC exercises. The safety-case at a high level is the responsibility of the vendor and thus, design review can be very different with the U.S. approach. Recent developments provide cooperation agreements between U.S.-Canadian regulatory bodies. Finally, during the G7-linked Clean Energy Ministerial held in Vancouver (May 2019)[7], Canada declared nuclear energy as a key part of the solution to mitigate climate change and transition to a low-carbon economy.

The Canadian nuclear landscape is transitioning; while maintaining its legacy fleet of operating CANDU reactors, future operations will either host a SMR with conventional fuel (new to Canada), or 'downscale' the well-known CANDU design into SMR configuration. In either case, Canada plans to maintain a skilled nuclear workforce and nuclear supply chain consisting respectively of some 40,000 to 80,000 direct and indirect professionals.

III. Braving the future of nuclear as a young professional

As the conversation around the world grows as to how we can reduce the effects of climate change, more and more young people are starting to see the merits that nuclear power can play in this endeavor. With nuclear power of interest so many young professionals, such as Millennials and Generation Zs, they bring a new and refreshed perspective to the nuclear industry. Many of these young professionals are looking for a way that nuclear power can be made more accessible around the world to reduce carbon emissions, not just in big cities, but in remote and isolated communities. This is where the appeal for SMRs arises for the young generation.

The young generation is accustomed to the ideology and pace of technology development that Silicon Valley set for the world: new, profitable, quickly deployed, and environmentally-friendly. As many young professionals are becoming attracted to the nuclear industry, they bring this ideology with them and have the desire to make nuclear power as accessible as the latest iPhone. It is for this reason that the young generation has such a strong affinity to SMRs. SMR technology brings the promise of Generation IV technology, which "will use fuel more efficiently, reduce waste production, be economically competitive, and meet stringent standards of safety and proliferation resistance[8]."

Entering the nuclear sector in 2020 is an exciting opportunity for new graduates, as there are dozens of SMR companies in North America looking for young and enthusiastic talent. Now, more than ever, is the perfect time to hire this young talent and raise these newly graduated nuclear engineers to carry the next wave of Generation IV nuclear technology into the future. The success of SMR technology hinges on the ability to convince Millennials and Generation Zs that are not currently in the nuclear industry, that nuclear is the solution to the world's energy and climate crisis. A commonly quoted colloquialism in chemistry is "like dissolves like," which means: if we are to convince the Millennials and Generations Zs about nuclear, SMR companies need to hire more people that are Millennials and Generations Zs.

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Hydropower Status in India

Introduction

This article highlights the present status of Hydropower in India. An attempt is made to present some of the reasons for the gap between huge promise/potential of Hydropower in India and its actual status/ exploitation (which is much below the potential) are described. The challenges faced while setting up a Hydropower Project in India are enumerated. The article also brings some perspectives of the author from his experiences gained in Small Hydro/Micro Hydro Power sector.

Present Status

As on date, India ranks as the fifth largest producer of Hydropower in the world with an installed capacity of 50.07 GW (50,070 MW). This is as per the 2020 Hydropower Status Report released by International Hydro Power Association (IHA) recently.

It is highlighted in the report that India has overtaken Japan to occupy the fifth position in the list. It is reported that while only 154 MW of new Hydropower capacity was added in the year 2019, there was a 25% increase in annual generation from Hydropower in India.

By 2030, India is committed to have 40% of its installed capacity from non fossil fuel sources. India's renewable energy target is 175 GW by 2022 & 450 GW by 2030. As solar & wind power renewable energies are time dependent and not firm sources of power, Hydropower is extremely important for grid integration of renewable energy and to balance the infirmities in the grid. At the present estimate, Hydropower contributes around 13% of the energy produced in India. This percentage of Hydropower in the energy mix needs to substantially go up for India to successfully meet its renewable energy targets.

The Indian Government brought many policy boosts in the year 2019 to boost and revive the Hydropower Industry, which has been facing many challenges over the years.

Author

B.R. Muralidhar has nearly 38 years of experience in Hydraulic & Mechanical design of Hydro Turbines & Rotodynamic Pumps. He has handled nearly 70 Small / Large Hydro Projects with capacities ranging from 1 MW to 100 MW. Presently he gives consultancy through his consultancy firm, Amogha Flowtek Solutions, Bangalore, India.

Most important among these has been to classify all Hydropower Projects as Renewable Energy Projects. Earlier only Hydropower Projects of up to 25 MW were classified as Renewable Energy Projects. It is to be noted that all countries have classified Hydropower Projects as Renewables.

The inclusion of all Hydro Electric Projects (HEPs) as Renewables will give them access to subsidies and benefits available to the Renewable Energy Projects. These benefits include waiver of interstate transmission charges, must run status and accelerated depreciation benefits. All these are meant to promote investment in this sector. However, large Hydropower projects (i.e. greater than 25 MW capacity) will continue to require all required statutory clearances (forest & environment clearances, related Impact Assessment, etc.) to ensure that sustainability concerns are addressed.

In addition, Hydro Power Obligation (HPO) will be identified as a separate entity within Renewable Purchase Obligation (RPO). This aims at ensuring that the distribution utilities meet a certain portion of their total power requirement through Hydropower.

Tariff rationalisation steps have been taken for Hydropower Projects. These include increasing repayment period from 12 to 18 years and project life from 35 years to 40 years. An escalation of 2% in Hydropower tariffs has also been allowed, but is subject to approval of appropriate regulatory commissions. All these steps are intended to make Hydropower projects more viable by backlogging the debt repayments and lowering regulated tariff in the initial years.

Budgetary support for the flood mitigation component and infrastructure of HEPs (like roads, bridges etc) will be provided on a case-to-case basis. The above costs can then be excluded in determining tariffs, making it more attractive commercially. It will also encourage multipurpose use of Hydropower like flood control, irrigation, drought mitigation, etc. Each project will be scrutinised on a case to case basis by Public Investment Board or Cabinet Committee on Economic Affairs to decide on the amount of funding. The upper limit for the grants has been fixed at Rs 15 Million (~$0.1969 Million) per MW for projects up to 200 MW & Rs 10 Million (~$0.1313 Million) per MW for projects above 200 MW.

While all the above policy initiatives are certainly steps that will boost the development of Hydropower sector, and are most welcome steps, considerable challenges remain to be overcome for Indian Hydropower sector to fulfill its full potential. Some of them are mentioned below.

Compared to conventional fossil-based fuel projects & renewable energy projects, HEPs take from 5 to 13 years for completion whereas coal-based plants take about 4 to 5 years for completion. Renewable Energy projects can be set up even faster, sometimes in less than a year.

HEPs also involve much larger capital expenditure, with cost of setting up a HEP estimated to be around Rs 100 Million ($1.32 Million) per MW compared to Rs 70 to 75 Million ($0.93 to $0.99 Million) for a coal-based power project and Rs 60 to 65 Million ($0.79 Million to $0.86 Million) per MW for a solar power project.

The longer time taken for completion of HEPs & its higher capital costs lead to higher tariff of HEPs during the initial years. The composite tariff for NHPC's Chutak HEP (44 MW) was Rs 8.26 ($0.11) per KWH & that for Nimmo Bazgo (45 MW) HEP it was Rs 9.24 ($0.12) per KWH.

Added to this are the uncertainties & challenges related to land acquisition, environmental & forest clearances, issues related to rehabilitation & resettlement of locals. The state in which the HEP is located demand free supply of power from the HEP (12% of power generated is given as free power to state in which project is located & 1% is given as free power for Local Area Development). There is shortage of skilled EPC (Engineering/Procurement/Construction) Contractors for HEPs. Distribution Companies do not have long term power procurement bids for HEPs.

All the above factors make the HEPs more risky & many times financially unviable compared to other sources of power, and hence there is much less of private investment in HEP sector. The private sector share in HEPs is around 7% compared to 40% of private sector share in thermal power plants & around 95% in wind and solar power plants.

Hence, the policy initiatives that the latest policy on Hydro Power Sector by the Government of India to give a boost to

Hydro Power is very timely & very essential. It is hoped that these policy initiative will revive the Hydro Power Sector & enable it to contribute its rightful share to the India Energy Mix.

As of 29th February 2020, there are 38 Hydro projects of capacity above 25 MW which are under construction in India with a total capacity of 12973 MW. Out of these, 13 projects are under the Central Government with a total capacity of 8389 MW, 12 projects under different state sectors with a total capacity of 2712 MW, and 13 under the Private Sector with a total capacity of 1872 MW.

At the start of 2019, there were around 13 stalled HEPs with a cumulative capacity of 4,706 MW. Out of these, 8 projects were facing financial difficulties, two were having regulatory and legal issues, two were facing local opposition, and one project had dispute with the contractor as the reason for the delay.

