Energy Council of Canada
Conseil canadien de l'énergie

Energy in Canada @150 and Beyond

Five Possibilities for Energy Technology

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One in a series of papers prepared by Canadian energy sector leaders – at the invitation of the Energy Council of Canada – exploring key aspects of our ongoing national energy story on the occasion of the 150th anniversary of Confederation.

Summary: John Barrett and John Stewart share their thoughts on five possibilities for energy technology arising from Canada's nuclear sector and how they could unfold in the medium-to-long term. Starting with what they see as the most likely, they profile recycling of nuclear fuel, advances in small and/or advanced nuclear reactors, district energy systems driven by nuclear energy, fusion energy, and widespread penetration of electric vehicles.

Forecasting is hard. There are many possible futures and only one real one, so the odds of being wrong are high. Yet industries and governments need to build infrastructure with fifty- to one-hundred-year implications.

Canada's nuclear energy industry is a foundation stone, not just of our present energy system, but of the sustainable energy system we're building. This is not just marketing hype: it's backed by real investment decisions, which in turn must be backed by informed judgements about likely future scenarios.

So let us share with you the Canadian Nuclear Association's views on five technology possibilities arising from Canada's nuclear sector and how we see them unfolding in the medium-to-long term – starting with the outcomes we see as being most likely.

1. Recycling of Nuclear Fuel – *Likelihood 100% (technical success accomplished, commercialization proceeding)*

Recycling of nuclear fuel is a fait accompli, and Canada made it happen. Nuclear has always been highly sustainable because of its low life-cycle environmental impacts and uranium's abundant presence in the earth's crust. Recycling fuel pulls nuclear more tightly into the renewable and sustainable end of the environmental spectrum.

Canada's CANDU reactor designs have always been uniquely well-suited to burning recycled fuel. This was recognized decades ago and research in this area has gone on ever since. In 2011, CANDU vendor **SNC-Lavalin (SNCL)** and China National Nuclear Corporation (CNNC) began collaborating to develop the Advanced Fuel CANDU Reactor (AFCR). AFCR runs on recycled uranium fuel from light water reactors (LWRs) that are in use in many countries.

AFCR can use recycled uranium to increase uranium utilization efficiency – or it can use thorium, a new fertile material of much greater abundance than uranium. This is attractive for countries such as China that have reserves of used uranium from conventional LWRs as well as indigenous thorium. This opens up potential new markets for AFCRs worldwide.

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An AFCR can be fueled by reusing the recycled uranium from the spent fuel produced by four LWRs, helping China reduce its spent fuel volume. By doing this, China also generates more electricity from carbon-free sources, with benefits for local air quality – a big concern in much of the country – as well as for global climate goals. Each AFCR twin reactor saves up to 13 million tonnes of CO^2 per year when displacing traditional coal-fired power plants.

China already operates two CANDU reactors that are world leaders in high-capacity power generating performance.

2. Widespread Use of Small and/or Advanced Reactors – *Likelihood 90% (very high in the global market)*

Until now, designers of power reactors aimed to serve major power grids where large plant size is an advantage. But not all reactor designs served such markets. Some needed to be far smaller, such as those for research or experimental purposes at many universities (as at Québec's École Polytechnique, Ontario's McMaster University, the Saskatchewan Research Council and elsewhere). And some were not only small, but modular: they were meant to be easily removed from their installation and perhaps transported when they needed to be refueled or replaced. Small reactors have been very successful for sixty years in propelling naval vessels like aircraft carriers, submarines and icebreakers in the fleets of several countries.

Small reactors produced in a factory by the dozens or hundreds – and returned to the factory when decommissioned – could be more widely applicable than reactors built-to-purpose on site in ones, twos and fours. Small modular reactors could drive more large ships, heat building complexes, process natural resources, and supply reliable power to remote communities – all without carbon emissions.

Combined with passive safety systems, new fuel cycles, low emissions and smaller waste volumes, these changes could transform the availability of carbon-free energy in our society in the coming decades. Canada's **Terrestrial Energy** is an exciting case of a more innovative design.

Many elements of these changes have already been demonstrated; there's not much doubt that they can work as technologies. Rather, the remaining barriers are concentrated in the regulatory sphere (would a licence allow reactors to be operated remotely?) and the economic sphere (given a certain regulatory model, how many units must be produced for the business case to work?).

The answers will vary among jurisdictions and applications, but they are very likely to be positive in some cases. So we see little doubt of widespread use of small modular reactors in some countries by 2050. Canada should be a leading contender due to high energy use, many remote communities, and already possessing a safe, sophisticated and viable nuclear industry.

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This has the potentially to dramatically liberate Canada's development in regions that are currently limited by being off the grid. Providing almost unlimited clean energy to communities that have been energy-poor is an exciting idea that truly catches the imagination of many. And for those operating remote mining sites or using fossil fuels for bitumen extraction in oil sands production regions, such clean, mobile power sources could be a real game-changer, providing quantities of needed energy but without GHG emissions.

3. District Energy Systems – Serving Multiple Buildings with Nuclear Energy – *Likelihood 70% (high in the global market)*

Building heat, especially in cold climates like Canada's, is a difficult energy and emissions problem. Today, heating buildings is overwhelmingly accomplished with carbon-emitting fossil fuels. Generally, each building has its own system, making it harder to achieve efficient scale and apply professional management. And heat losses are enormous, partly because there are few public measures to manage them.

District energy systems – in which a single furnace supplies heat, and possibly air conditioning and power as well, through pipes and wires to a cluster of buildings – look like an important step forward in solving these problems. **ENMAX's** District Energy Centre in Calgary is a great example. While it's powered by a fossil fuel (natural gas), it's very efficient because it applies professional management and supplies energy at a large scale.

