ADVANCED ENERGY PRIMER

Foundations of the Energy Industry

The Queen's Energy & Commodities Association (QECA) is an undergraduate club focused on energy and commodities. As a joint-venture Engineering-Commerce club, QECA aims to showcase the relevance of these sectors from both a technical and financial perspective. As Canada is uniquely poised as a major producer of energy and raw materials, we explore the technology and business environment to develop these resources while highlighting the opportunities and careers available. QECA's primary objective is to raise the profile of these industries at Queen's through hosting presentations, socials and industry speakers as well as developing partnerships with conferences and clubs on-campus.

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TERMINOLOGY

Aboriginal: defined in Section 35 of the Canadian Constitution as referring to the first inhabitants of Canada, including First Nations, Inuit, and Metis people. It is both a legal term, as well as a commonly used term. It is an adjective, not a noun, and to be capitalized (like African, or European).

Ally-ship: an Ally to Aboriginal people is a Non-Aboriginal who walks beside, not in front. It is not about taking the lead, but listening and acting in solidarity in ways that Aboriginal people deem acceptable. Allies to Aboriginal people listen and stand in solidarity with them. Without this, non-Aboriginal people cannot know what actions are acceptable.

Alternating current (AC): type of electric current that oscillates between flow direction, showing a sinusoidal current wave pattern [1]; typical form of electricity that is used by consumers.

Capital costs: cost of upgrading, maintaining or acquiring new renewable facility assets.

Clean Energy Fund: Commenced in 2009, this fund promotes clean energy research, development and demonstration projects with an objective to "support the development of new, cutting-edge technologies that are essential for reducing GHG". [2]

Direct Current (DC): form of electric current that flows in a singular direction, showing a straight line current pattern. [1]

Dispatchable generation: source that can provide energy on demand. [3]

Energy: power created from using resources.

GHG: greenhouse gases; gases with the ability to contain heat in the atmosphere, contributing to global warming including carbon dioxide, methane, etc. [4]

Grid: system of power lines, electrical transformers and substations with the sole purpose being to connect energy producers to consumers.

Hybrid projects: two separate renewable energy technologies, such as wind and solar, located on the same land to share grid links and increase reliability of power production. [5]

IESO: Independent Electricity System Operator; responsible for managing Ontario's electricity.

kWh: kilowatt hour; energy unit equivalent to 3.6 megajoules. [6]

Load: power demanded by users.

Mtoe: million tonnes of oil equivalent; energy unit equal to the quantity of energy gained through burning one million tonnes of crude oil (approximately 11,630,000,000 kWh). [7]

OPEC: Organization of the Petroleum Exporting Countries [8]; organization of countries who work together to "stabilize the oil market". [8]

Ramp rate: rate at which a power plant can increase or decrease output.

Ramping: the ability of a generating facility to start and stop on command.

Renewable energy systems: these include the generation facilities included, but not limited to, solar, wind, hydro, bioenergy, and thermal power, as well as energy storage and integration infrastructure.

A Note on Language – what are the right words when discussing Indigenous matters and when do you use them?
Terminology is tricky; a term that might be acceptable to some may be offensive to others, however fear of using the "wrong" word should never prevent discussions about or with Aboriginal peoples. Where possible, the specific name of the community (note spelling and pronunciation) is always preferred. Recognize as well that there is no general Aboriginal culture, history, or heritage; they are each unique to the community.

In 2016, over 13,000 Mtoe of energy was consumed worldwide. Energy is consumed in our daily life from the simple act of switching on a light to complex manufacturing processes creating our goods. Harnessing energy transformed gave us the ability to manufacture and allows for the comforts that we know today, such as our heating units. However, many people do not understand the global impact of energy generation and use. This guide will act as an overview to introduce you to the world of energy.

GENERATION

Energy can be produced from renewable and non-renewable sources. A large move towards renewable energy production has been made due to the environmental benefits, with 11.3% of the world electricity in 2016 being from renewable sources, an increase of 4.4 % from 2011. [5]

Solar

Solar panels are made of photovoltaic cells, which take sunlight and convert it into DC electricity. A device known as an inverter takes the direct current electricity and converts into AC electricity. The converted electricity is then sent to an electrical panel which sends the power to lights and appliances. There are no emissions during use. [10]

Wind

Wind turbines utilize aircraft wing shaped blades that are rotated by the wind. The blades are attached to a rotor and a shaft, which turns a generator producing electricity. The amount of electricity produced from a wind turbine is dependent on various factors, such as the wind speed, turbulence, the height of the turbine towers, and if the turbine use. a gear box to increase the rotational speed from the shaft to the generator. There are no emissions during use, however other environmental consequence such as noise pollution exist. (htt10)