As per the reply given in Rajya Sabha by the Honourable Minister of State for Power, Shri R.K. Singh on 17th March 2020 the Government of India has taken many steps to revive many of these stalled projects, some of them being in Arunachal Pradesh. Notable among them are Teesta – III (1200 MW), Subansri Lower (2000 MW) , Teesta – VI (500 MW) & Rangit (120 MW).

In addition, Pre-investment approval has been given for India's largest Hydropower Project, Dibang Multipurpose Project (2880 MW) of NHPC in Arunachal Pradesh.

Shining example of Hydropower Usefulness

Hydropower proved itself in India on 5th April 2020 by helping to maintain grid stability even after being subjected to huge drop in demand, in what some describe as the largest such experiment the world has seen. Honourable Prime Minister Shri Narendra Modi had called on all Indians to switch off their lights for 9 minutes from 9 p.m. on 5th April 2020 to express solidarity & oneness amidst the COVID-19 pandemic. India responded enthusiastically for this call. This resulted in a fall in demand of about 31 GW (31,089 MW) in the given time period of 9 minutes. After 9:09 p.m., the power requirement also went up by around 25 GW (25,000 MW) in a time period of 20 minutes. This fall in demand & subsequent increase in power demand was managed without any grid collapse mainly due to the flexibility & ability of Hydro Power Stations to shut down quickly and then come back to rated power generation quickly.

India's Power System Operation Corporation (POSOCO) had anticipated a much smaller reduction of 12 to 14 GW power reduction during the nine-minute period as compared to the 31 GW reduction that actually took place. It is reported that after PM Modi called for the show of unity by switching off lights on 5th April 2020, POSOCO had a conference call with all state load dispatch centres & major Hydro Power Stations in the country on 4th April and began mock exercises on hydro ramping almost immediately.

As the time for the lights off vigil approached, Hydropower generation was maximised. When people started switching off lights between 8:55 and 9:10 p.m., hydro power generation was reduced from 25,559 MW down to 8,016 MW to match the reduction in demand. As the demand increased after 9:10 p.m., with people switching the lights on, the hydro power generation was ramped up to meet the increasing power demand.

This can be vividly seen in the graph released by POSOCO which shows the power demand change on 5th April from 8:30 p.m. to 9:30 p.m., as compared to power demand change during the same period on 4th April, a normal day.

In its preliminary report, POSOCO thanked all hydro power operators as well as gas, thermal and wind power operators for their cooperation and support during this period. The report mentioned that all power system parameters were maintained within limits.

Mr Nichlas Troja, a Senior Hydropower Analyst at International Hydropower association said, "This experiment provides a good example of how Hydropower can provide flexibility and stability to the grid system under extreme circumstances. It again highlights the need for greater investment in flexible generation sources, particularly pumped hydro power storage."

Professor Arun Kumar of the Indian Institute of Technology Roorkee said, "The support provided by the flexibility of hydro power resources to meet the rapid drop and rise in the demand on 5th April 2020 triggered policy-makers to seriously think of installing Hydropower projects, along with pumped storage."

Status of Small Hydro Power Projects (SHP's) in India

As per Ministry of New & Renewable Energy (MNRE), Hydro Projects with a capacity up to 25 MW are classified as Small Hydro Projects (SHPs). As Small Hydro Projects have a lesser effect on ecology & topography of the region, they have lesser regulatory requirements compared to Large Hydro Projects.

MNRE is the designated agency for providing Central Financial Assistance (CFA) for SHPs.

As per MNRE, until December 2019 a total of 1125 SHPs have been set up in India aggregate capacity of 5647 MW and 111 SHPs of aggregate capacity of 554 MW are under various stages of construction. The estimated power generation from this existing 5647 MW of installed capacity is 14840 Million Units (MU) at 30% Plant Load Factor (PLF).

As per the Hydropower data base of July 2016, compiled by Alternate Hydro Energy Centre of IIT, Roorkee, there are 7133 potential SHP sites have been identified with an aggregate capacity of 21,133.65 MW. From this it can be inferred that actual installed SHP capacity is around 26.7 % of potential capacity.

Unlike Large Hydropower Projects, SHPs are primarily governed by the policies of individual State Governments. The Central Government supports SHP sector by giving support for carrying out Detailed Survey & Investigation, preparation of Detailed Project Reports (DPR), funding Renovation & Modernisation of SHPs in Government sector & in preparation of data base for prospective SHPs.

Most of the SHPs are 'Run of the River' and do not require storage. Hence, they do not encounter the rehabilitation & resettlement issues associated with large Hydro Projects. They in addition meet power requirements of remote and isolated places in a decentralised manner and provide local employment opportunity. SHPs unlike Solar & Wind Power are firm sources of Renewable Energy Power.

In spite of all the above advantages associated with SHPs & the support being provided by MNRE, SHPs in India at present are in dire straits. There are very few SHPs being installed by Private Power Producers. As far as the author of this article can remember, the number of SHPs bids floated in India in the last 10 years are less than ten.

There are many reasons for this slide in the interest of Independent Power Producers (IPPs) in installing SHPs.

One of the first issues that will keep the IPPS out of SHPs is regulatory issues. As the SHP policies are governed by the State Governments, there is a wide difference in the policies of each State. Even though MNRE has mandated the clearances to be taken for installing SHPs, many States have policies which are almost as rigid as those for Large Hydro Projects. Particularly difficult to get has been Irrigation Clearance in many States. Many States charge free power from SHPs & demand local area development allowance. This to an extent negates the subsidy given by MNRE for SHPs.

MNRE after meeting/getting feedback from all stakeholders has some out with a draft proposal to support SHPs which are comparatively larger in size and which can feed power to the grid. The draft proposal mentions that the period for the Small Hydropower Development (SHP Development) is from April 2017 to until end of Fifteenth Finance Commission i.e. March 2025. It proposes that the ongoing projects, which started earlier to April 2017 would be governed by earlier rules of Central Financial Assistance (CFA). The new rules for CFA would apply to all projects started between April 2017 and March 2025.

One of the main conclusions got from the feedback is that higher tariff of SHPs resulting in reluctance of Distribution Companies (DISCOMs) is a big challenge to the fast growth of MHP sector in India. Compared to Wind & Solar Renewable Energy Projects, the tariffs of SHPs are much higher.

CERC (Central Electricity Regulatory Commission) has proposed for Financial Year 2019 - 2020 a levelised tariff of Rs 6.23 ($0.83) per Unit for less than 5 MW Projects & Rs 5.21 ($0.069) per KWH for 5 to 25 MW SHPs for all states other than Himachal Pradesh, West Bengal & North Eastern States. For Himachal Pradesh, West Bengal & North Eastern States, the proposed corresponding tariffs are Rs 5.27 ($0.070) per KWH

& Rs 4.44 ($0.059) per KWH respectively.

The new draft proposal would keep the tariff of Small MHP from 3 MW to 10 MW at Rs 4 ($0.053) per Kilowatt Hour (KWH) or Rs 4 ($0.053) per Unit. If the Projects are unviable at this tariff, Viability Gap Funding (VGF) will be provided by MNRE.

It is proposed to make the State Government do all the Feasibility Studies, prepare DPR, and create a bundle of SHPs. MNRE would fund this exercise at Rs 10 Lakhs ($0.13 Lakhs) per Project subject to a maximum of 10 projects per year. It is proposed to make it compulsory for the State Government to allot these projects on a competitive bidding process.

It is hoped that the above proposals and its improvements, if any, are approved and become a policy at the earliest as there has been no policy from the last couple of years on Small Hydropower. It would help the sector get back to its feet after lying dormant for a long time.

Micro Hydro & Pico Hydro Power Status:

As per MNRE, Hydro Projects of capacity less than 100 kW are called Micro Hydro Projects and those of capacity less than or equal to 5 kW are called Pico Hydro Projects. The earlier policy encouraged the establishment of Micro Hydro and Pico Hydro Projects. This policy was for Micro Hydro Projects & Water Mills. The Himalayan region had a number of water mills installed about a century ago. These mills used the flowing water in the streams/canals in the Himalayan region to run mills which were used to grind wheat, flour, etc.

The scheme encouraged modernisation of these water mills and also encouraged generating off grid electric power from these water mills. Many other states, which are not in the Himalayan, also benefited from this scheme and established many Pico Hydro Plants which generated off grid, localised power, and fed it into individual houses, estates, farms.

One very successful example of the Pico Hydro Installation has been Chembu Village in Kodagu District of Karnataka State.

In this village almost every house has a Pico Hydro Turbine installation and generates locally the power required for that house. In some places in this village, there have been installations running from last 10 years without any trouble. The author of this article was privileged to be a part of this story as he was involved in designing and manufacturing of these Pico Hydro Generating Units. As on date, there are more than 1000 Pico Hydro Generating Units installed and working in Karnataka. The leader in this segment has been Uttarakhand State where many more installations are working. Kerala is another state which has a good number of Pico Hydro Generating Units providing localised, decentralised renewable power.

