Opportunities for Canadian energy technologies in global markets

Summary Document

This analysis was commissioned by Natural Resources Canada, and performed by McKinsey & Co. It does not necessarily represent the views of the Government of Canada.

In response to the unique challenges facing Canada, there are four things Canadian governments can do to create a more enabling environment

DETAILS ON NEXT SLIDE

	Specific challenges facing Canada	Potential government actions to build an enabling environment
Access to markets	Export market is particularly important for Canada: ▪ Canada has a relatively small domestic market (compared to the US or China) ▪ Inexpensive power drives GDP in Canada, but means that emerging energy technologies are less competitive, and may take longer to be cost competitive here than in some other countries	Create stronger domestic demand through policy and provide additional support to companies exporting to emerging (e.g., Asia, Africa) and competitive (e.g., US, European Union (EU) markets
Access to capital	Scarcity of private funding and a poorly performing venture capital market	Help coordinate provincial and federal financing vehicles (e.g., venture capital (VC), government “prizes”) to address a broader range of opportunities
Access to talent	Shortage of skilled labour in key areas (e.g., oil sands operators, power plant engineers); loss of entrepreneurial talent to US market	Cultivate domestic talent and ensure access to international sources as required
Coordination of institutions	Less government action in energy space relative to other countries at the federal level; opportunity to work in a more focused and disciplined way to achieve the same results as other jurisdictions	Create a highly coordinated network of government institutions, such as research centres and startup incubators, to support technology developers along the entire innovation funnel

In response to the unique challenges facing Canada, there are four things Canadian governments could do to create a more enabling environment

	Example actions
1. Create stronger domestic demand through policy and provide additional support for companies exporting to price competitive markets	▪ Use policy to ensure stable, robust domestic demand in target energy sectors and consequently spur industry innovation (e.g. standards like California's building efficiency codes, incentives like the US's shale gas production tax credit) Provide a range of export assistance: ▪ Provide assistance in navigating international intellectual property (IP) law ▪ Help connect small companies with international customers to enable set-up of demonstration projects (e.g., Israel's exports) ▪ Facilitate visits of foreign stakeholders to tour Canadian industry ▪ Enhance domestic resources to help companies prepare strategies for export (e.g. networks to connect participants that form export supply chains)
2. Help coordinate provincial and federal financing vehicles (e.g., VC, government "prizes") to address a broader range of opportunities	▪ Encourage collaboration and risk-sharing between regional and federal capital (e.g., federal support when regional VCs or universities find a promising technology investment) ▪ Explore options to reduce premature technology sales for raising capital, e.g., – Provide alternate sources of capital so that entrepreneurs do not feel unduly pressured to seek short-term profit by selling IP – Place restrictions on VC funds to keep IP in Canada until sustainable business is built ▪ Offer cash or in-kind "prizes" as rewards to technology developers that take risks, ensuring targeted spending when technology progress occurs
3. Cultivate domestic talent and ensure access to international sources as required	▪ Create vocational/educational programs that serve energy technology developers (e.g., Norway's oil and gas) ▪ Ensure that developers are able to import skills (e.g., Taiwan's semiconductors) ▪ Develop culture of technology entrepreneurism, give best entrepreneurs reasons to stay
4. Create a highly coordinated network of government institutions, such as research centres and startup incubators, to support technology developers along the entire innovation funnel	Ensure that this network is collectively able to: ▪ Coordinate research, development and deployment (RD&D) with standards/regulations policy programs (e.g., Singapore's water) ▪ Ensure government institutions are integrated with industry and set-up to utilize co-funding programs and seed risk capital; particularly help small and medium enterprises (SMEs) who are most challenged in accessing capital (e.g., Finland's Innovation Fund, SITRA) ▪ Take direct role in commercialization of new technologies through public-private partnerships (e.g., Taiwan's semiconductors)

SOURCE: Expert, industry, and government interviews; market reports, McKinsey EPNG and SRP Practices
See Appendix for case studies of successful actions in each of the four recommendation areas

Based on this global forecast fourteen technology areas are poised to have significant market pull by 2020 (1/2)

	Technology area	Technologies under consideration	Market size and drivers
Fossil fuels	Unconven-tional gas	Shale gas extraction, supply chain and field management, gas to liquid and liquefied natural gas (LNG), environmental technologies	Unconventional gas will be 30% of North American gas production by 2020 due to improved extraction technology, causing flat natural gas prices
	Unconven-tional oil	Bitumen extraction, upgrade, environmental technologies, pipelines	~$100B market in 2020 for oil sands ($20B in capital expenditure and ~$80B in revenue) due to improved extraction techniques and rising conventional oil prices (Unconventional oil only attractive at high oil prices, which are expected to continue)
Renewable and Clean Energy	Solar Photo-voltaic (PV)	Poly-Silicon to PV module value chain, balance of system, end applications, concentrated solar power (CSP)	PV modules market $325B worldwide by 2020, $962B by 2030 driven by decreases in PV module price and new applications
	Wind	Wind Turbine Generator (WTG) components, manufacturing and operation	WTG market $680B by 2020, increases in reliability, efficiency and cost-effectiveness driving worldwide adoption
	Bioenergy	Biomass collection and processing, bioheat, biopower, combined heat and power (CHP)	$100-200B potential in capital expenditure in 2020, mostly in EU markets driven by regulatory requirements
	Biofuels /Biorefinery	Production of biodiesel, bioethanol, other 2nd generation biofuels and biorefinery products	64 gigaliters (GL) cellulosic biofuel demand in 2020, with 400 new plants built for cellulosic biofuels. Markets driven by regulations, subsidies, strategic considerations (e.g. bio-jet fuels) and low cost of 1st generation bio-ethanol.

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

Based on this global forecast fourteen technology areas are poised to have significant market pull by 2020 (2/2)

	Technology area	Technologies under consideration	Market size and drivers
Distribu-tion	Smart Grid	Metering, grid storage, network, demand management/response, appliances, software and integration, transmission & distribution (T&D) components, renewables integration	$41B in 2011 for hardware and software, growth driven by increased utility adoption $10B by 2020 in T&D components driven by utility adoption of more efficient, reliable, and controllable power electronic components
Buildings and Communi-ties	Energy Efficient (EE) Buildings	Advanced windows value chain, heating and cooling value chain, system integration, prefab houses	30% of energy use today, large 2011 market for windows ($69B) and heating and cooling ($130B), strict regulations will drive new construction and refits to higher efficiency
	Advanced lighting	Light emitting diode (LED) lighting (semiconductor, packaging, luminaire, control)	$38B LED lighting market by 2020, driven by banning of incandescents and decrease in cost of LEDs
Energy intensive industrial processes	Waste to energy (WTE)	Equipment, design and engineering, construction	$4B in revenue, $77B equipment market in 2014, EU markets driven by tipping fees
	Water	Water treatment equipment, operation and maintenance, consumer and commercial products	$515B global market in 2011 ($110B for equipment), increasing pressure on water supplies driven by both population and industrial/mining/extraction demand
	EE Industrial	Industrial process optimization	32% of energy use today, disruptive processes can save up to 50% of energy use and reduce emissions
Transpor-tation	Compressed natural gas (CNG)/LNG fleets	Natural gas (NG) engines and refueling infrastructure	Long term compressed natural gas/liquid natural gas heavy vehicle adoption in North America (NA) (1/5 of heavy vehicles by 2020) spurred by low NG prices
	Next generation (Next-gen) auto	Internal combustion engine (ICE) technology, regenerative braking, lightweighting, batteries, motors, charging infrastructure	22M plug-in hybrid electric vehicles (PHEV) /year by 2020, 87M by 2050 with increasing battery electric vehicle (EV) adoption in China

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

Ten additional technology areas were considered based on their strategic importance to Canada and their link to our resources

	Technology area	Technologies under consideration	Market size and drivers
Fossil fuels	Enhanced HC Recovery	Enhanced oil recovery (EOR) and coal bed-methane (CBM)	$36B market in 2011 from Canada's EOR revenue and global capital expenditures, driven by higher oil prices
	CCS: Carbon capture and storage	Carbon capture, coal and natural gas (NG) CCS builds, CO2 transport and storage	CCS for offsetting oil sands CO_2 cost. Dependent on CO_2 price acceptance in EU and China; slow growth until 2030+, $230B in capital expenditures on gas and coal CCS in 2050
	Gasification	Gasification of coal into syngas or fuel	Canada has large coal and biomass resources. $4B global equipment market, mostly driven by China.
Renew-able energy sources	Uranium mining	Uranium mining, uranium mining waste management	$14B global mining market, Canada has 2nd largest reserves and a top uranium miner (Cameco)
	Nuclear technologies	Traditional reactors, uranium enrichment, nuclear fusion, small-scale reactors	45-50GW to retire/refurbish by 2050, several are Candu; $10B enrichment market in 2020; 400-500B new builds primarily in China and India. Long-term potential in fusion and small-scale.
	Geothermal	Power generation (equipment, engineering, project management), CHP	Canada has large untapped geothermal potential. $3B market mostly in US and Japan (with some delays in Onsen), some opportunities in South America.
	Traditional Hydro	Conventional hydro equipment and services	Canada's power is more than 50% hydro through 2050. $420B global capital expenditures for conventional hydro in 2020, large projects mostly driven by governments.
	Unconvential Hydro	Run of river, hydrokinetic, marine power generation	Canada has natural expertise and some new technology. Large market opportunity if technology is developed.
Transport ation	Advanced trains and aircraft	Electric rail and urban transit, aircraft assembly and engine design	Bombardier is 3rd largest aircraft original equipment manufacturer (OEM) ($10B in revenues 2011) and also a major player in rail ($10B in revenues 2011). Attracts international suppliers and domestic growth.
	Fuel cell systems	Hydrogen fuel cells, charging infrastructure, fuel cells in grid storage	Canada has significant investments in hydrogen fuel cell development. Large potential beyond 2020-2030 depending on fuel regulations and technology cost reduction

SOURCE: McKinsey Global Energy Perspective Model, market research, expert interviews

There are six categories of levers that government can use to help remove the barriers to improving Canadian technology competitiveness