Hydroelectric

Hydropower systems are driven by the kinetic energy of water as it flows downstream. Hydropower facilities can vary in size, but they all use a dam (diversion structure) to divert the natural flow of the water to generate power. The water's energy is converted into electricity through turbines and generators, and then fed back to the grid as electricity. Hydroelectric power, while renewable, can impact biological ecosystems of the surrounding region. [12]

Nuclear

Nuclear power is the product of nuclear fission reaction in which uranium atoms are bombarded with neutrons. This reaction releases energy, heating water to produce steam. The steam is channelled to drive a turbine that produces electricity. Although it has a high fixed cost, nuclear power generators provide the energy grid with a stable source of electrici ty at a low variable cost. Emissions are minimal,

which has been an attraction as governments try to achieve lower carbon emissions, although spent nuclear fuel must be handled and stored properly.

Oil and Gas

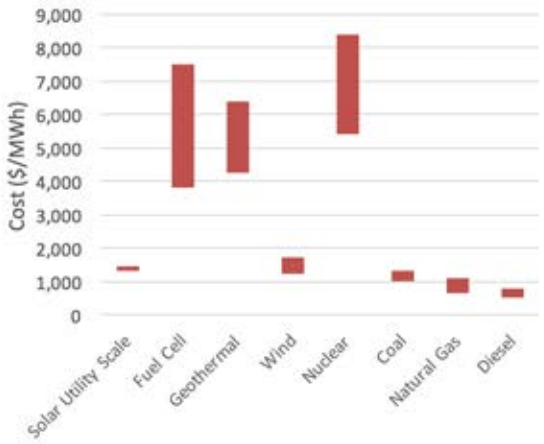
Oil and gas are a naturally occurring mixture of hydrogen and carbon atoms (hydrocarbons) which are found in underground reservoirs within sedimentary rocks. Crude oil is extracted from the rock reservoirs and is often mixed with natural gas, carbon dioxide, saltwater, sulphur and/or sand, and must be separated before use in power generation, plastic, lubrica tion, or other alternate applications. The technology to convert natural gas to power offers a range of efficiency and flexibility. Combustion turbines can quickly start-up (i.e., some within five minutes) to respond to periods of high demand/prices.

COSTS ASSOCIATED WITH PRODUCTION

Capital Costs

Energy production is a capital intensive industry that requires a large upfront payment to build facilities, transmission lines and other vital infrastructure. The typical range of capital costs of various projects can be seen on a $US/MWh basis on the graph to the left. [13] As shown, typical oil and gas production is less capital intensive than large scale renewable energy production.

Although demands for energy will increase with population growth and development, capital costs have fallen across the energy industry, particularly within the solar and wind subsectors. This fall can be attributed to increased efficiency of energy production due to technological improvements. As a result, investors are realizing greater returns on their renewable investments and will be more willing to engage in these projects [13]