It is hoped that the new policy on Small Hydro Power / Micro Hydro Power continues to encourage these Micro / Pico Hydro Projects as there still many villages in the country which can use decentralised Pico Hydro Power very effectively. While it is true that almost all villages in the Country have solar power installations to get decentralised power, they are not very effective during monsoon season. Pico Hydro / Micro Hydro units are an excellent source of decentralised renewable energy in the monsoon season with the additional advantage of being firm power.

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Scenario Planning: A Study of Our Futures

Have you ever wondered how the World Economic Forum plans for complex global issues such as the AIDS-HIV pandemic? Or why BMW is experimenting with hydrogen vehicles? Or maybe even why Shell, a traditional oil & gas company, is buying up electric vehicle charging infrastructure? The answer lies with one process that each of these entities use to plan for a complex future: strategic foresight. In fact, more than half of Fortune 500 companies now use this process to not only survive, but thrive.

The time is right to explore the benefits of the strategic foresight process for the utility industry, which faces an uncertain future as energy markets evolve to address complex issues. Among these:

Excess Power on the Grid

Across the world, negative prices are being registered not just for electricity generated from solar and wind, but also from hydropower and gas. This is in part due to weather patterns, such as a rainy season in the U.S. Pacific Northwest, as well as policies offering federal investment and production tax credits. At times, these negative prices reflect a tough choice that a particular company had to make. At the Waha hub in the Permian Basin, for instance, next-day gas negative prices have followed drilling of record amounts of oil. The associated gas that comes out of the ground with the oil must be flared, burned, or sent through gas pipelines. Due to restrictions on flaring and burning, companies are having to pay others to take the excess gas via the pipelines in order for oil extraction to continue.[1]

Shifting Regulatory Priorities

Federal level subsidies are supporting the growth of new sectors and technologies. For instance, a recent U.S. Department of Energy

Author

*Zainub Dungarwalla works as an Energy Policy & Business Strategy Executive Advisor for Palo Verde Generating Station (Arizona Public Service). She thinks deeply about historic and emerging world trends to formulate plausible energy futures, which she uses to help teams navigate complex discussions and ultimately to cultivate a culture of informed innovation. She frequently posts on LinkedIn and can be contacted via email at **Zainub.Dungarwalla@gmail.com**.*

(DOE)-sponsored study authored by the Nuclear Alternative Project (NAP), a non-profit organization comprised of Puerto Rican engineers, examines the feasibility of using nuclear Small Modular Reactors (SMRs) in Puerto Rico. Currently, 98% of the island's electricity comes from imported fossil fuels, which require multiple shipments of fossil fuels per month. The study indicates that SMRs, which are 50-600 MW, could provide tremendous relief here, as they would only require refueling shipments once every two years or once every 10 to 15 years for 1-20 MW microreactors.[2] Further, the hope of NAP is that the Puerto Rico SMR project will access further subsidies, such as loan guarantees.

Research and development subsidies like the one mentioned above are highly valued across all major generating source types, but amounts can fluctuate every year as political support shifts. State level subsidies are similarly susceptible to change, but offer many potential pathways toward new futures.

Social Pressure for Cleaner Energy

Private investors are increasingly leaning on companies to produce stronger Environmental, Social, and Governance (ESG) commitments. At times, they are using technological advances to assist with their investment strategies. Consider that robo-investing programs can automatically grade companies based on a number of social responsibility criteria, inclusive of ESG commitments, to provide personalized investor advice. Some of these grading systems restrict investing in tobacco, weapons, fossil fuels – at times, even nuclear power. This is a signal that pressures for clean energy are coming not just from grassroots activism, but also from the financial community.

Demand for Customer Control

The grid continues to become more and more decentralized and new technologies are emerging, from customers selling home generated electricity back onto the grid ("prosumers"), to electric vehicle cars serving as battery backup for the grid ("vehicle-to-grid"). As many of these technologies converge, new ecosystems emerge. Imagine a customer with solar panels that can supply a large portion of the power needed for their house. In the hours where there is excess home generation, they can then sell back into the grid or potentially re-direct it to their side-business: selling electricity to their neighbors via a peer-to-peer payment system built into an easy to navigate phone app that allows for automated smart contracts.

Understanding Change

With so much uncertainty and disruption ahead, utilities need a plan capable of adapting not just to one forecast or prediction, but to a range of plausible scenarios. This is where strategic foresight is most useful.

Strategic foresight is a process designed to assist companies as they navigate futures that are both highly complex and highly uncertain (**Figure 1**).

In these situations, we understand that forecasts and predictions often fail because they assume one future based on what is known today. In order to plan for what may yet remain unknown, however, industries must do

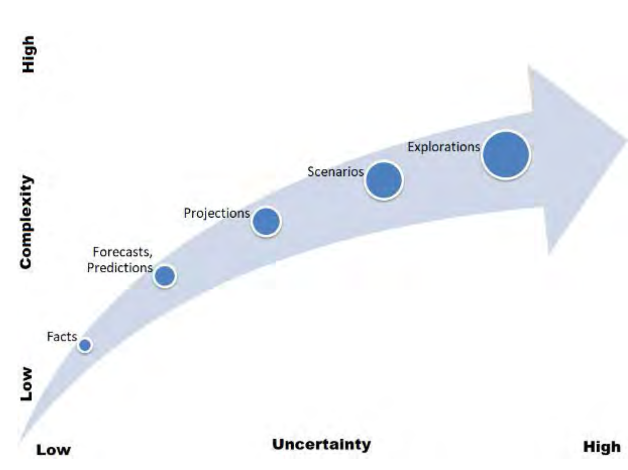

Figure 1: Distinguishing between different types of futures thinking. (Adapted from Seerp Wigboldus et al. by Zainub Dungarwalla.[3])

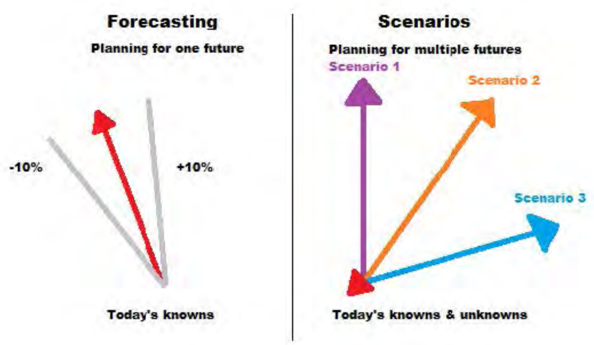

Figure 2: Forecast planning vs. scenario planning. (Adapted from Van der Heijden et al. by Zainub Dungarwalla.[4])

more; they must plan for multiple scenarios representing how the future may unfold. Scenarios portray multiple alternative future pathways facing an industry in order to boost preparedness around what is known and unknown today (**Figure 2**).

Forecast Planning: Shell

Figure 3 shows the years in which predictions were made about oil prices. In each year, we see that predictions (yellow diagonal lines) were not only incorrect, but displayed a clear positive bias, predicting the price of oil would be higher in the future to better position the company. These forecasts failed to predict the extent to which macro forces, from global politics to economics, could affect the company's future. In 1981, the Second Oil Crisis hit due to the Iranian Revolution, causing oil prices to fall. In 1984, global oil production increased in step with falling demand, driving prices further down.

Recognizing that traditional forecasts exist by virtue of the idea that the conditions of the future will largely reflect today's reality and that this simply isn't a reliable method-ology for making decisions more than five years out, Shell decided to try a different approach. More than 50 years ago, the company began to think differently about the future in order to help make better decisions today.

Shell eventually began developing alternative futures with longer-term outlooks in 1965. Through this exercise, they considered oil-price volatility as one of many important macro trends. When the Middle East oil embargo precipitated a global energy crisis, Shell was prepared to act while others were not. Today at Shell, and many other large companies, the ability to look at longer-term plausible futures has anchored their companies' success.

Forecast Planning: General Electric (GE)

In 2015, GE was the leading manufacturer of gas turbines. As world pressure continued to increase for clean solutions, GE subsequently shed almost 3/4th market cap-italization within a short two-year window as customers turned to other, non-fossil fuel-based products. Reflecting back, the Chief Executive Officer (CEO) noted that GE was late to respond to the pressures on the business.[6] Today,

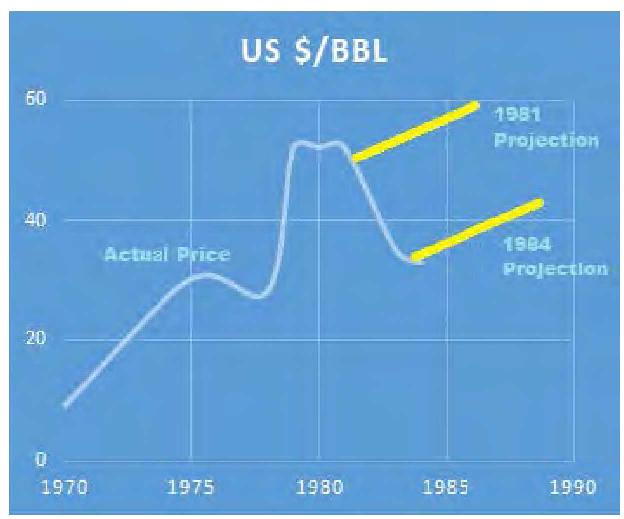

Figure 3: Shell oil price forecasts of $/Barrel of oil (BBL) vs. year. (Adapted from Mark Hinnells by Zainub Dungarwalla.[5])

GE is quick to adapt and provides tools to help customers prepare for a future of decarbonization, digitalization, and decentralization.