	Examples
Direct investment	▪ Government labs; grants for research, development, and demonstration; provision of risk capital for technology commercialization ▪ Provision of capital for pilots or deployment, including procurement (e.g., piloting leading-edge efficiency tech in government buildings)
Incentives & financing	▪ Low-interest loans to stimulate demand for technology adoption ▪ Tariffs or tax breaks related to technology adoption
Infrastructure investment	▪ Physical infrastructure investments to enable specific industries (e.g., charging stations for EV)
Standards and regulations	▪ Performance standards, potentially with disincentives ▪ Licenses & permits ▪ IP protection laws
Education and information	▪ Providing monitoring data to end users ▪ Consumer labeling (e.g., Energy Star) ▪ Investments in labor capabilities and capacity to enable an industry (e.g., building education capacity for researchers and field workers)
Foster collaboration	▪ Establishment of national vision and strategy ▪ Network building and connection of stakeholders ▪ Multi-lateral offerings (e.g., utility-funded installation of home energy efficiency tech by private company)

Five natural "clusters" of opportunity for government to intervene to maximize opportunities in energy technologies

DETAILS ON FOLLOWING PAGES

Cluster	Technology areas	Cluster assessment
1 Unconventional oil and gas	▪ Unconventional oil ▪ Unconventional gas	▪ Industry players are already investing heavily in technology RD&D and commercialization of oil and gas technologies ▪ Canadian government can sustain advantage by fostering collaboration around environmental technologies to enable the social license to operate
2 Next generation transportation	▪ Next-gen auto ▪ CNG/LNG	▪ Industry players are already investing heavily in RD&D and commercialization of EV or PHEV components in anticipation of fuel efficiency standards ▪ Canadian government can be a leader in regulations and standards, and selectively invest in best-in-class technologies to ensure Canada continues to be a manufacturing hub and build exportable infrastructure capabilities
3 Energy-efficiency technologies	▪ EE buildings ▪ EE industrials ▪ Water	▪ Market is already making some investments on technology development, but both adoption and development are slow due to structural challenges ▪ Canadian governments can drive innovation through education, incentives for early adoption and/or progressively tightening regulatory standards
4 Distributed power generation	▪ Unconventional hydro ▪ Bioenergy ▪ Waste to energy ▪ Solar	▪ Fast growth and emerging market, Canada is one of multiple countries with technology development, but high levels of competition ▪ Canadian governments can drive global competitiveness by selectively deploying the most appropriate levers (described on slide 18) based on benchmarking specific Canadian technologies to global competition
5 Potential longer term opportunities	▪ CCS ▪ Fuel cell systems ▪ Biorefineries and biofuels	▪ Markets are potentially attractive, but outlook and timing depends strongly on either major regulatory shifts or technology breakthrough ▪ Postpone further large-scale government support until key developments or major industry investment decrease the level of commercialization risk ▪ Offer "prizes" as incentives for faster development as low-risk option
Market forces are effective	▪ Traditional hydro ▪ Uranium mining ▪ Advanced trains/jets	▪ Market leaders and technologies are established ▪ Since private industry is investing to remove market barriers (e.g., technology, cost barriers), there is limited need for government actions

1 Canadian governments could sustain advantage on unconventional oil and gas

Technology area	Description of barrier	Highest potential levers	Rationale including international examples
▪ Unconventional oil and gas: water treatment, air quality and land remediation	▪ New environmental tech exists at small scales, but need to be proven with pilots ▪ Industry usually stalls full-scale pilots until regulations are mandated and enforced ▪ Despite short-term increased costs, phased standards often encourages development of new environmental technologies at attractive long-term economics and global competitiveness	▪ **Foster collaboration** across potentially competitive companies to facilitate tech transfer of environmental technologies across industries (e.g., a research centre, or consortiums) ▪ Consider **regulation/standards** to spur domestic innovation in the long term ▪ **Incentivize** private sector firms (e.g. reduced Provincial royalties, risk-sharing, government prizes for solutions to solve technological challenges)	▪ Improving performance of environmental technologies is essential for social license to operate and for broad exportability (e.g., certain regions have banned shale gas) ▪ Consortiums can help reduce cost base across industrial players ▪ Phased regulations have proven successful in spurring innovation, and if Canadian governments are more aggressive than other jurisdictions in these regulations, it could ensure long term competitiveness of Canadian technologies (e.g. building efficiency in California, water in Singapore) ▪ Once developed, the environmental technologies can be exported to other regions or industries
▪ Unconventional oil: drilling and extraction technologies	▪ Lowering costs of drilling and extraction is important to maintain advantage through tapping into currently uneconomic resources: – To show viability of a new in-situ extraction technique, it must be piloted at full-scale – Operators face a trade-off of piloting new techniques vs. immediate production	▪ **Foster collaboration** between technology holders and oil majors, help form consortium between oil majors ▪ **Incentivize** private sector firms (e.g. reduced royalties, risk-sharing, government prizes for solutions to solve tech challenges)	▪ Oil companies are currently investing in developing the technology through pilots, but Canadian governments can help accelerate this process through incentives (e.g., shale gas in the US) and enabling connections between industry players (e.g., oil and gas sector development in Norway)

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

2 Canadian governments could cultivate Canadian leadership in next generation transport

Technology area	Description of barrier	Highest potential levers	Rationale including international examples
▪ Next-gen auto: accelerate PHEV adoption through lowering costs	▪ While industry is already investing in batteries, advanced internal combustion engines (ICEs) and lightweight vehicles, speed of adoption is dependent on lowering costs through achieving scale	▪ **Regulations and standards** for fuel efficiency to lead US/EU ▪ **Incentivize** auto suppliers to build-up supply chain in Canada	▪ If Canada sets fuel efficiency regulations that are more advanced and aggressive than the US/EU, it can cement Canada's role as a pilot site for new technologies (e.g. building efficiency in California)
▪ Next-gen auto: PHEV infrastructure	▪ Uncertainty in charging standards, uncertain technological advancement and competition among manufacturers has slowed adoption of PHEV ▪ Manufacturers are deferring infrastructure investment until demand is greater	▪ **Infrastructure investment** – either directly or in coordination with private sector firms ▪ **Foster collaboration** to drive adoption of a unified charging standard and enable innovation and export of Canadian infrastructure technologies/services	▪ Canada could be an early leader in infrastructure, attracting foreign investment for pilots and then develop innovation and export capabilities
▪ Next-gen auto: inexpensive electric motors	▪ Rare-earth magnets are a critical cost component for electric motors ▪ China has established a low-cost rare-earth supply, stifling rare-earth mining investments in other countries – China has thus become global leader of e-motor manufacturing and technology, vehicle OEMs are concerned over lack of competition	▪ **Infrastructure investment** in creating a rare earth supply in Canada ▪ **Incentivize** OEMs to be present and participate in an e-motor hub in Canada (e.g. tax advantages, reduced infrastructure costs, etc.) ▪ **Regulations and standards** related to the environmental impact of rare earth mining ▪ **Foster collaboration** among mining companies, auto suppliers and OEMs	▪ Competing successfully with China will require measures to increase Canada's cost competitiveness (e.g., increase scale of operations by attracting foreign direct investment) (e.g., semiconductors in Taiwan, wind in Denmark)
▪ CNG/LNG: adoption	▪ Fleet owners reluctant to invest in additional vehicle premium due to risk aversion and previous poor experience with NG price volatility ▪ Lack of CNG/LNG codes and standards	▪ **Regulations and standards** – to drive adoption and to harmonize standards with those of the US ▪ **Educate and inform** fleet owners on the benefits of CNG/LNG adoption	▪ Given US will be the largest CNG/LNG fleet market, Canada could have the same standards and infrastructure to enable export ▪ Infrastructure investments would also be important in longer term

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

3 Canadian governments could cultivate Canadian leadership in energy efficiency technologies

Technology area	Description of barrier	Highest potential levers	Rationale including international examples
▪ EE buildings/ industrials: adoption	▪ Although technology is economically attractive, other barriers exist such as – Limited awareness of energy efficiency gains – Risk aversion – Builders/Industrial players focus on short term returns or face lack of capital – Misaligned incentives (e.g., builders versus owners, owners versus renters)	▪ **Regulations and standards -** strengthen federal regulations and encourage and assist provincial efforts (e.g., building codes, utility regulation and revenue decoupling, energy audits, and efficiency upgrades) ▪ **Educate and inform** on the benefits of adoption given risk aversion ▪ **Direct procurement** for public sector buildings (e.g., schools, hospitals) ▪ **Incentives targeted on industrials** (e.g. interest free loan, share energy savings to pay back capex) to encourage early adoption	▪ Lack of adoption is driven by lack of awareness and understanding of the benefits despite the total cost of ownership being economically attractive. Staged regulations is the most powerful (particularly for buildings), but education and incentives are also useful levers for early adopters (e.g., building efficiency in California, industrial efficiency in the Netherlands)
▪ EE buildings/ industrials: new technology development	▪ Buildings is a commodity market with low margins and lack of talent in select areas limits RD&D spending by current industry players, slowing development of disruptive technologies ▪ Small innovative companies have difficulty attracting funding for early development and pilots	▪ **Direct investment** in government conducted research ▪ **Educate** talent through programs and funding for the development of research and vocational programs related to the sector ▪ **Regulations and standards** will spur innovation in the private sector	▪ Due to a shortage of RD&D talent in small companies, Canadian government needs to directly invest in short term. In parallel, investing in industrial education now and putting in regulations later will spur private investment. (e.g. education for oil and gas in Norway, semiconductors in Taiwan)
▪ Water: adoption of EE technologies	▪ Water utilities are risk-averse and slow to adopt new technologies: – Prefer to defer large capital investments – Favor local contracts given prior experience	▪ **Regulations and standards** to be strengthened to spur domestic innovation in low cost technologies and attract foreign investment in pilots ▪ **Foster collaboration** between utilities and industry players to encourage adoption	▪ Given the strong presence of water treatment companies in Canada, key would be to use regulations to drive innovation and sustain the advantage (e.g., water in Singapore)

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

4 Canadian governments could support select distributed power generation technologies – based on risk/reward calculations