The challenge is not just to build many more such systems, but to build them with a low- or zero-emission source of energy, particularly one that's reliable in the middle of a dense city through a Canadian winter. Even with better storage, it's hard to see renewables doing that.

Small nuclear reactors certainly look like a good answer. Even with the modest uncertainty around their licensing and commercialization, we see them quite likely to be applied in this way by 2050.

Again, Canada is one of the places where the case should be strongest. The pace of adoption might be constrained mainly by the slow replacement of heating systems and the building stock, rather than by any limitations of reactor technology.

4. Fusion Energy – *Likelihood 60% (for technical success – commercialization less predictable)*

Imagine this: it's 1897, and you're asked to speculate on the outlook for transport in the 1930s. What do you say about flight?

You could say, "Heavier-than-air flight is theoretically possible, but it's always supposed to be right around the corner and we're still waiting. So we'll believe it when we see it, and write it off until then. Let's assume the aviation future will be balloons and airships."

Or you could say, "We give heavier-than-air flight a better-than-even chance of working well technically by 1930, but it's very hard to say how competitive it will be."

Seeing this as a metaphor for fusion energy, we prefer the second answer. Fusion's certainly possible; the challenge is just to get more energy out of the system than you have to put into it (net positive energy). As with flight (actually achieved in 1903), it's impossible to know exactly how far away that first liftoff is. We suspect it will happen sooner rather than later, and will be well controlled for energy production by 2050. Burnaby, BC's **General Fusion** is well advanced in prototyping the heart of a magnetized target fusion reactor. Other approaches are being pursued at the Universities of Alberta and Saskatchewan, and elsewhere.

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Nuclear generating stations were in service in the 1950s, just twelve to fifteen years after the first controlled fission reaction. But that process was accelerated by determined joint government-industry development, rapidly expanding power demand, and a lack of good electricity generating alternatives. Between now and 2030, even where power demand is growing rapidly, fusion would have to compete with many energy sources and with safe, sophisticated existing reactors – not to mention new, more advanced designs.

5. Widespread Use of Zero Emission Vehicles (ZEVs) – *Likelihood 100% (but with great uncertainty around how widespread, what technologies will come out on top, and what that will mean for the rest of the energy system)*

Why discuss vehicles in an article about nuclear technology? Because transport is about 30 per cent of all our energy use. Major changes in vehicles' energy supply will place new demands on the whole energy system, including nuclear. There will be changes, but it's hard to know which changes and what this means for those of us who supply energy.

Because road vehicles are a major source of both dirty air and greenhouse gases, the pressure to move to lower emissions is very strong. Rechargeable, all-electric vehicles (EVs) are already available and, while somewhat expensive to buy, are a real option for some consumers. And they are becoming competitive in many urban fleet-purchase decisions. We will see more rechargeable electric vehicles. We just can't say how quickly or widely they'll be taken up.

That being said, we think the media, and many analysts, have over-focused on rechargeable EVs. A major zero-emission alternative may have been underestimated: hydrogen-powered fuel cell vehicles, which carry a tank of hydrogen gas and turn it into water and electricity, driving the wheels. Hydrogen fuel cells have had successful demonstrations in Canada, notably in city buses powered by Canada's **Ballard Power Systems**. They avoid the range-limit and recharge-time problems of rechargeable EVs, which are turn-offs for consumers. If distribution of hydrogen for vehicles was as available as electric charging stations, then hydrogen might be very competitive.

But that's a big if. Hence the difficulty of predicting what kind of ZEVs we'll drive, or how many of us will drive them. And hence the difficulty of knowing what this means for the energy supply system. We might need to generate more power at night, when EVs are being recharged. Alternatively, we might need to make and distribute hydrogen throughout the economy in very large quantities. Both of these are tailor-made applications for sustainable nuclear energy. But they are very different in terms of implementation, and that's a big variable for the whole energy system.

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With its small footprint, scalability, and reliability, nuclear technology is virtually certain to have a place at the heart of future low-carbon energy systems – but we can't say for sure how its workload will be shared by heating, resource processing, electricity generation and/or hydrogen production.

The Bottom Line: Keep Our Eyes on the Zero Emission Prize

People like gadgets, and we become loyal to causes. It's easy to become passionate about one technology or another.

But while we're all pursuing our preferred technology pathways, it's important not to confuse means with ends. Keep one eye on the ultimate goal. We often talk about technology and change like they are ends in themselves.

Recycling nuclear fuel, better and more useful reactors, cleaner heat for buildings, fusion power, zero-emission vehicles: these are all seductive ideas in their way. They all have believers – as do renewable energy, microgrids, biofuels, geothermal energy and other pathways.

But let's remember that their desirability and success have to be measured by whether and how they help us get to what we're all really after. Assuming we are not widely mistaken about climate change, its causes, and the main threats to our ecosystem, that further goal is zero net emissions sometime in this century. And remember that even this is not an end in itself. We reduce emissions for a reason: we need a sustainable planet to live on.

Dr. John Barrett has expertise in international relations, Canadian foreign policy, corporate business planning and strategic communications. His career spans the federal public service, international organizations, policy think-tanks and universities. He has guided numerous international negotiations, held various diplomatic postings, and served in the NATO international staff. Dr. Barrett is currently on leave from the Department of Foreign Affairs, Trade and Development.

John Stewart leads the development of policy and research products at CNA, and co-chairs the Public Affairs Advisory Committee. He also chairs the Policy Committee of Canada's National Electricity Roundtable, and is CNA's representative to the Washington-based Global Nexus Initiative. John worked with the U.S. Embassy in Ottawa from 1990 to 2010. An advocate for the productive integration of immigrants into Canadian society, he has led two of Ottawa's immigrant services organizations.