Forecast Planning: The Problem with Assumptions

Many companies operate off a set number of assumptions and facts that are used to create forecasts. Take, for instance, the gas pricing related to the Permian Basin. Until the current pandemic unfolded, day-ahead negative pricing was beginning to be registered. This was fueled by increased extraction for oil, which subsequently increased the amount of associated gas. Per the World Bank, we are experiencing the steepest oil drop on record, due in part to a significant drop in global transportation use. By the end of May 2020 oil prices were sitting at half their value, as compared to the end of 2019.[7]

Oil extraction might throttle down in response, reducing or eliminating negative gas prices.

Scenario Planning: Nuclear Industry

To avoid being surprised by outside forces, the nuclear industry must shift from assessing the future based on forecasts alone (probability) to a position of curiosity regarding what could happen in the future (plausibility).[8] Allowing for a consideration of what is possible will widen the view of the changing world, help teams go beyond straight-line future projections, and, most importantly, provide a way to acknowledge and design for complex disruption ahead.

Seemingly unrelated external trends can and will fold together to create the new future in which nuclear power operates. Scenario planning starts with acknowledging that we do not know for certain what this future will be, but we can imagine several plausible possibilities. Knowing these, we can then test current business practices in these future scenarios by asking the following sample questions:

- How will our current way of working change in the future?
- How will our existing strategies perform in a variety of different scenarios?
- Where are we vulnerable?
- What are the new opportunities?[9]

Ultimately, we may find that a specific plant modification being considered today only makes sense in one scenario (e.g. a future where a nuclear license is extended) but not in another (e.g. an energy market with increasing negative pricing). Other options may make sense no matter which scenario takes shape, such as cost effectiveness.

Reactive vs. Proactive Strategy

Strategic foresight can also reveal new opportunities that an industry can be proactive about pursuing. It is possible to transform a threat into an opportunity.

Currently the market signal for hydrogen is weak, but changing. During the 2017 World Economic Forum in Davos, Switzerland, multiple companies joined to form the Hydrogen Council. The aim for this partnership is to accelerate investment, development, and commercialization of hydrogen technology, sending a signal to the energy market that change is afoot.[10] Different states and countries are also beginning to announce hydrogen road maps to help with deep decarbonization efforts, and market intelligence companies are predicting a rapid uptick in hydrogen applications in the future – from long-term energy storage, hand sanitizer production, to powering airplanes, and more.

Could this represent a growing opportunity for carbon-free nuclear power to provide the electricity for hydrogen production via low temperature electrolysis (LTE)? Currently, less than 0.1% of hydrogen is produced through use of an electrolyzer, while the majority is produced using fossil fuel sources. In fact, 6% of global natural gas and 2% of coal usage is attributed to hydrogen generation alone.[11] The nuclear industry can join larger energy conversations and advocate for nuclear power along with renewables as the key to a future hydrogen economy. Currently, industry lingo provides room for definitions of blue and grey hydrogen, both of which originate from fossil fuels, as well as green hydrogen, which originates from renewables. There is no color designation for nuclear power, thus making it difficult to hope for inclusive policies and to inspire the next generation of innovators.

Consider also that the cement industry is seeking climate change action. Cement production accounts for 8% of carbon emissions globally. If the industry were a country, it would be the third largest emitter behind the U.S. and China. The predominant global process creates 50% of the emissions from the calcination step, a chemical process, 40% from heating the kiln by burning fossil fuels, and 10% from electricity for machinery and other processes.[12] The Global Cement and Concrete Association (GCCA) focuses on sustainable development and represents nearly half of global production capacity. They are inspiring and partnering with others to create new "green" cement solutions, which are based on the use of renewables exclusively.[13] Could parts of the kiln process be electrified? Could nuclear power supply the carbon-free electricity? Could the carbon emissions be further reduced by using nuclear power for attached carbon capture, utilization, and storage technology for the steps that can't be electrified? These questions could reveal new opportunities.

The United Nations projects the formation of 43 mega-cities around the world by 2030.[14] How will they access electricity – as well as water, education, and jobs, especially in low income countries? Will future cities use community owned solar and micro-nuclear reactors to power smaller neighborhoods? Or, will we as a society see the value in using large solar fields and nuclear reactors to provide multiple services including electricity for all, hydrogen-powered transportation, and desalination to provide much needed drinking water?

Design Thinking vs. Future's Thinking

Utility companies have frequently focused on how to solve today's problems, thinking about the intersection

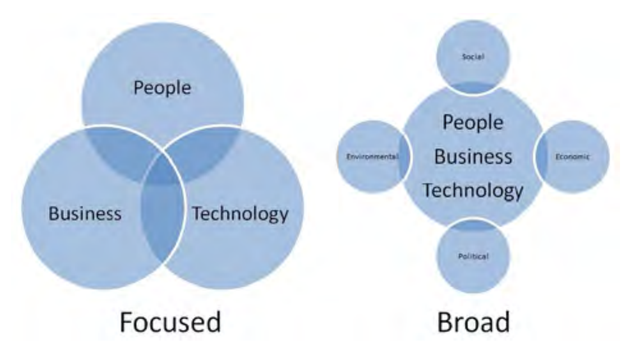

Figure 4: Design thinking vs. futures thinking. (Adapted from Anna Roumiantseva and Dave Weissburg by Zainub Dungarwalla.[15])

of people, business, and technology in the present and the near-term future. Futures thinking, however, requires a broader approach that also assesses social, economic, political, and environmental trends in the present and in the far-reaching future (**Figure 4**). This is a considerably harder task, but it comes with the reward of a robust strategic plan.

Iterative Process

Ultimately, scenario planning provides a structured process around which to have these strategic conversations, as well as to document them, track them, and take action. The structure of the scenario planning process involves multiple steps in continuous iteration. By using this process, it ensures that discussions lead to action and that organizations not only become more resilient to future external changes, but thrive both in the near- and long-term.

When a large number of options are laid out on the table, a company has to make the choice between what should be worked on in the current business planning cycle (typically 1-3 years), and what should be worked on at a later time. Since the world is dynamic and always changing, it is vitally important for an organization to actively monitor the external world for both changes in prominent trends (e.g. electrification), as well as new, weak, and emerging signals of upheaval. Such an early warning system could allow the nuclear industry time to safely react and steer the industry in the right direction to adapt.

Teams can feed known trends, as well as new, weak, and emerging ones, back into the business planning process, allowing for continuous reassessment to determine if the organization is working on the right strategies, at the right time. They can also try to determine, for example, if deferred strategies should be accelerated or if current actions should be paused. In effect, it creates a business planning environment that is flexible and continuously refreshed, as opposed to one that is set and not re-visited until the next business planning cycle, which may be years down the line.

Conclusion

The end goal of scenario planning is to embed formal mechanisms to encourage, create, support and sustain innovative ideas that not only keep a company viable, but make it thrive – even in the face of great uncertainty.

Through this approach, companies can develop processes that foster collaboration where politics, economics, technology, society, and the environment intersect, ultimately transcending traditional bottlenecks and barriers to progress.

The nuclear industry must build a robust industry now, so it can be resilient to external forces in the future. To do this, they must put the future on today's agenda, with a full understanding that operational effectiveness alone is not enough to survive. Can nuclear power learn and collaborate with experts in surgical robots, solar roads, Silicon Valley high-tech, venture capital for companies such as Lyft, and big thinker space explores to find more solutions? Absolutely.

Strategic foresight tools, which create a deliberate and methodological process, can help drive this effort, cultivating a culture of innovation and transformation while maintaining a sharp focus on complex safety and regulatory requirements.

With this in mind, one question remains: will the future shape the nuclear industry, or will the nuclear industry shape the future?