Technology area	Description of barrier	Possible levers to be used	Preliminary view of risks/rewards
▪ Un-conven-tional hydro	▪ Long term commercial pilots to prove out the reliability of technology	▪ **Direct investment** in commercial scale pilots for low-head river projects ▪ **Incentivize adoption** through price guarantee for excess electricity	▪ Large unconventional hydro potential globally ▪ Canada has strong domestic resources and emerging potential technology leaders ▪ Strong competition and risk of copying leading to foreign purchase of Canadian IP before economic benefit to Canada
▪ Bio-energy	▪ Pilots to advance combined heat and power (CHP) technology along learning curve particularly for small-scale plants	▪ **Direct investment** in production of commercial scale pilots for combined heat & power plants to advance along learning curve and lower costs and enable whole system export	▪ Large growth in bioenergy expected in EU due to 2020 renewable targets ▪ Canada has some leadership in CHP from pulp & paper industry and innovation ▪ Regulation uncertainty for biomass as a renewable power may curb long term growth ▪ Difficult to export plants of significant size to EU
▪ Waste-to-Energy	▪ Sourcing feedstock for WTE plants is difficult given risk aversion of utilities to enter into new contracts ▪ Lack of tipping fees in Canada	▪ **Incentivize** municipal utilities to ensure feedstock availability for WTE start-ups	▪ Large untapped global potential for waste to energy, driven by high urban density ▪ Canada has potential technology leaders ▪ Foreign purchase of Canadian WTE IP before economic benefit to Canada ▪ Weak domestic market given lack of tipping fees, so pilots will need to be in US or EU
▪ Solar	▪ Pilots to prove out solar PV offgrid technology and reduce costs	▪ **Direct investment** in development of domestic solar PV off-grid pilots ▪ **Incentivize** communities to participate to pilots	▪ Large market potential particularly in developing nations with solar resources ▪ Canada has some tech and a major company ▪ Solar resources are limited in Canadian offgrid ▪ Chinese companies may focus on offgrid-PV given that it is a significant niche

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

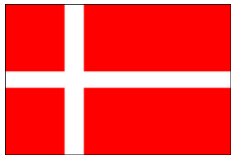
5 Canadian governments could wait for key developments before investing in technologies with potential longer-term impact

Technology area	Description of barrier	Possible levers to be used	Necessary development
▪ CCS	▪ Technology not economic without high CO_2 prices ($40-50 range)	▪ **Direct investment** in RD&D and pilots related to capture and sequestration technologies ▪ **Regulations and standards** related to carbon accounting and sequestration liability	▪ US or China make a significant commitment to mandatory carbon price at $40-50 ▪ Industry makes significant contribution and/or volunteer to reduce emissions driven by social license to operate
▪ Fuel cell systems	▪ Technology not yet economic without higher fuel efficiency standards ▪ "Chicken and egg" challenge around infrastructure investment	▪ **Incentivize** foreign investment in Canadian fuel cell vehicle production ▪ **Direct investment** in fuel-cell technology RD&D ▪ **Infrastructure investment** to incentivize mass adoption of fuel cells	▪ Break-through in catalyst research ▪ A major player invests in infrastructure ▪ Large OEM makes major bet on hydrogen, e.g., mass production for fleets
▪ Bio refineries and biofuels	▪ Cost of woody biomass low-carbon (LC) biofuel technologies is high compared with other 2nd generation biofuels ▪ Biorefinery products not yet well defined (thermal or biochemical technologies)	▪ **Direct investment** in RD&D and pilot plants ▪ **Incentivize** foreign investment through the reduction of feedstock risk with long-term contracts ▪ **Foster collaboration** to allow integration of biorefinery and CHP (e.g. gasification)	▪ A major government (or private corporation of global scale) mandate for use of bio-plastics or other bio-products (e.g. set-aside for LC fuel requirements) ▪ Breakthrough in cost position of lignocellulosic technologies ▪ Consistent and cost-effective bioproducts from thermal gasification technologies (allowing value-added synergy with CHP)

SOURCE: Expert, industry, and government interviews; market reports; McKinsey EPNG and SRP Practices

Appendix – case studies, individual technologies

Case study – Wind power in Denmark



In the 1980s, Denmark's government recognized the need for greater energy independence and lower GHG emissions

- Made a decision to accept short-term economic pain for longer-term benefit

Government used multiple levers to establish and grow its wind industry

- Investment in R&D including testing centers for new technologies
- Gradually decreasing subsidies, a carbon tax, and a Feed-in Tariff (FIT) with guaranteed grid connection reduced risk to investors by ensuring reliable revenues
- Technology standards to ensure quality
- Stable demand has reduced regulatory risk and matured the wind industry, encouraging Danish pension funds to invest

Today, Denmark is energy independent and holds 40% market share in the wind industry

SOURCE: Government websites, press search

Case study – Industrial energy efficiency in the Netherlands

Ministry of Economic Affairs makes Long Term Agreements (LTAs) with industry, which are voluntary, collaborative compacts to reduce energy intensity of operations and feedstock

- Companies perform EE assessments, draw plans for reduction and expected impact, and monitor and report progress
- New plans are submitted every 4 years to push continual improvement and provide consistency to companies and the efficiency industry
- Efficiency measures are required to be economical with payback periods of 5 years or less
- Government agency, Senternovem, assists companies in creating plans, navigating policy, and sharing best practices

Since its inception in 1990s, LTA program has:

- Signed on over 1,000 companies representing 90% of industrial energy consumption
- Yielded a ~20% increase in efficiency

SOURCE: Government websites, press search

Case study – Ethanol in Brazil

National agency, Institute of Sugar and Alcohol, created to manage ethanol industry

- Direct investment in infrastructure projects
- Low-cost credit and financing to sugarcane industry to grow feedstock supply
- Mandatory ethanol blending in vehicle fuels; voluntary and then mandatory manufacturing targets of ethanol-only vehicles; provided industry time to adapt
- Ethanol-only government fleets provide consistent demand
- Education to create consumer demand
- Collaboration with US government to share technology and create international standards
- In response to rising prices in 2011, government implemented a temporary reduction in the fuel-blending minimum from 25% to 18%

Brazil has captured a strong share of ethanol market

- Second largest producer behind US
- For several years, was largest exporter

SOURCE: Government websites, press search

Case study – Water efficiency in Singapore

Despite limited natural resources, Singapore has become increasingly efficient due to the government's holistic approach to management:

- National supply is provided by the "Four Taps" – local water catchments, imports, reclaimed water, and desalination
- Three agencies dominate water management – the Ministry of the Environment and Water Resources (MEWR), the Public Utilities Board (PUB), and the National Environment Agency (NEA)
- Regulations: Careful land management by PUB protects reservoirs from pollution
- Government has funded R&D, facilities, and marketing campaigns for reclaimed water, called NEWater, which is fed into industrial uses and drinking supplies; also funded R&D and facilities for desalination
- Incentives: Pricing was adjusted to remove subsidies and reflect the full cost of supplying water, encouraging conservation
- Foster collaboration: The Environment and Water Industry Development Council was established to support the development of Singapore as a water research hub, including attracting foreign and private sector investment

Singapore is on-track to becoming water-independent

- Water agreements with Malaysia have been allowed to expire due to Singapore's lower needs
- Reclaimed water provides 30% of demand and desalination supplies 10%; these numbers are expected to grow to 50% and 30%, respectively, within the next few decades

SOURCE: Government websites, press search

Case study – Energy efficient buildings in California

California's Title 24 code is on the leading edge of building efficiency standards[1]

- Standards & regulations: 2014 code update will make California standards among the most efficient in the US and world
- The code is expected to continue increasing in stringency over time, offering both consistency and time to adapt
  - Independent panel of engineers decide net present value (NPV) and payback of new efficiency technologies
  - Technologies with payback of 7 years or less are included in code; builders given 3 years to adopt newly-included technologies
- Performance-based standards allow flexibility in implementation
  - Builders can either adopt designated technologies or show, using government-approved models, equivalent performance of alternative technologies, which motivates innovation
- Pairs with appliance efficiency standards and more stringent voluntary standards
- "Public goods fee" on utility bills used to fund efficiency programs and updates to the building code; reliable funding ensures continuation of efficiency efforts and consistency for the industry

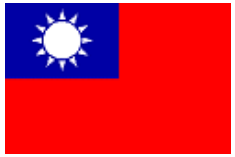
Due to building codes, other energy efficiency measures, and some climate effects, California:

- Has second-lowest per capita energy consumption of the US states
- Has experienced lower growth in total energy consumption than most other US states

1 Comparisons of codes are complicated by climate differences, but California's standards are used as a model by other jurisdictions, including US states and other countries

SOURCE: Government websites, press search

Case study – Semiconductors in Taiwan



Government intervention followed three important principles:

- Synchrony with a long-term vision
- Careful timing of intervention, including the exit of government when appropriate
- Coordination of policy across the value chain

Government identified electronics as a promising emergent technology and established agencies to facilitate its growth

- Established Electronics Research and Service Organization (ERSO) to lead development of industry, including allocating R&D funding
- Founded research centers at multiple universities
- Founded the Industrial Technology Research Institute (ITRI) to foster collaboration between industry and academia and to facilitate technology transfer from developed nations to domestic industry
- Devoted an agency to attracting foreign and expatriate talent, including streamlining immigration and raising the salary cap on foreign employees of government-funded organizations

Supported the maturation of domestic industry with tax incentives, access to knowledge and R&D funding, low-cost loans, and employee benefits such as housing and medical care

Partnered with private sector to establish foundries that have since privatized and dominated the world market

SOURCE: Government websites, press search

Case study – Exporting in Israel

Israel exports high-value-add goods (24% chemicals, 20% electronics[1]) to a diverse set of markets (24% US, 30% EU, 22% Asia, 24% other[2])

A number of government agencies offer support to domestic companies selling abroad

- Foreign Ministry sets up representative offices in target markets to introduce Israeli companies to potential trading partners and offer resources and infrastructure(e.g., office space, assistance navigating immigration law)
- America-Israel Chambers of Commerce introduce US companies and investors to Israeli industries in order to attract trade and investment
- Israel Export and International Cooperation Institute (IEICI) founded by government and private sector to facilitate exports

Israel's annual exports are worth C$80 billion

1 Includes office equipment and appliances
2 Excludes diamonds

SOURCE: Statistics Canada, Israel Central Bureau of Statistics, expert interview

Case study – Shale gas in the US

Government has provided support at each stage of the shale gas industry's development

- Mineral-rights law gives landowners rather than government consistent rights to resources, encouraging exploration and exploitation of resources
- Government-funded research produced necessary equipment and processes
- Public-private partnerships demonstrated commercial-scale operations
- Production tax credit lasting ~20 years incented production before it was independently economical
- Regulations are transparent and largely standardized with some variation among States
- There is room for further research and environmental regulations to improve public acceptance

US has become a global leader in shale gas

- US companies and operations are on leading edge of technology development
- Rapid increase in production dropped natural gas prices, encouraging NG consumption, and spurred interest in exploiting shale gas resources outside the US

SOURCE: Government websites, press search

Case study – Oil and gas in Norway

Government identified four tasks for itself:

- Establish long term vision, aligned with key stakeholders, and manifested in proactive adjustments to regulations
- Leverage experience of international oil companies through a thoughtful resource access policy for frontier exploration
- Ensure competition among companies
- Support local R&D