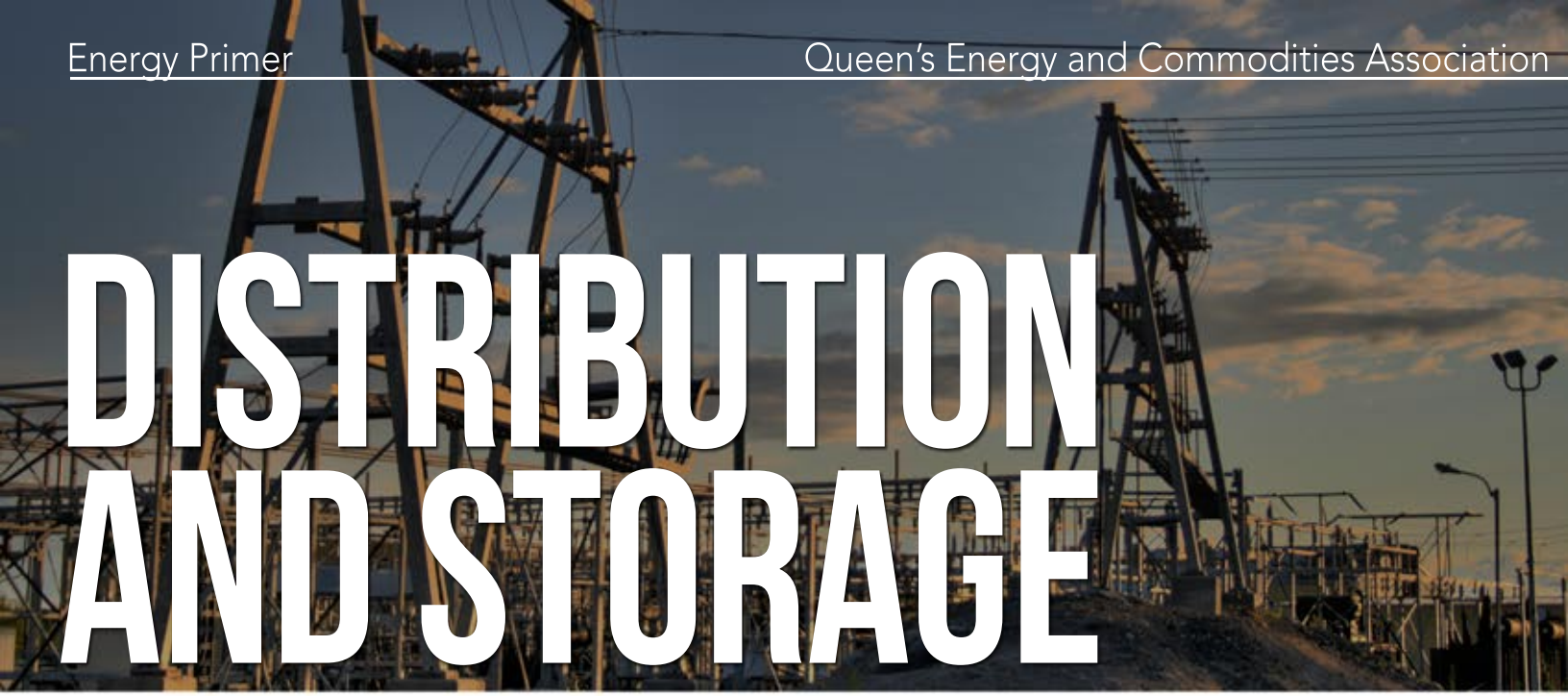


Operating Costs

Operating costs have fallen due to increased efficiency, technological improvements and mass production. Operating costs represent a small portion of total costs, especially at utility or commercial scales. The emergence of hybrid projects has the potential to further reduce operating costs by as much as 13% by spreading out maintenance, equipment, and personal and overhead costs. [5]

SUBSIDY CONSIDERATIONS

Government subsidies assist in financing energy production projects, allowing private companies to afford the capital intensive undertaking. On April 13, 2017, Orsted, a Danish-based renewable energy company, was awarded the right to construct three offshore wind farms in the German North Sea and announced that two of these projects would be completed without the use of government subsidies. [14] Although this unprecedented action depicts the increasing ability for renewable energy to compete with traditional energy generation, renewable energy is still very dependent on government subsidies. The Government Canada for example, supports clean energy research through the Energy novation Program with a 24 million budget through 2017 [14], in addition to the Clean Energy Fund and a plethora of other projects.



DISTRIBUTION AND STORAGE

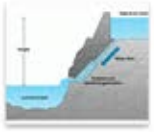
Distribution Network

Electric-power transmission lines carry power from generating plants to the distribution systems that feed electricity to domestic, commercial and industrial users.The role of grid operators is to ensure that power supply always equals real-time power demand. This balancing act is achieved by attempting to accurately forecast the load with controllable generation assets, ready to be dispatched if needed. Baseload facilities cover the minimum demand while daily peaks in energy demand are met by ramping up dispatchable generation sources. The ability for dispatchable generation to ramp up and down quickly is critical to managing variable loads and grid stability. The variability of renewable energy generation sources adds an additional challenge, not previously faced by the grid. Renewable energy resources are inherently variable due to characteristic weather fluctuations. This becomes increasingly difficult to manage as the fleet of renewable energy resources grows. [15]

Energy Storage

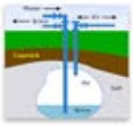
To allow stability of the grid, energy storage is used. Energy storage is technology that allows energy to be stored and then introduced to the grid when demand is high. For example, a strong wind can power a wind turbine in the middle of the night, creating electricity. As demand is low during the night, the energy can be stored until demand increases. When the increase occurs, this energy can then be returned to the grid and used by consumers. The energy can be stored as kinetic, potential, chemical or thermal energy by the battery module. Examples of energy storage include:

Flywheel



Pumped Hydropower

Battery



Compressed Air

Through the use of energy storage, renewable energy is made to be a more viable and attractive mode of energy generation. As mentioned, renewable energy can provide intermittent sources of energy. Energy storage allows for the ability of the storage of the energy for later use. This allows for a constant stream of energy to be introduced to the grid that is proportionate to the energy demand. [18]

Power Marketing

Typically, there are two energy markets, day-ahead and real-time, that work together to ensure demand is met. The Day-Ahead Energy Market is dictated by demand forecasts issued by the IESO on a daily basis. Generators submit offers to the IESO indicating the amount of energy they can supply and at what price. The IESO accepts the lowest-cost offers to supply electricity until sufficient megawatts are available to meet Ontario's demand [21]. The day-ahead market lets market participants commit to buy and sell electricity a day prior to the operating day to help avoid price volatility. The Real-Time

Energy Market allows participants buy and sell wholesale electricity during the course of the operating day to balance the difference between day-ahead commitments and real-time demand [22]. Some types of generators are more expensive to operate than others – as a result, the wholesale price of electricity rises as more expensive forms of genera tion are brought online to meet demand. A new market clearing price (MCP) for electricity is set every five minutes [21].