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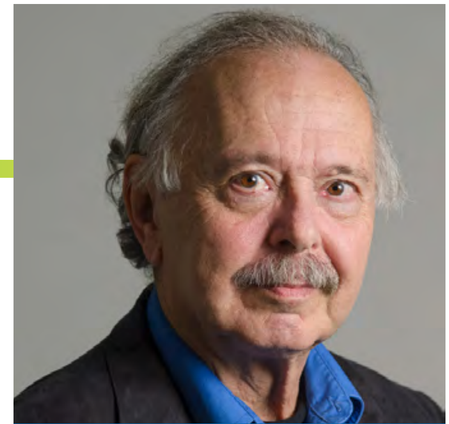

Strong Isolation of Nuclear Waste[1]

In many parts of the world, if you dig 1 to 2 km deep, you'll reach a geologic formation that is remarkably well-isolated from the surface. Such a formation may offer an ideal location for the disposal of high-level nuclear waste and other hazardous materials. This rock is so deep that a traditional mined repository is unattractive; for example, the temperature is typically 50° to 65°C at these depths. Yet those deep formations can be easily reached with a vertical access bore hole followed by horizontal storage sections, as shown in **Figure 1** (following page).

Could the waste escape from this deep burial? The most worrisome escape mechanism is dissolution of radioisotopes in brine that flows slowly through cracks and pores in the rock. Once dissolved, the radioisotopes can move by diffusion and advection, maybe even through a new or undetected earthquake fault. In deep rocks, brines typically fill a few percent of the rock by volume. Although the brines are in cracks and in pores, we know they communicate with each other since the pressure found in these brines tends to be the hydrostatic pressure, that is, approximately one atmosphere for every 10 meters of depth. Within the rock itself, the lithostatic pressure is typically two to three times greater.

Geologists in the oil and gas industry will tell you that these brines are "stagnant", but that means only that any movement is small on a decade time scale. The time scales for human safety in nuclear are longer. Regulations require that buried nuclear waste be isolated for tens of thousands of years, and in some cases, for a million years. The tiny flow velocity of 1 cm per year, undetectable by standard methods, could transport waste 1 km in 100,000 years.

Traditional safety analyses for deep geology use measurements of the permeability of the rock and estimates of the driving forces, including temperature, pressure and salinity gradients. These are put into complex computer models to calculate

Author

Richard A. Muller, CTO, Deep Isolation Inc., Co-Founder, Berkeley Earth, Professor of Physics, UC Berkeley, emeritus

diffusion and transport times. The models need to include the possibility of old undiscovered earthquake faults and future new ones.

Such faults could create disturbed zones along the fissures that have relatively high permeability paths to the surface.

Theory and models are essential, but nothing beats an actual measurement. Is there any hope of observing super-small brine flow rates? In fact, relevant methods have been developed over the past few years that can provide excellent estimates for water stagnation. Using such methods, geologists have shown that there are numerous sites around the world that have had little movement for deep brines over the past million years or more, and some show ages of tens to hundreds of millions of years.

Strong Isolation

We use the term "strong isolation" to characterize a formation that has held its entrained water stagnant for 100,000 years or longer. Determination of strong isolation from measurements of brine and rock isotopes is not necessarily a requirement for a waste repository, but if it is present, it offers a compelling argument that the waste will not be transported to the surface by brine flow, even for a geologic time scale.

Upward flow of deep brines is dominantly driven by advection, which in turn is driven by temperature gradients, deep pressurized saline aquifers, topography and stress changes. Convection can occur when the deeper water, due to heating from below, becomes less dense than the water above it. It rises, like a balloon, until contact with the upper rock cools it sufficiently. Then it flows around and downward, eventually to be reheated and rise again. A large convective cell is created, similar to that seen in the formation of thunderheads in the atmosphere. This relatively rapid flow could, in principle, carry dissolved radioactive waste up to aquifers and the biosphere.

A comparison to the lower atmosphere might be useful. The upper atmosphere of the Earth has a "temperature inversion"—it gets warmer with altitude—so it does not normally have convective cells. This region becomes stagnant and stratified, giving rise to the aptly named *stratosphere*. Inversions near the surface make air stagnant and that allows the accumulation of smog and other pollutants. Similar stratification can take place in deep brines. A sufficient condition for strong isolation is that the density increase due to salinity be greater than the density decrease due to temperature.

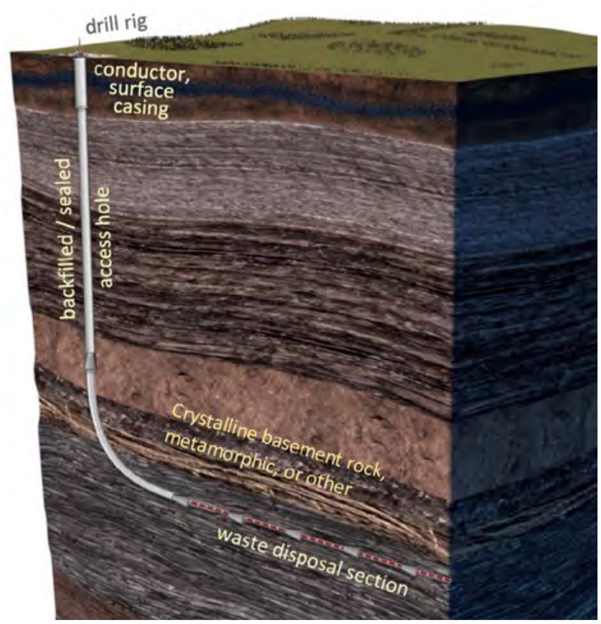

Figure 1: Waste isolation in a deep horizontal borehole, as proposed by Deep Isolation Inc. We prefer to have the horizontal storage or disposal section in a formation for which radioisotope measurements indicate strongly isolated brine. Not to scale; the diameter of the horizontal drill hole is about ½ meter, and the depth is 1,500 meters. The curved section is so gradual that steel casing easily moves around it during installation, and the canisters experience no bending force as they are lowered through the curved region.

Source: Deep Isolation Inc.

Measurement

Methods have been developed over recent decades that allow us to measure not only the stagnation of underground waters, but whether it has been stagnant for hundreds of thousands to millions of years. One of the best indicators is chlorine-36, a radioisotope with a 300,000-year half-life. Cl-36 is produced underground from natural uranium and thorium in the rock formation. The physics is a bit complex but interesting. Both uranium and thorium are present at levels that are typically measured in parts per million, but that is enough. Because of their long half-lives (4.5 billion and 14 billion years for U-238 and Th-232, respectively) and despite their continuing decay, the levels of uranium are constant for the time periods of interest to us (100,000 to several million years). Both atoms decay by emitting alpha particles (identical to the nuclei of helium atoms) and many of these alpha particles collide with nuclei in the rock (particularly sodium, magnesium and aluminum) and knock out neutrons. Some of these neutrons are absorbed on ordinary non-radioactive chlorine, Cl-35, to produce Cl-36. This happens at a constant rate, so the Cl-36 concentration increases with time. But when the Cl-36 has been around for hundreds of thousands of years, then there are significant losses from its own radioactive decay.

If none of the Cl-36 is transported out of the formation, then eventually its rate of decay matches its rate of production. That condition has been given the (unfortunately obscure) name"secular equilibrium." For any given rock, from the concentrations and distributions of the key elements, we can calculate what the secular equilibrium level of Cl-36 should be. If the measured level of Cl-36 matches secular equilibrium, then we know that the Cl-36 has not been mixed with surface water (or any water with low uranium and thorium) for many half-lives, typically five or more, that is, for at least 1.5 million years. Imagine, for example, a disposal region in a crystalline basement rock, overlaid by a formation of sandstone or other sedimentary rock with low Cl-36/Cl-35. Secular equilibrium in the basement rock would show isolation from this overlying layer.

What happens if the brine is moving? Then the Cl-36 won't reach its secular equilibrium concentration. The required differential equations are easily solved, but here is a simple rule: If we find the level of Cl-36 is at half of the secular equilibrium level, then the water has been stagnant for about one half-life, that is, about 0.3 million years. If it is ¾ of the secular equilibrium level, then it has been stagnant for two half-lives, 0.6 million years.

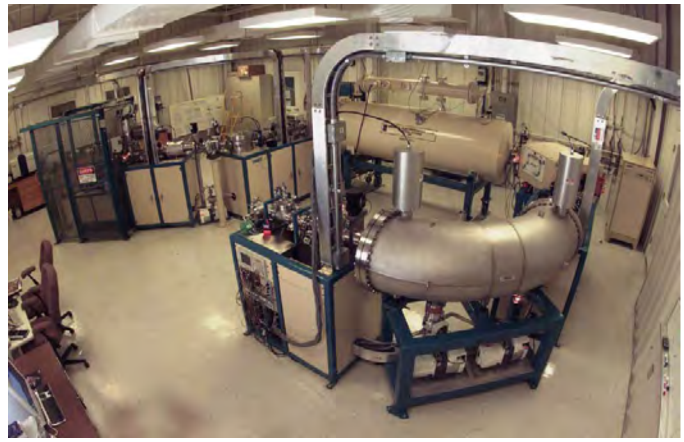

Figure 2. The Accelerator Mass Spectrometer at the Lawrence Livermore National Laboratory, an instrument that we might use to measure Cl-36 from deep boreholes.