Government used four primary instruments:

- Access to Norwegian Continental Shelf to bring in foreign players with knowledge
- Support domestic players (including government-owned Statoil)
  - Education system was adjusted to train locals and build training capacity
  - Licensing system required involvement of national players in all oil and gas (O&G) operations
  - Policies (e.g., recommendations in licenses, joint ventures facilitating knowledge transfer) encouraged contracting of domestic oil field service and equipment (OFSE) players
  - Gradually decreasing support gave national players time to develop and establish strong domestic presences before extending operations internationally
- Frequent adjustments to fiscal regime incents research, exploration, development (e.g., investments in R&D are deducted from taxable income)
- Support for innovation using a combination of levers (e.g., Statoil program provided technical and financial expertise, piloting, and mentorship for startups with O&G technologies)

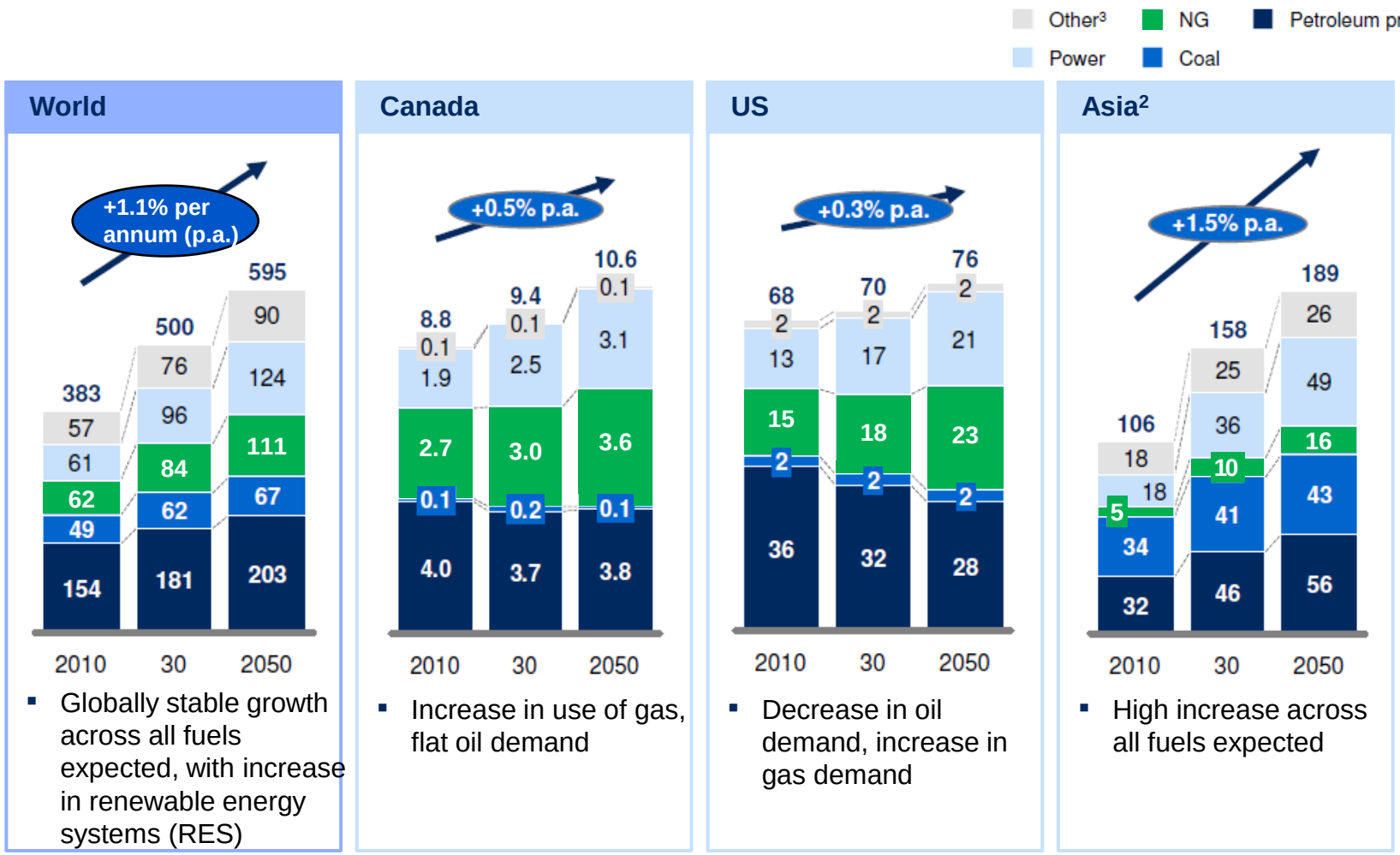
Today, Norway is third largest exporter of oil and sixth largest producer of gas

- Revenues from O&G industry fed into large Petroleum Fund and pension funds
- Norwegian OFSE sector is a key exporter with nearly half of revenue ($45 billion in 2009) from international sales

SOURCE: McKinsey EPNG Practice, press search

Global energy demand for fossil and other fuel types

Final Energy Demand[1], QBTU



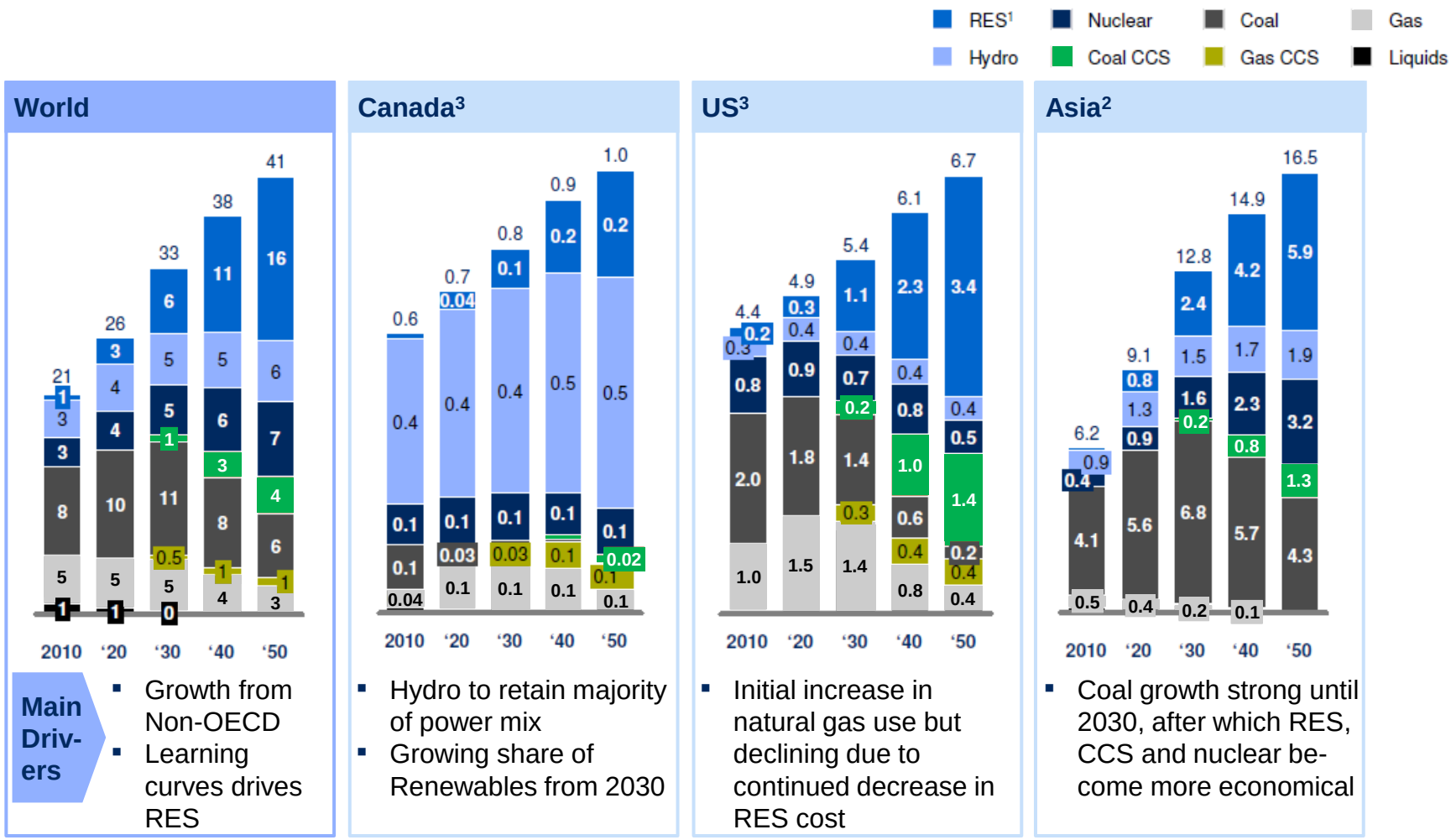
- Globally stable growth across all fuels expected, with increase in renewable energy systems (RES)
- Increase in use of gas, flat oil demand
- Decrease in oil demand, increase in gas demand
- High increase across all fuels expected

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan
3 Other includes use of biomass, renewables etc

SOURCE: McKinsey Global Energy Perspective

Fuel mix for power generation

Fuel mix of power production[4],('000 TWh)

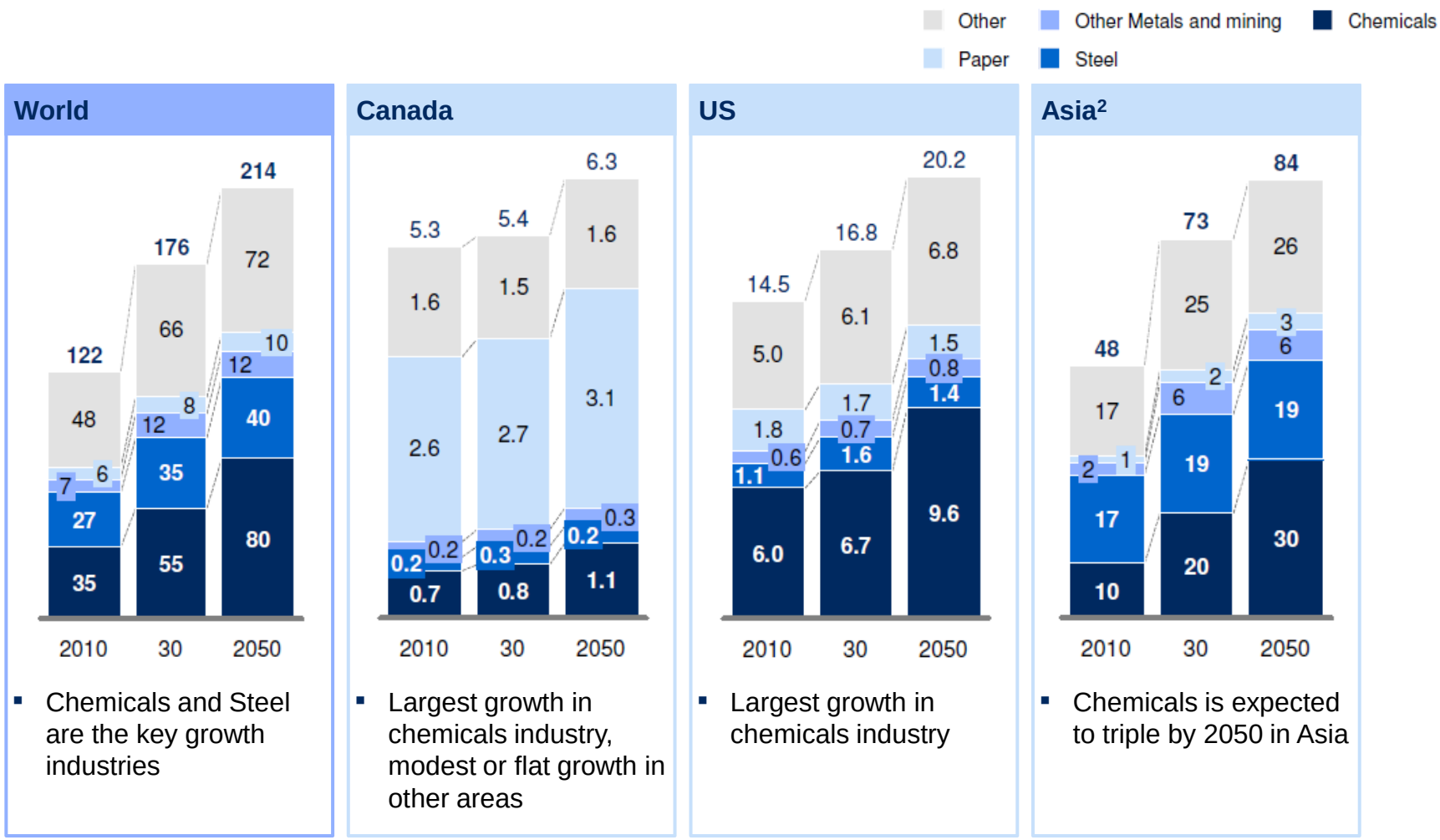


1 Renewable Energy Systems (RES) are Solar PV, Solar CSP, Wind Onshore, Wind Offshore, and Biomass
2 Asia includes India, China and Japan
3 Carbon-Capture-and-Storage (CCS) enabled by CO2-prices in US, China and Canada; no CO2-prices assumed in other non-Organization for Economic Co-operation and Development (OECD) countries
4 All of RES, Nuclear, Hydro are used for electricity production; Coal, gas and liquids used in power production are included for comparison purposes

SOURCE: McKinsey Global Energy Perspective

Energy demand across industrial sectors

Final energy demand by sector[1], QBTU



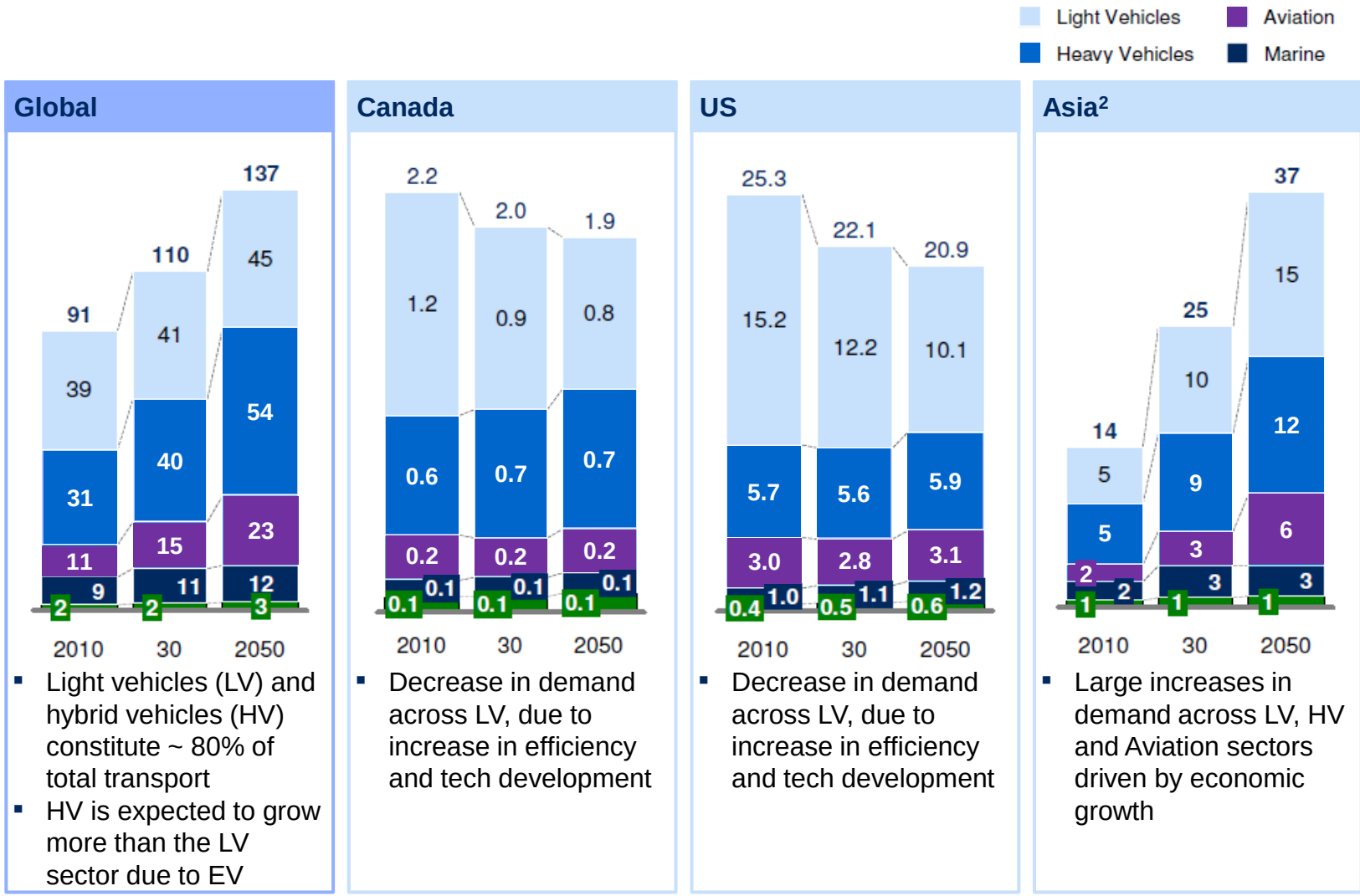
- Chemicals and Steel are the key growth industries
- Largest growth in chemicals industry, modest or flat growth in other areas
- Largest growth in chemicals industry
- Chemicals is expected to triple by 2050 in Asia

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

Energy demand across transportation sectors

Final energy demand by sector[1], QBTU



- Light vehicles (LV) and hybrid vehicles (HV) constitute ~ 80% of total transport
- HV is expected to grow more than the LV sector due to EV

- Decrease in demand across LV, due to increase in efficiency and tech development

- Decrease in demand across LV, due to increase in efficiency and tech development

- Large increases in demand across LV, HV and Aviation sectors driven by economic growth

1 Differs from primary demand due to exclusion of the conversion losses in the power generation industry
2 Asia includes India, China, and Japan

SOURCE: McKinsey Global Energy Perspective

Fossil Fuels: Unconventional Oil

Technology Areas Under Consideration

- Drilling, extraction (including mining, steam-assisted gravity drainage (SAGD), etc) from oil sands
- Converting (including upgrading and refining) bitumen and heavy oil for export
- Environmental (water, land, air) technologies and remediation; tailings management
- Domestic pipelines and pipeline technologies

Canada has a clear advantage

Market and Tech Overview

The oil sands market is large and fast growing driven by worldwide demand for oil and advances in extraction technology :

Large and fast-growing global market for oil sands crude, economic at oil prices > $60-70/barrel (bbl)

- Third largest oil reserve (175 billion barrel of oil equivalent (BBOE))
- $100-200B market by 2020 in oil derived from oil sands, with most growth from in-situ sources (80%)
- Several paths to market with varying economics
  - Export via US refineries (discount due to oversupply and transport cost)
  - Export to international markets (limited today by pipeline capacity)
  - Domestic use (limited demand)
  - Upgrading and export of more refined products (high capital cost, but saves on transportation)

Full scale pilots are needed to prove new technology development

- All players improving SAGD[1] front end – electrothermal and radio frequency (RF) heating, solvents, in-situ steam
- Continuing improvement of environmental (water, air, land) technologies

Pipelines are essential for oil & gas distribution

- Pipeline construction worldwide was $60B in 2012
- Majority of pipeline build in Asia
- Most innovation is on safety and cost reduction

Canada's Advantage

Canada has large oil sands resources and several domestic companies well positioned to capture and exploit its value:

Canadian companies are present along the entire value chain

- Continuing merger and acquisition (M&A) activity

Leading technologies are developed in Canada

- SAGD result of successful provincial and Federal Canadian gov't/industry collaboration
- Canada's Oil Sands Innovation Alliance (COSIA) – Canadian consortium, improving tailings management, GHG and land remediation

Canadian access to global markets may be limited

- Export of resource limited by pipeline capacity
- Canadian refineries currently configured for lighter oils
- Canadian oil sands technologies may not be applicable in other heavy oil deposits (e.g., Venezuela)

Canadian expertise in pipelines and monitoring technologies

- Major global companies
- Some new technology for Intrusive robots to monitor pipe wall thickness
- External monitors to listen for changes in pipeline condition

Investment thesis

To maintain Canada's advantage, Canada could continue to rapidly innovate drilling, extraction and other technologies, lower barriers to oil export (e.g., more cost effective and safe pipelines) and seek additional applications for oil-sands technologies

- **Lower the cost of Canadian oil exports by continuing through pilot and full-scale testing of in-situ extraction technologies**
  - Multinationals already making large R&D efforts
- **Develop advanced environmental technologies for domestic and export use in other markets**
  - Oil-sands require advanced environmental technologies that are transferrable to mining and other industries