Source: Wikipedia.org (https://en.wikipedia.org/wiki/Accelerator_mass_spectrometry)

According to Wikipedia, "This image is a work of a United States Department of Energy (or predecessor organization) employee, taken or made as part of that person's official duties. As a work of the U.S. federal government, the image is in the public domain.

The most sensitive and precise method for measuring the Cl-36/Cl-35 ratio is accelerator mass spectrometry. **Figure 2** shows a tandem system at the Lawrence Livermore National Laboratory that routinely makes the kind of measurements we require.

There are other ways to measure the age of the water that derive from the presence of uranium and thorium.

Here are a few:

He-4. Most of the alpha particles from uranium and thorium avoid absorption and come to rest in the rock. Because they have a strong positive charge, they steal the weakly bound outer electrons from other elements and become helium atoms. This helium can escape as a gas or be carried away by brine flow; if it remains, it accumulates. Its accumulation gives a measure for the isolation of the formation. Measurements of helium in Germany have given isolation ages greater than100 million years.

Ne-21. This stable but rare isotope of neon is produced in the rock by alpha particles hitting nuclei of oxygen and fluorine. Since it doesn't decay, its build-up above the natural levels (0.27%) can indicate very long ages. In Canada it has shown that brine in a basin is more than a billion years old.

I-129. This radioactive isotope of iodine has a half-life of 16 million years and is produced by spontaneous fission of U-238. From the known rate of such fission, we can use the abundance of I-129 to estimate stagnation age. Similar to Cl-36, the production of I-129 in the deep subsurface reaches a balance between production and decay, and its concentration eventually reaches secular equilibrium. Because it has a much longer half-life than Cl-36, I-129 can provide information on the stagnation of brines for tens to hundreds of millions of years.

There are many other isotope methods that can be used to determine groundwater flow over a long period. For short periods of time, C-14 (5,730-year half-life) can be useful. Kr-81 (229,000- year half-life) is produced in the atmosphere, and its measurement at depth can indicate that surface water is moving downward. The levels of the other isotopes, including those of argon and xenon, can provide additional information relevant to the long-term isolation of the brines.

A frequently cited concern is the possible presence of unknown earthquake faults. Strong isolation offers an indication that their effect is not important. If such faults have not caused the groundwater to mix in a million years, then it is unlikely that similar faults will cause transport in the future. If the water has reached or is close to secular equilibrium, then no mechanism has transported the water away in 1.5 million years or more, not just earthquake faults but changes in climate that could change water pressure distributions and even trigger glacial scouring of the surface. (The last ice age ended only 20,000 years ago.)

Some might object that Cl-36 only measures the isolation of Cl-36, not of the water that carries it. That is correct. If the chlorine interacts with the local rocks, its migration can be slowed. In fact, such interactions are thought to be small. But more importantly, it is the migration of Cl-36 that is more relevant for nuclear waste disposal than is the rate of water flow. Cl-36 and I-129 have sufficient concentration in the waste and long enough half-lives that they present a potential radiation threat to generations even a million years or more in the future. Water may be the transport vehicle, but it is the chlorine itself whose upward movement through the rock poses the threat to human safety.

Strong Support

Although this article is about "strong isolation," it is important to recognize that this criterion is only one of several in site evaluation. Just as important is strong support from the community, the regulators, and other stakeholders. Engagement with these constituents must begin early. Informed consent is a minimal criterion; it is better for the community to be strongly supportive. Such support should not be expected to develop rapidly; slow, and sure, is preferred.

Consider this hypothetical example. Assume that there is waste at an existing nuclear power plant and that the community is seeking options to dispose of this waste. To begin, we initiate a conversation with local community stakeholders to understand what their values, interests, and visions are for their future. What is their perspective on the existence of this waste? What are their feelings about transporting the waste to a disposal site elsewhere? Would they rather keep the waste in interim storage above ground or would they prefer a more permanent disposal solution onsite or nearby?

If the community looks on horizontal borehole disposal favorably, then we study nearby drill hole logs (these are, by law, publicly available in all U.S. states). We might create a seismic profile of the site to see if the underground structure is similar to that at the closest drill holes. If it is similar, then we drill a pilot hole, perhaps 6 inches in diameter and 2 km deep. In this hole we measure profile of temperature and salinity. If the brine density increases sufficiently rapidly to suggest stability, we analyze the brine samples for the isotopes that can indicate strong isolation. If we find secular equilibrium, and overlying formation with different levels of the isotopes, we have evidence for strong isolation. We would then run computer simulations to confirm our understanding.

If the samples do *not* show strong isolation, then there are several options for the community. These include:

- Do nothing. Keep the waste in surface storage until a better solution is found.
- Drill deeper, in hopes of finding a strong isolation formation.
- Select a different location.
- Examine the results to determine if the failure of strong isolation is due to local mixing with a nearby formation but still strongly isolated from the surface, and thus possibly still suitable for waste disposal.

Our company, Deep Isolation, believes that the early and continued involvement of the community leads to a better-informed public and a better decision. Deep Isolation is committed to working only at locations where there is belief in the solution. *Strong isolation* is important, but no more important than *strong support*.

Final Thoughts

An important aspect of the strong isolation criterion is that good sites can be evaluated independently of computer modeling of fluid flow and radionuclide transport. We are not arguing that such a model isn't needed, only that a physical measurement showing strong isolation can be a good independent confirmation of safety.

Based on the strong isolation criterion, we expect that there are many safe sites around the country and around the world. Should we pick the best of these sites and bring all the waste there? Not necessarily. "Best" involves more than geology; it should include community support and transportation concerns and much more. We might choose to have many sites, perhaps located close to the nuclear reactor locations where the waste is currently stored.

Deep horizontal boreholes are excellent for waste *disposal*, but they can also be beneficial for temporary *storage* of waste. Deep boreholes can be an alternative to surface water pools and dry casks where waste is currently stored. Future retrieval from a storage borehole is not difficult; the drilling industry recovers objects from holes with ease. At Deep Isolation in early 2019, we demonstrated the recovery of a prototype canister that had been unlatched and left at depth. From an economic perspective, if the waste is to be stored for longer than 15 years, we estimate the borehole storage option to be less expensive than surface storage, due to reduced security costs. After 20 to 40 years, it has the potential to be less than half the cost of surface storage.

Even though the science behind it is subtle, the basic concept of strong isolation is relatively simple to understand. We've found that it has an appeal to the public who are often distrustful of complex computer models and the assumptions they require. Just as radiocarbon dating has been successfully used to measure the ages of old bones, radio-chlorine and other methods can be used to measure the age of deep brines. If the brines have been stagnant over a hundred thousand years or more, then they are unlikely to carry any waste to the surface for the next few hundred thousand years. Strong isolation may be the most direct indicator of the physical safety of disposed nuclear waste.

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1. An earlier version of this article appeared in Nuclear Engineering International.

ASQ

The Challenge of Siting a High-Level Waste Repository

In early February 2020, President Trump announced that he would pull support for the Yucca Mountain high level waste (HLW) repository in Nevada, thereby reversing his Administration's approach to revitalizing and seeking appropriations for the continuation of the project which had been terminated during the Obama Administration. *"Nevada, I hear you on Yucca Mountain and my Administration will respect you!"* he posted on Twitter and he committed to exploring new approaches for addressing the challenge of HLW disposal. While the nature of those next steps is not immediately clear, it is worth reflecting on how we got to where we find ourselves today, the experience of others in approaching HLW disposal, and developments that may influence the path forward.

The policies and responsibilities for HLW disposal stem largely from the legislation embodied in the Nuclear Waste Policy Act of 1982 (NWPA), Public Law No. 97-425, as codified in Title 42 of the United States Code, §10101 *et seq*. Discussion and debate over approaches to waste disposal had stretched back to the late 1950s, but the NWPA is the legislation that outlined national policy and the framework for addressing waste disposal and, significantly, it sets many of the general parameters within which we must deal with HLW today. The NWPA was intended to *"establish the Federal responsibility, and a definite Federal policy, for the disposal of such waste and spent fuel."* NWPA §111(b)(2). As noted in the opening statement of purpose for the act, Congress intended to *"establish a schedule for the siting, construction, and operation of repositories that will provide reasonable assurance that the public and the environment will be adequately protected from the hazards posed by high-level waste and such spent nuclear fuel as may disposed of in a repository."* NWPA §111(b)(1).

Author

Stephen G. Burns served as a Commissioner on the US Nuclear Regulatory Commission from November 2014 through April 2019 and was designated Chairman by President Obama from January 2015 until January 2017. Prior to his service as Commissioner, he was the Head of Legal Affairs at the OECD Nuclear Energy Agency from April 2012 through October 2014. He had previously served at the NRC from 1978-2012 in a number of positions, including General Counsel.