1 Steam Assisted Gravity Drainage – for in-situ extraction, steam pumped into well heats bitumen, increases flow

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

Renewables and Clean Energy: Solar PV

Technology Areas Under Consideration

- Early value chain (polySi, ingot/wafer, cell/module) commoditized – heavy cost pressure, large global players
- Balance of System (BOS) value chain (inverter, mounting, cables, installation) has large cost pressure
- Increasing specialization later in value chain (project development, engineering, procurement and construction (EPC), power production ownership)
- Concentrated solar PV

Canada could take lead in emerging market

Market and Tech Overview

Large and fast growing market but highly commoditized through most of the value chain (with China dominating manufacturing):

PV panel market expected to reach $325B by 2020, $962B by 2030

- Market driven by increasing power demand and decreasing production cost (40% by 2015, 60% by 2030)
- Large expenditures in Asia ($440B in 2030) to meet power needs

Value chain is commoditized, some opportunities in niche downstream applications

- Most innovation through incremental improvements in efficiency and scale
- Large investments in China have resulted in oversupply that will drive consolidation upstream
- Downstream will become specialized to serve final customer needs

Concentrated PV market small, pilot stage tech

- Many companies insolvent or undergoing acquisitions
- Long term competition with low cost thin film PV
- Most competitive in larger, direct sun installations
- Lower cost-of-entry due to less PV content
- Concentrator photovoltaic (CPV) industry installed 40MW in 2011

Canada's Advantage

Canada has a large scale solar company which is an established low-cost player and several smaller companies, with limited domestic need for solar power

Canada has several smaller companies with significant VC backing, but finding difficulty in breaking into market

- >150M VC capital paid-to-date
- Mix of companies along value chain
- Many companies being acquired or facing significant operating problems[1]

Canada has little domestic need for solar except in niche areas

- Solar more expensive even during peak hours given hydro/nuclear as base load, gas for peak
- Could have advantage for offgrid and rural power generation

Investment thesis

Canada's opportunity is to focus on niches such as offgrid power generation for domestic and possible export use

Offgrid power generation

- Offgrid areas (e.g. rural areas with high distribution costs) may benefit from local power generation
- If Canada develops integrated solutions (e.g., solar+ diesel+ water), could be exportable to developing nations

Grow downstream solar systems integrators and applications

- Smaller players can serve regional utilities and companies in domestic Smart Grid applications
- With sufficient expertise could expand to NA market

Niche play in concentrated solar PV

- Many challenges in solar PV are in systems integration and installation
- Unclear if there is a sustainable CDN advantage

1 US National Renewable Energy Laboratory (NREL) "Opportunities and Challenges for Development of a Mature Concentrating Photovoltaic Industry", August 2012

SOURCE: McKinsey Sustainability and Resource Productivity Practice

Renewables and Clean Energy: Wind

Technology Areas Under Consideration

- Wind turbine suppliers (tower, blade, generator, power electronics), OEMs and operators
- Advanced Drive Trains (e.g. permanent magnet generators, advanced gearboxes, rotors, wind forecasting)

Other countries have a clear advantage

Market and Tech Overview

The global market for wind is large, but mostly cost driven with large global players outside Canada and incremental technology innovation

Wind global market to grow to $680B by 2020
- Largest growth in US, Europe and China

Most of value chain is cost driven, with incremental technology development
- Entry of Chinese manufacturers has led to widespread cost pressure
- Increasing standardization of components leads to commoditization
- OEMs optimizing supply chains also placing pressure on suppliers

Continuing incremental technology innovation
- Increase in drivetrain reliability through new gearbox and generator technologies
- Increases in overall efficiency through wind forecasting, dynamic load modulation and rotor designs

Canada's Advantage

Although Canada has domestic wind resources, most power will still be obtained from hydropower/nuclear, and it does not have any well-established wind turbine generator (WTG) players

Canada has domestic wind resources
- Canada has large areas suited to wind farms
- Wind is a potentially cost-effective energy source for remote locations where long-distance power distribution is expensive

Most manufacturing and innovation will be led by Chinese and EU players
- Canada will not have cost or expertise advantage in most areas
- Proximity to US does not reduce cost enough to compete with offshore production
- Specialized components (e.g. cold-weather blades) could be niche but will be competing with Denmark and other EU countries with cold climates

Wind energy is politically favorable and there is a FIT program in Ontario
- FIT programs have encouraged installation of wind farms

Investment thesis

Canada's opportunity is limited to niche domestic consumption

Offgrid power generation
- Wind may be more economical for niche remote applications where long-distance distribution is expensive
- Competing with natural gas and coal, not suitable as sole baseline energy source

Supplementary RES
- Net economic value must be determined in light of inexpensive hydro and nuclear power generation

High technology component supply
- Smaller suppliers could develop advanced components and operational technologies (e.g. wind-forecasting, load modulation)
- Unclear if there is a sustainable Canadian advantage

SOURCE: McKinsey Sustainability and Resource Productivity Practice

Renewables and Clean Energy: Geothermal

Technology Areas Under Consideration

- Power generation using geothermal resources
- Combined Heat and Power (CHP) applications
- Does not include ground source heat pump applications

Other countries have a clear advantage

Market and Tech Overview

Geothermal is a small, slowly growing market with mature technology

Small and slow growth market

- Small market today $3B, mostly in US, Japan
- Most geothermal in Canada located near low-cost hydro, so few incentives for utilities to develop geothermal capacity

Technology is mature with established global leaders

- Technologies for power generation are mature across the value chain
- Technologies for Combined Heat Power are also relatively mature
- Global technology and market leaders already well-established (US, Japan)

Canada's Advantage

Although Canada has large geothermal potential, most of these are not economic given hydro resources, and most technology leaders are in the US and Japan

Canada has large geothermal potential and drilling/exploration experiences and expertise

- Large untapped potential in geo thermal resources, but not as attractive as some other countries
- Historically has not been developed given availability of hydro and nuclear power
- Hot water coming to surface from conventional operations
- Western Sedimentary Basin mapped
- Extensive human resources and business infrastructure for drilling in Western Canada

US and Japan are the market and technology leaders

- Most attractive geothermal resources are in select countries, e.g., US, Japan, New Zealand and Iceland
- As a result, the same countries have developed the technology and market domestically

Investment thesis

Canada's opportunities in geothermal are limited to domestic power generation (where regionally economic) and some CHP applications

Potential for domestic power generation and CHP

- Could be attractive for offgrid applications or integration with building in rural communities
- Canadian Geothermal Energy Association (CanGEA) estimates 5000MW of accessible geothermal in Western Canada

SOURCE: McKinsey Sustainability and Resource Productivity Practice

Renewables and Clean Energy: Uranium Mining

Technology Areas Under Consideration

- Uranium mining , conversion, fuel fabrication and reclamation
- Mining waste management

Canada has a clear advantage

Market and Tech Overview

The global market for uranium and derivative products is large and growing, driven by continued nuclear builds in Asia, with continuing technological innovation

Large global markets in mining and conversion

- $14B mining market by 2020, 5% compound annual growth rate (CAGR), 23% margins,
- $8B conversion, storage and reprocessing market by 2020, 2% CAGR, 5-10% margins

Technology for mining is advancing in niches:

- Methods for efficient and environmentally friendly extraction of uranium ore, refinement and fuel-rod production
- Nuclear base-load matching using load control and energy storage
- Reclamation of spent nuclear material
- Waste management and conversion to revenue products and disposal
- Radiation, health and safety monitoring technologies; early detection and response

Canada's Advantage

Canada has large uranium resources and is well established in supplying global markets

Uranium resources and mining majors

- 3rd highest uranium reserves
- 2nd highest for extraction
- Underground/open mines with heap leaching of low grade ore

Investment thesis

Canada's opportunity is to maintain its position as a top uranium mining nation

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

Renewables and Clean Energy: Nuclear Technologies

Technology Areas Under Consideration

- New reactor construction (reactor, containment, power generation, utilities)
- Reactor decommissioning (nuclear waste handling, worker safety)
- Advanced Fuel cycles
- Small scale nuclear reactors (design, manufacturing)
- Nuclear fusion

Other countries have a clear advantage

Market and Tech Overview

The nuclear reactor market has new builds, opportunities in refurbishment and decommissioning, and long-term technology development in miniature fission and fusion

Most new construction of nuclear power plants in China, France and Russia

- $400B capital expenditures in 2020, mostly in China and Russia
- Delays in Japan and EU due to Fukushima
- $5-6B/unit (1GW)
- Large gov't backed projects, strong advantage to domestic companies and local contractors
- Some activity in thorium based reactors

Refurbishment and decommissioning

- 45-50 GW to retire in US and Japan by 2030
- $1-2B/refurbishment

Small nuclear plants

- Immature technology for remote off grid, industrial applications
- Technology leaders not in Canada

Nuclear fusion

- Still in early stage R&D, with multiple large efforts across US, Asia, EU
- No major roadblocks, but large engineering hurdles making timeline uncertain (>20 years)

Canada's Advantage

Canada has expertise in niche technology development, including CANDU reactor expertise

Canada has some development of technologies to increase the efficiency and environmental friendliness of nuclear plants

Canada has a small-scale fusion reactor effort

Investment thesis

Canada has little opportunity in new reactor builds based on current Candu design

Long term development of next generation fission reactors for domestic use

Small nuclear plants/Fusion

- Long term potential, but significant investment required

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

Renewables and Clean Energy: Bioenergy

Technology Areas Under Consideration

- Biopower (electricity)
- Bioheat
- Biomass collection, processing, and densification

Canada could take lead in emerging market

Market and Tech Overview

The biopower market is fast growing, with mature technology, but is regionally driven, with most of the growth in EU due to regulatory requirements

Small 2012 market for biopower, but fast growth

- $100-200B in capital expenditures in 2020, declining after 2020
- EU markets require biopower due to 20% renewable regulatory requirement by 2020
- Largest capital expenditures in EU and China

Biopower is mature technology

- Retrofit of coal plants is well proven and looking for cost reduction opportunities
- Densification technology is critical for export markets and also relatively mature, with some R&D focused on minor efficiency gains
- Economical biomass collection and processing is significant part of cost, as it is labor intensive

Uncertain public opinion and environmental risks of plant based bioenergy

Canada's Advantage

Canada has large forests and some export potential for pellets, but is not a clear technology leader

Canada has vast forest resources and industry expertise including mill waste and beetle-kill

- Technological leaders in efficient forestry operations, although high labour costs and difficulty to export
- Underemployed forestry workforce

Export market for Canadian wood pellets is small

- Canada currently exports <$500M USD in wood pellets to EU

Some technology development in bioenergy CHP systems

Investment thesis

Canada's opportunity is to develop exportable biomass technologies

Shift to small-scale CHP niche investments for technology

- Large scale bioenergy projects in China or EU unlikely to import CAD technology since combustion/gasification is mature technology

Higher value technologies can be derived by integrating biorefinery concept

- R&D in biorefinery is still fragmented, heavy investment in US and EU academic/industry partnerships
- Integration of biorefinery into current thermal gasification technologies is closest technology to commercialization

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

Renewables and Clean Energy: Biofuels/Biorefinery

Technology Areas Under Consideration

- Next generation biofuels
- Drop-in fuels
- Biogas
- Value added biorefinery products

Potential long term opportunity

Market and Tech Overview

Biofuels markets are large and growing driven by demand for RES, with continuing innovation in 2nd generation biofuels

Bioethanol is large and established market, with greater growth driven by demand for renewable fuels and energy security

- 2010: 98 GL bioethanol demand (51 in US), 23 GL biodiesel (mostly EU)
- 2020: 260 GL bioethanol (89 in US), 64 GL biodiesel (EU and Asia)
- 360 new advanced biofuel (e.g., cellulosic) plants needed in US by 2022 to meet Renewable Fuel Standard 2 (RFS2) mandate (16 GL cellulosic biofuel), only 30 new conventional biofuel plants needed

Woody biomass biorefineries require further R&D

- Biorefinery products likely >10 years away using enzymatic or biochemical processes
- Some biorefinery integration using current gasification techologies (e.g, CHP), but high-value products are uncertain and unreliable due to variability in syngas stream

Biogas is less attractive in markets where inexpensive natural gas is available

Canada's Advantage

Canada has large forests, but these may not be the best precursors for bulk biofuels (e.g. diesel and ethanol), with most industry leaders are in EU/US

Canada has vast ligno-cellulosic feedstock resources (forests, forest residue, and forest processing by-products)

- Lignocellulose not preferred feedstock, due to pretreatment requirements

Significant industry activity in producing 2nd generation biofuels, but mostly in US/EU

- $3B in capital expenditures over next three years for ~1BL/yr cellulosic ethanol, almost all in USA, almost all with agricultural residues

Investment thesis

Canada's opportunity is greater R&D for value-added forest products (e.g. biorefinery)

Woody biomass biorefinery is long-term source of value-added forest products

- Unlikely to compete with agricultural waste for LC ethanol production
- Niche LC chemistry R&D required
- Proven applications of integration with thermal gasification (e.g., CHP) might be closest technology to commercialization

SOURCE: McKinsey Oil and Gas Practice, Market research, expert interviews

Renewables and Clean Energy: Conventional Hydroelectric

Technology Areas Under Consideration

- Conventional hydroelectricity technology (turbines & generators)
- Hydro project management

Canada has a clear advantage

Market and Tech Overview

The hydropower market is large worldwide, but markets tend to be regional, with mature technologies owned by EU firms

Hydro is slow growth, but high value
- $420B in capital expenditures in 2020

Mature technologies, mostly EU owned tech
- 3 EU majors (Alstrom, Andritz)
- Fast growth in BRIC companies
- Increasing cost pressure from China

Limited exportability
- Much of worldwide hydro is state owned
- Emerging markets likely to use domestic rather than foreign engineering
- Net exporter of electricity to US: $3.8B @ $64.91/megawatt hour (Mwh), in exports, $1.3 B @ $56.59/Mwh in imports in 2008

Canada's Advantage

Canada has large domestic hydropower resources and some project management engineering expertise, but top ten technology manufacturers are located elsewhere

Vast water resources and hydroelectric capacity
- 3rd largest hydroelectric power producer in the world
- Attracts energy intensive manufacturing

Project management engineering expertise
- Including international contractors for siting, preparation, heavy civil engineering

No Canadian companies in top 10 turbine or generator manufacturers
- Some presence of EU companies in Canada

Investment thesis

Canada's opportunity is to continue to attract power-intensive industries and export power to the US

Canada could export project management engineering expertise
- Only place in conventional hydro value chain Canada is likely to compete

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

Renewables and Clean Energy: Unconventional Hydro/Marine

Technology Areas Under Consideration

- Run of river hydro and low-head hydrokinetic (in-river)
- Tidal, wave (marine) energy

Canada could take lead in emerging market

Market and Tech Overview

The unconventional hydro market is still nascent with new technologies on the horizon but no clear winner

All unconventional hydro markets are fragmented with moderate R&D, but still anyone's game

- Most feasibility studies determine too costly for amount of power produced

Marine is niche market in some coastal zones

- Most feasibility studies determine too costly for amount of power produced
- Wave energy is also a niche market, and still immature technology

Hydrokinetic (in-river) has large global potential

- 100 GW global capacity of in-river
- Many small start-ups with pilots, mostly in US
- Seems likely to see commercial pilots within 5 years

Canada's Advantage

Canada has both large hydropower resources and technical expertise in innovative hydropower technologies

Large hydropower resources and hydroelectric expertise

- 3rd largest hydroelectric power producer in the world
- Engineering expertise (turbines, fluid mechanics) transferable to unconventional hydro

Several companies developing run of river hydro technologies, likely competition with US companies

- 70 preliminary permits for hydrokinetic in US

Investment thesis

Canada's opportunity is to commercialize and export unconventional hydro technologies

Low-head hydrokinetic turbines have export potential, but may be difficult to prevent entry of large players

- Easy to export small units
- Danger in copying and low barriers to entry
- Immediate scale-up, protect key IP, while focusing on cost reduction for small units for fast adoption and to maintain market share

SOURCE: McKinsey Electricity, Power, Nuclear and Generation Practice

Distribution: Smart Grid (AMI, HAN, Demand/Management, Appliances)

Technology Areas Under Consideration

- Automated Meter Integration (AMI), Home area network (HAN)
- Demand management/response, storage, appliances, program management, financial services

Other countries have a clear advantage

Market and Tech Overview

Smart grid market is large and rapidly growing, but highly commoditized at most points in the value chain

Overall Smart Grid market $41B in 2011 and rapidly growing

- Market driven by long term shift of utilities worldwide to Smart Grid distribution systems
- Market is a mix of global and regional suppliers and (generally) highly fragmented utilities markets

Equipment and network infrastructure value chain commoditized

- Upstream components have little innovation (with exception of power electronics in transmission/distribution), and are commoditized
- Limited opportunities for entry downstream
- Slow adoption by risk-averse utilities
- Some first-mover advantage in software

Major technical issues in Smart Grid pilots include:

- **Cost estimation –** difficult to estimate system costs, overruns publicized
- **Standards** in many cases not yet in place and can cause delays
- **Pricing and distribution models** are difficult to evaluate except at scale, and so are risky
- **Integration of local power sources and large drains** (e.g. PV, storage and EV) still experimental

Canada's Advantage

Canada has some domestic players downstream in the value chain and a less fragmented utilities market than in the US, but most global players are located elsewhere

Canada has a less fragmented utilities market than US

- In majority of provinces, utilities are vertically integrated Crown corporations with some investor owned distributors
- Smart-meter rollouts in Ontario completed in 2010, giving some Canadian companies early advantage
- **Downside:** Crown corporations may be able to implement Smart Grids quickly but may not be economical or exportable
- New Brunswick (NB) Power entering multi-year smart-grid program
  - Part of NB Power reduce and shift demand (RASD) energy blueprint
  - Includes smart thermostats, appliances, dashboards, thermal storage
  - R&D center to create 40 new jobs

Canada has several Smart Grid startups, but no clear winners

Investment thesis

Canada can gain domestic benefits by adopting Smart Grid technologies early and attracting foreign players willing to invest in Canadian markets

Domestic gains from early Smart Grid adoption

- Early adoption could lead to lower domestic power prices, higher utilization of existing resources
- Power utilities are concentrated on EV charging infrastructure, speeding domestic development
- Software and integration are often regional utility-scale solutions

Attract manufacturers and local development of Smart Grid appliances and equipment

- Could bring smart grid manufacturing to Canada
- PV and vehicle integration still being developed
- Downside: margins in Smart Grid appliances slim (5%)
- Other countries following same strategy

SOURCE: McKinsey Sustainability and Resource Productivity Practice

Distribution: Smart Grid (Power electronics in T&D)

Technology Areas Under Consideration

- Power electronics used in distribution: transformers, high-voltage direct current (HVDC), flexible AC transmission systems (FACTS), fault-detection/isolation/resolution, switching, sensing, volt-var, PV and wind power conversion
- Not included is power electronics in vehicles (specialized supply chain described in EV) and consumer electronics (not part of large scale power distribution)

Other countries have a clear advantage

Market and Tech Overview

Power electronics in smartgrid transmission and distribution (T&D) is a large and growing market, with both continuous innovation and the possibility of disruptive change on the horizon

Power electronics in distribution to grow to $10B by 2020

- 3x market growth from 2010
- Driven by large growth in wind and PV markets
- Longer term growth expected in transmission and distribution markets with introduction of thyristor replacements

Continuous Silicon (SI)-based technology improvement with disruptive silicon carbide (SiC) and gallium nitride (GaN) chips on the horizon

- Si-based semiconductor and package cost and performance continually improving
- SiC- and GaN based components still at early stage (laboratory and limited production) but recognized as potentially disruptive
- Chip production likely to be in a few large fabrication facilities
- Power module design still open to innovation and new applications

Canada's Advantage

Most innovation in power electronics is outside Canada, driven by large capital investments and strong consumer and auto industries

Most manufacturing and innovation well developed and located in US, EU and Japan, not Canada

- Large development costs including fabrication facilities, R&D pipeline and supplier networks
- Large players dominate upstream in value chain due to large fixed costs (semiconductor manufacturing and module packaging)
- Development also driven by large consumer electronics, PV, wind and EV industries
- Many players also find horizontal and vertical integration advantageous and are actively expanding their reach and capabilities
- Canadian telecom background may help in power electronics design

Investment thesis

Canada's opportunities are limited to niche applications combining multiple technologies and power electronics

Niche applications in power distribution for domestic consumption or export

- Niches (e.g. specialized high-power switches and sensors, integration into utility systems) still fragmented and not served by the majors
- Limited potential for long term domestic growth/GDP, as major manufacturers will compete with or acquire rapidly growing technologies