The major aspects of the NWPA address (a) responsibilities of the Federal government for HLW disposal; (b) a funding mechanism for the development and operation of a repository; (c) a process for identifying potential sites for a repository; and (d) a licensing framework for the proposed repository. Essentially, the NWPA assigns the Federal government responsibility for permanent disposal of HLW, but those who generate HLW or spent fuel are obligated to enter into a contract with the Department of Energy (DOE) for the disposal of such waste. DOE promulgated regulations in 10 CFR Part 961 that reflect the *"Standard Contract for Disposal of Spent Nuclear Fuel and/or High Level Radioactive Waste."* Moreover, the NWPA established the funding mechanism by which operators of commercial nuclear power plants would pay the government a fee per kilowatt-hour of generated electricity from the plants that would be used to support the development, licensing and construction of a repository by DOE.

Apart from DOE's responsibilities for ultimate construction and operation of the repository, both the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) were assigned important roles with respect to an HLW repository. EPA was to promulgate public health standards to limit radiation exposures by persons in the vicinity of the repository who would be most likely exposed to potential releases of radioactive material via all environmental pathways, such as air, soil and groundwater. The NRC was assigned the role of licensing authority and regulator over a proposed repository. As a general matter, the NRC does not have regulatory authority over facilities under DOE's domain unless – as with the NWPA – it is specifically granted such authority.

The NWPA provided for a fairly swift site evaluation process that involved the Secretary of Energy's issuance of general guidelines after consultation with relevant Federal agencies and "interested Governors" of states for the recommendation of potential repository sites. By 1986, the Secretary had identified as required by law five sites, all in the south and west as possible locations for the first repository and suitable for further characterization, and the Secretary then recommended to the President three of those sites as candidates for further characterization. Those three sites were Yucca Mountain in Nevada, Deaf Smith County, Texas, and Hanford, Washington, geologically characterized respectively as volcanic tuff, salt, and basalt. Perhaps not unexpectedly, no state jumped at the opportunity to remain on the list of selected sites.

Although DOE had carried through on the process specified in the NWPA to identify feasible sites for location of a repository, Congress stopped the process of evaluating multiple sites and instead directed DOE to consider solely Yucca Mountain as the candidate site under the Nuclear Waste Policy Amendments Act of 1987 (NWPAA), Public Law No. 100-203, Title V – colorfully labeled by Senator Harry Reid as the "Screw Nevada Act." The NWPAA halted the process for identification of second repository site and research on granite sites (i.e. in the northeast) absent specific appropriations. The NWPAA also essentially suspended efforts under the NWPA for possible establishment of a monitored retrievable storage (MRS) site, given the bar in the legislation on construction of an MRS facility until the NRC had authorized construction of the first disposal repository. Although the NWPAA established an Office of the Nuclear Waste Negotiator, headed by a Presidential appointee, with the task of seeking a willing tribal authority or state to host a repository or MRS at a qualified site, the office was terminated by the mid-1990s without having achieved the goal. A Nuclear Waste Technical Advisory Board (NWTAB) was also established as a panel of experts to evaluate and report on DOE activities under the NWPA, such as siting and HLW packaging and transport. The NWTAB is authorized to continue its activities until the year after a repository begins to accept HLW.

Despite the perceived intention of the NWPAA to move progress along toward establishing a repository site, forward movement was slow in the 1990s. Additional legislation included in the Energy Policy Act of 1992, Public Law No. 102-486 *(see section 801)*, contained new direction to the EPA with respect to promulgation of standards for protection against potential hazards resulting from the storage or disposal of radioactive materials at Yucca Mountain. The legislation clarified the relationship of EPA's responsibilities for Yucca Mountain with respect to other statutes such as the Safe Drinking Water Act and required EPA to engage the National Academy of Sciences to prepare an expert report to be considered by EPA in its standards' development.

Significantly, the 1998 date prescribed in the original NWPA for DOE's obligation to take title of spent fuel and waste for disposal passed without a repository being available. Litigation ensued and ultimately resulted in DOE being held responsible for breach of the standard contract for waste disposal and the resulting damages that utilities could show for costs incurred as a result of DOE's delay in taking their spent fuel.

Not until 14 February 2002, did the Secretary of Energy recommend to the President, as provided in section 114(a) of the NWPA, that the Yucca Mountain site be approved for development of a repository. President Bush approved the recommendation the next day. Using the process provided under the NWPA, the Governor of Nevada lodged a notice of disapproval of the site selection in April 2002, but the Congress rejected the disapproval and overrode it in a joint resolution passed in July 2002. Notwithstanding the opening provided by congressional action to proceed with the Yucca Mountain licensing (and the perhaps unrealistic expectation in the NWPA providing for the filing of the application 90 days after congressional approval), it was not until June 2008, well into the last year of the Bush Administration, that DOE filed its application with the NRC for the construction authorization for the Yucca Mountain repository.

The NRC accepted the application for review in October 2008. The filing of the application triggered not only the NRC's technical review process, but also NRC's formal hearing process. Nearly 300 "contentions" – i.e. contested issues – were admitted for resolution through the adjudicatory process, of which 220 had been proffered by the state of Nevada. Under the NWPA, DOE's application for the construction authorization triggered a three-year period within which NRC was to complete its review, with the possibility of one year's extension under circumstances provided in the statute. Such a provision was unique in legislation governing the NRC's conduct and resolution of licensing matters.

Although the NRC staff continued with its technical review of the Yucca Mountain application, the change in administration in 2009, signaled at best uncertainty ahead for the proposed repository. President Obama, who was supported by Senator Reid, had expressed his opposition to the Yucca Mountain site during the presidential campaign, and his Secretary of Energy Steven Chu testified before the Senate in March 2009 that *"both the President and I have made clear that Yucca Mountain is not a workable option."*

It was not until a year later, in March 2010, that DOE formally moved the NRC's Atomic Safety and Licensing Board (ASLB) to withdraw the Yucca Mountain application, which the ASLB denied in June 2010. The decision was appealed to the full Commission, but no decision was immediately forthcoming given the even split among the four commissioners who were eligible to vote on Yucca Mountain matters. The fifth commissioner had recused himself from participating in any matters related to the Yucca Mountain project due to his earlier consulting work for DOE related to the Yucca Mountain application. The President's budget for fiscal year 2011 included no further funding for the Yucca Mountain project and led to NRC Chairman Jaczko later in 2010 to direct the NRC staff to suspend further review of the application. Due in part to the recusal of the one commissioner, Chairman Jaczko's direction was not overturned by a majority of the remaining commissioners. Although no new appropriations could be expected, the NRC did have upwards of $13 million in "carryover" funds available from prior appropriations.

Finally, in September 2011, the Commission issued a brief order reflecting that it was split 2-2 on whether to take action either to overturn or to uphold the ASLB's earlier order denying DOE's motion to withdraw. The Commission did direct, however, the ASLB to take steps to resolve open matters before it and to document the history of the proceeding before the end of the fiscal year. As presaged in an earlier challenge in federal court to DOE's withdrawal motion which was dismissed as premature, those who opposed DOE's withdrawal of the application and the NRC's failure to continue the licensing review filed a *writ of mandamus* in the federal court of appeals for the District of Columbia circuit seeking to compel NRC to resume the review. Before issuing its final ruling, the court had stayed its hand to allow either the NRC to act or the Congress to affirmatively halt further review or prevent expenditure of previously appropriated funds. But ultimately, the court issued the mandamus in October 2013 to compel the NRC to continue its review in its decision in *In re Aiken County*, 725 F.3d 255 (D.C. Cir. 2013).

In light of the court's ruling, the Commission shortly thereafter ordered the staff to resume its review. In January 2015, the staff completed its safety evaluation report on the construction authorization application, and in May 2016, the staff issued a supplement to the environmental impact statement related to groundwater. These actions completed the staff review. The adjudicatory proceeding remains suspended, but NRC has largely expended the remaining appropriated funds available for the Yucca Mountain review.

The foregoing story depicts the difficulty, delay, and discord in progressing toward a high level waste repository. Before reflecting on the possible next steps within the United States, it's worth taking a snapshot of the progress – or lack thereof – in other countries. Internationally, deep geological disposal reflects the general policy preference for disposal of long-lived intermediate level waste and HLW (including spent fuel). However, other than the Waste Isolation Pilot Plant in New Mexico, there are currently no other deep geological repositories licensed for operation worldwide.

Some countries like Finland and Sweden have made substantial progress toward siting a repository, while others are only at an incipient stage, and still others like Germany have re-set their approach. A recent report by the OECD Nuclear Energy Agency, *Management and Disposal of High-Level Radioactive Waste: Global Progress and Solutions* (2020), gives a timeline for countries considered to be further along in the process of siting a repository. Of the nine countries listed (Finland, France, Sweden, the United States, China, Canada, Germany, Switzerland and Japan), all initiated feasibility and site investigation studies nearly 30 or more years ago.