SOURCE: McKinsey Advanced Industrials Practice

Buildings and Communities: Advanced lighting

Technology Areas Under Consideration

- Lamp, ballast/optics, luminaire, external control (including system level control, automation)
- Does not include organic light-emitting diode (OLED) and flexible LED displays
- Active power management
- Alternative lighting techniques

Other countries have a clear advantage

Market and Tech Overview

The global market for advanced lighting is large, with strong growth particularly in LEDs, driven by continuous cost reduction and regulations

LED global market expected to grow to $38B by 2020

- Driven by replacement of incandescents (voluntary and required by regulation)
- Also increased overall demand

LED technology rapidly commoditizing upstream, with some areas for innovation downstream

- Upstream chip and packaging in process of commodification and consolidation, with large cost advantages and capacity build-out in China and Taiwan
- Luminaire market fragmented but has many large players

Niche technologies are emerging downstream

- Active power management (fluorescent/LED dimming at a building-wide level)
- Non-conventional lighting (light-pipe/daylighting)

Canada's Advantage

Canadian companies may be present in niche downstream applications, but competition is high throughout all parts of the value chain

Canadian companies unlikely to be competitive in LED lighting except in niche downstream applications

- Upstream entry unlikely, as Chinese and Taiwanese making massive investments in chip manufacture with large gov't subsidies of metal-organic chemical vapour deposition (MOCVD) capacity
- Downstream applications still highly fragmented, but Canadian companies unlikely to be competitive in cost-driven manufacturing
- May be possible to enter where application requires advanced design, manufacturing optimization (e.g. quality control and scaling)
- Canada companies small compared to Chinese players

Several other gov'ts funding general lighting development

- US Department of Environment "L-Prize" for drop-in incandescent replacement spurred development

Investment thesis

Canada's opportunity is to stimulate domestic usage of LEDs, with some possibility of exporting niche products and services

Stimulate domestic luminaire growth through large-scale public LED adoption programs

- Encourage local manufacturers to take advantage of ability to work closely with Canadian contractors and gov't

Possible export of outdoor luminaires

- Chinese market is especially attractive, and gov't street light LED pilot targeting 65% penetration by 2015
- In public projects, partnering with general engineering firms more favorable as they are further downstream
- Procurement is major cost disadvantage – will likely have to do manufacturing in China, limiting Canadian jobs and GDP impact

SOURCE: McKinsey Advanced Industrials Practice

Buildings and Communities: Energy Efficient buildings

Technology Areas Under Consideration

- Advanced windows value chain (raw materials, assembly, services)
- HVAC value chain (manufacturing, services) includes small scale CHP
- Pre-fabricated (pre-fab) EE houses

Canada could take lead in emerging market

Market and Tech Overview

The global windows and HVAC market is large and growing, with most demand in Asia, and relatively mature technologies, emerging pre-fab EE houses

Large and moderately growing demand for windows and HVAC

- $69B windows global market 2011
- $130B HVAC global market 2011
- Moderately growing demand, mostly driven by growth in Asia

Current technology is relatively mature, with some emerging innovative technologies

- Technology innovation has focused on energy efficiency
- Examples: active windows, liquid desiccants for cooling, CHP for heating

Building owners need regulations of incentives for adoption

- Market failure when building owner has to buy the EE equipment, but the renter is the one who saves on energy bills

Prefab EE houses are emerging, but the market for them is still small and immature

Canada's Advantage

Canada has a cold climate, a large window manufacturer and is a leader in net-zero building initiatives, but it is unclear if this will give it a competitive advantage over other global players

Cold climate encourages efficient building adoption
Canada manufactures windows

Canada is a leader in net-zero energy building initiatives

- Net-zero energy homes are promoted, with standards
- Canada Mortgage and Housing Corporation is sponsoring the Equilibrium Sustainable Housing Competition
- Several pilot homes for net-zero passive house
- Energy-Star qualified prefabricated homes have been introduced, including LED/Cine Reflect Lighting (CRL), heat recovery ventilation (HRV), skylights, solar tubes, insulating concrete forms (ICF) foundation, local sourced building materials and no-volatile organic compound (VOC) paints and finishes, $60-$90/square foot

Investment thesis

Canada's opportunity is to capture the domestic benefit of increased building efficiency early, with the possibility of export to global markets

Increase domestic building efficiency through adoption of efficient windows and HVAC

- Majority of residential housing is poorly insulated, with windows accounting for 10-20% of energy losses
- Active window coatings can reduce life cycle costs by 30-45% over 30 year period
- Incentives and/or regulations for adoption might address market failure

Possible export of pre-fab homes, but high labour costs in Canada suggest that this is most likely a domestic market

SOURCE: McKinsey Sustainability and Resource Productivity Practice

Energy Intensive Industrial Processes: EE Industrial Processes

Technology Areas Under Consideration

- Energy efficient processes for a variety of industries including chemicals, steel, mining and other metals, pulp and paper, cement and agriculture

Canada could take lead in emerging market

Market and Tech Overview

Large markets with potential for both continuous improvement and disruptive innovation

Large market with moderate growth

- Industrials drive 32% of the global energy consumption today
- Moderate (1.1%p.a.) growth is expected
- Most growth in China

Current technologies are well established, with potential for process disruptions

- Multiple incremental changes using established technologies can lead to 20-30% energy savings (e.g., system integration across multiple products, minimize waste streams, manage load, power, torque and speed)
- Innovations in enhanced instrumentation, monitoring and data interpreting systems to enable real-time control

Industries are aware of disruptive technologies, but need incentive for adoption

- Examples of potentially disruptive processes:
  - Steel: remove coking process
  - Mining: convert waste to revenue products or benign materials
  - Cement: refuse derived fuels
  - Paper: new products

Canada's Advantage

Canada's has many energy-intensive industries and some small companies with innovative technologies, but there are major competitors in the US and EU

Canada has significant steel, mining and other metals, pulp and paper, cement and agriculture industry today

US and EU are the global market and technology leaders in energy efficient processes and potentially disruptive processes

- Most of the energy efficient processes are known and use US/EU technologies, some manufacturing already moving to Asia given the regional demand
- US and EU viewed as the providers of technology and equipment leaders in energy efficiency equipment and processes

Canada has some small companies with innovative technologies

- Energy consumption avoidance with motor control
- Waste reduction and optimized process control
- Real-time monitoring and control

Investment thesis

Canada's greatest opportunity is to develop process technology that directly increases the competitiveness of Canadian companies

Potential to increase competitiveness of Canadian industrial companies

- Encourage broader adoption of known energy efficient processes (e.g., through capex financing)
- Encourage R&D on disruptive processes could provider longer term cost competitiveness

Some potential to export equipment associated with new processes (if developed)

- Most companies view processes as trade secrets that they would not want to share with competitors
- It is possible to export equipment associated with new processes if developed, but there is limited industrial equipment sector in Canada today

Energy Intensive Industrial Processes: Water

Technology Areas Under Consideration

- Engineering/Procurement/Construction (EPC) firms
- Products (pipes/pumps/valves, membranes, other filtration equipment, chemicals)
- Operation and Maintenance for Industrials and Municipalities (e.g. real-time source water monitoring and treatment efficiency)
- Commercial/Residential use (e.g., water filters/treatment for home) or small isolated communities and ships
- Infrastructure Management (e.g. pipeline condition, pipe network monitoring)

Canada could increase its global competitiveness

Market and Tech Overview

The water market is large, growing and technologically mature in many parts of the value-chain; new technologies face conservative water utilities regulation and scaling issues

Large and fast-growing global market for water

- $515B globally in 2011 equipment , services and operations
- $110B globally in equipment
- Highest growth in membranes and filtration equipment ($18B with >10% growth)
- Effective waste water processing is required for social license to operate in oil and gas industry
- Growing interest in pipeline leakage detection

R&D funding is required for new technology development

- Often little incentive to develop new technologies without regulations
- Many mature technologies already exist today, but innovations are emerging in membranes, filtration and pumps
- Unconventional oil and gas driving waste water treatment innovations

Canada's Advantage

Canada has several promising technology companies, but it has proven difficult to keep attractive technologies within Canada

Canadian companies are strongest in membranes and filtration equipment

- Cluster of water companies in Ontario

Leading technologies are developed in Canada in membranes and filtration equipment

Loss of manufacturing jobs due to foreign acquisition

Developing Electrokinetics water treatment

Investment thesis

Canada's opportunity is to grow and retain its existing strength in membrane and filtration, and attract foreign development to Canada, growing its water hub

Continue to grow existing strength around membranes and filtration equipment for both domestic and export market

- 2000+ directly employed in Ontario
- Need to help smaller start-ups scale-up: traditionally difficult given Canada's domestic market is weak

Become beach head for foreign companies that are trying to enter NA market

- Attract European players to test our NA market in Canada

Waste water treatment technology for oil and gas has some potential for export

- Potential to export for mining operations
- Potential to export for other unconventional oil and gas operations

SOURCE: McKinsey Sustainability and Resource Productivity Practice, expert interviews

Transportation: Fuel Cell Systems

Technology Areas Under Consideration

- Hydrogen fuel cells for vehicles
- Refueling infrastructure
- Integration of Fuel cells with grid-scale storage

Potential long term opportunity

Market and Tech Overview

The hydrogen fuel cell market is potentially large after 2020-2030 but until faces significant technology and adoption barriers in the interim

Hydrogen fuel cells seen as long term technology for vehicles

- History of unfulfilled promises (e.g. hydrogen economy support)
  - No major government commitments, niche areas in California, Iceland

Fuel cells depend on carbon regulation

- 10 gCO2/km: <5% market share by 2020, 30% market share by 2030
- 95 gCO2/km: 0% market share in 2020, <2% market share by 2030

Fuel cells compete with batteries for small vehicles, and biofuels for large vehicles

- Many experts say battery EV are likely to see commercialization first, due to rapid drop of lithium-ion battery prices
- Hydrogen vehicles also poses significant challenges for the OEM as they will now require 4 engines in parallel

Fuel cells in grid storage are promising but still have unproven economics compared to other forms of energy storage

Canada's Advantage

Canada has invested in fuel cell manufacturing and has developed some expertise – thus, already establishing Canada as a fuel cell manufacturer

Major R&D in Canada

Abundant natural gas leads to interim (non-renewable) hydrogen supply through reforming

- Some CDN expertise in both reforming and electrolysis

Investment thesis

Canada's opportunity is limited to continuing to fund long-term fuel-cell R&D and commercialization

Maintain R&D, with appreciable cost reduction requirements for continued funding

- Focus on platinum alternatives, synergies with near-term EV market , and infrastructure including grid-storage