Construction of the repository at the Olkiluoto site in Finland was authorized by the Finnish regulatory authority in 2016, and an operating application is expected in 2021. In Sweden, the proposed repository at the Forsmark site has gone through the review process before the Swedish nuclear regulator and the environmental review court and awaits final consultation and approval by the municipality and the government. France has carried out its geological disposal project Cigéo focused on the site in the Meuse/Haute-Marne. Significant public debate was held in 2013 and led ANDRA, the project operator, to submit additional safety reports in 2016. An application for construction authorization is expected in 2021. For Canada and Switzerland, we may not see an application filed for a site until well into this decade, and the timing in China, Germany and Japan is uncertain. Both Germany and Japan re-set to some degree their processes. Although the Gorleben site in Germany had been identified as the potential disposal site in 1977, parliamentary action in 2013 established a new process for site selection. Similarly in Japan, some revisions to the process for identifying a repository site were adopted by the cabinet in 2015. China is expected to begin construction of an underground rock laboratory for scientific research at the Xinchang site in Beishan in the next year and is aiming for the establishment of a repository by 2050.

Among the lessons from the international experience are the importance of strong scientific support for decision-making, clarity of organizational responsibilities, and building stakeholder confidence and support. These are lessons, too, from the American experience that led to the stalemate over Yucca Mountain. Are there any signs of a path forward – or how to blaze one?

In early 2010, Secretary Chu, at the direction of President Obama, established the Blue Ribbon Commission (BRC) on America's Nuclear Future. Co-chaired by Brent Scowcroft and former Congressman Lee Hamilton, the BRC was a bi-partisan group of scientists, academics, industry leaders, former government and elected officials. The BRC's members included future Secretary of Energy Ernest Moniz and future NRC Chair Allison Macfarlane. In its final report, the BRC made eight recommendations, the following of which are most important in thinking of the next steps toward addressing the HLW disposal conundrum:

1. A new, consent-based approach to siting future nuclear waste management facilities;

2. A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed;

3. Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management;

4. Prompt efforts to develop one or more geologic disposal facilities; and

5. Prompt efforts to develop one or more consolidated storage facilities.

The emphasis on the consent-based process and designation of a dedicated organization for management of waste disposal are lessons that are certainly reflective of international experience.

A number of bills have been introduced in Congress since the BRC report was issued which would implement some of these recommendations. For example, following their earlier initiative, Senators Murkowski, Alexander and Feinstein introduced a bill (S. 1234) in April 2019, which would, among other things, create an independent agency to take responsibility from DOE for management of the nuclear waste program, establish a consent-based process for siting consolidated storage facilities and a repository, site a consolidate storage facility without volume restrictions on storage, make available the waste fees charged to utilities available to the new waste agency without further appropriation, and authorize DOE to re-assess the policy on co-mingling defense waste with commercial spent fuel.

Unfortunately, little progress has been made to date. Resistance to such legislation has stemmed in part from those who still advocated the pursuit of Yucca Mountain as an HLW repository; such legislation was in effect the "wolf in sheep's clothing" to those who remained committed to Yucca Mountain. And although the current administration changed course and did not include funding for Yucca Mountain in the FY 2021 budget proposal, there has been some confusion over what its policy stance in fact is and how it intends to move forward.

So where does this all leave us? Apart from the political wrangling over policy, we have seen growing interest in the consolidated storage option, as evidenced by applications for such facilities submitted by private companies to NRC at sites in Texas (where a low-level waste facility is already operational) and New Mexico. NRC has the authority to license such facilities under existing law and, in fact, authorized the Private Fuel Storage facility in Utah in 2006, but the project did not proceed. NRC has the more recent applications under review; the Texas site has met with less resistance, particularly from state officials, than the one in New Mexico. Although some legislative changes may be necessary to effectively allow DOE contracting with the private operators of such facilities under DOE's "take title" authority, DOE has signaled its openness to such an arrangement. This would clearly provide greater impetus to consolidation of spent fuel now stored at reactor sites, including a number that have otherwise been decommissioned.

Other developments may also influence the approach to waste disposal in coming years. For example, re-purposing spent – or "used" – fuel for fuels to be used in advanced, Generation IV reactors may reduce waste volume. Others argue that the United States should move toward reprocessing, though the economics are not encouraging. Deep borehole technology is also being explored for waste disposal, though it seems not as likely as a means of disposal for commercial reactor fuel and faces the same institutional challenges as deep geological repositories in siting and acceptance. Ultimately, a repository will be needed, and we need to re-focus ourselves in meeting that objective.

In my view, the BRC report still provides a good roadmap for moving forward, even though there may be only incremental progress in the coming years, and legislation like that proposed in S. 1234 would help move us along. Consolidated storage can move us toward future solutions. A better focus on consent-based siting with meaningful involvement of stakeholders and broad community support is key. The establishment of an independent organization responsible for waste storage and disposal with access to the funding that has been established for such purposes is an important organizational improvement. Ensuring the competence and trust in the NRC as a regulator must be emphasized. And we must acknowledge that there is still a long journey ahead and that we will be realistically engaged in a deliberate, step-wise approach reflective, as the French have characterized it, of a "continual learning process."

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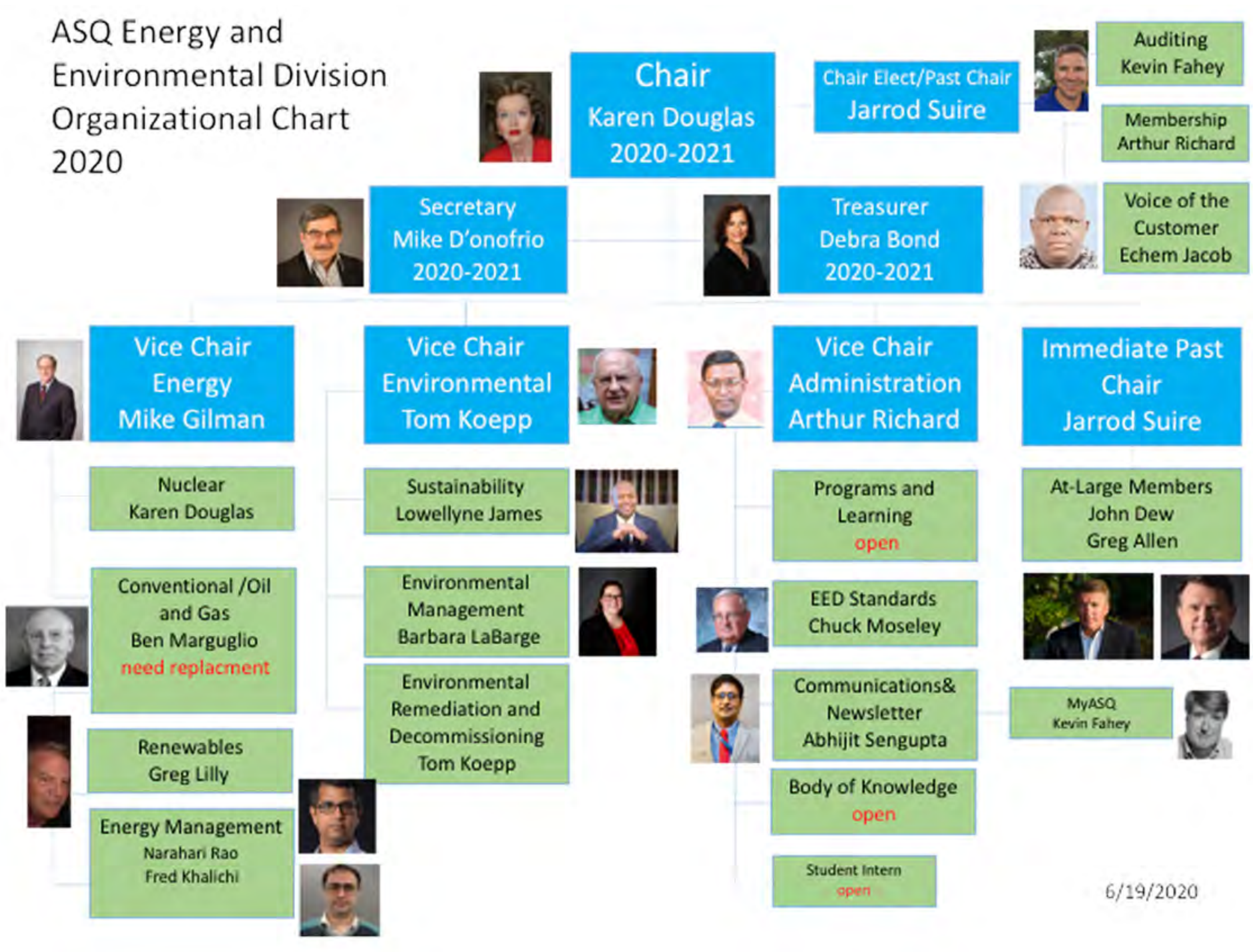

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