In addition to energy markets, renewable energy can be purchased through power purchase agreements (PPAs). A PPA is a contract between renewable energy developers and a buyer. The contract allows developers to secure financing and allows the buyer to save money on their energy costs by locking in predictable long-term pricing [23].

Social and Political Impacts

Energy provides the basis for a high quality of life. Energy can separate a thriving from a poor country. As countries do develop, their need for cost effective energy sources increases to power industry, healthcare and business. The goal of many developed regions, such as North America, is to assist the developing countries, such as India, in reducing energy consumption. Without increased energy efficiency, global energy demand will increase by 123% from 2010 to 2035. [24]

The cost of oil is strongly rooted in politics. The price of oil since 1960 has been largely dictated by OPEC, which is an organization interested in providing oil price stability for consumers and producers. The organization is made up of governments from the largest oil producing companies who can therefore control the supply of oil to the market. [25] The price of oil plummeted from $145 to $34 due to the global recession, showcasing the close tie between the global economy and oil prices. [26]. In comparison to the volatile price of oil, renewable energy presents a reliable energy source in terms of economics. [27]

Aboriginal People and Energy

Aboriginal voices are an important perspective in the

energy industry, as energy projects often negatively affect Aboriginal communities and surrounding resources, such as water, animals, and climate. Recently, there have been many protests that have caught the media's attention; North Dakota Access Pipeline protest by the Standing Rock Sioux Tribe (1) and Kinder Morgan Pipeline protests by the Squamish Nation, Tsleil-Waututh Nation, Coldwater Indian Band and Upper Nicola Band (2). It is not just protests against pipelines; in 1990 the Inuit and Cree people protested against the James Bay hydroelectric project. Often protests involve land disputes and discuss discrimination against Aboriginal people.
These protests often arise from a difference in worldviews regarding land. The Indigenous worldview sees the land as sacred and often as a gift from the Creator, whereas Western worldview sees the land and its resources as open for development and extraction for the benefits of human beings. Even with differing perspectives, by utilizing negotiation, listen ing and respect, a successful partnership can result.

Aboriginal Approach in Remote Communities

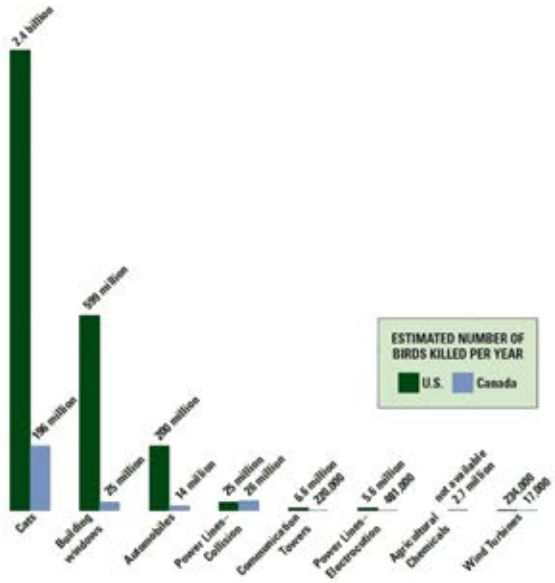
Aboriginal people have a very different worldview and this affects their priorities when it comes to the energy systems in their communities. The Smart Energy Ladder, as shown below, is long term energy plan and a powerful way to help communities that are off-grid to build energy systems that are more reliable and environmentally sound than diesel power.

1. Develop a Long-term Energy Plan and Map
2. Reduce Energy Demand
3. Promote Energy Efficiency Practices
4. Install a Better Diesel and Distribution System
5. Explore the Potential of Combined Heat & Power (CHP)
6. Build more Energy Efficient Infrastructure
7. Develop Renewable Energy & Grid Interconnection Options

Environmental Impact

Renewable energy has a lower environmental impact than non-renewable energy. The petroleum industry poses a significant potential hazard to the environment. The industry is a significant contributor to air pollution, which is linked to acid rain, global climate change, and human toxicity. Water usage and pollution is another major concern for the petroleum in dustry poses a significant potential hazard to the environment. The industry is a significant contributor to air pollution, which is linked to acid rain, global climate change, and human toxicity. Water usage and pollution is another major concern for the petroleum industry. In the Alberta Oil Sands, an average of about 3 barrels of fresh water is consumed for every barrel of oil produced [28]. Regulations are driving the industry to a more sustainable future; innovations such as carbon capture and storage and effective water recycling are leading to positive change in the industry [29].

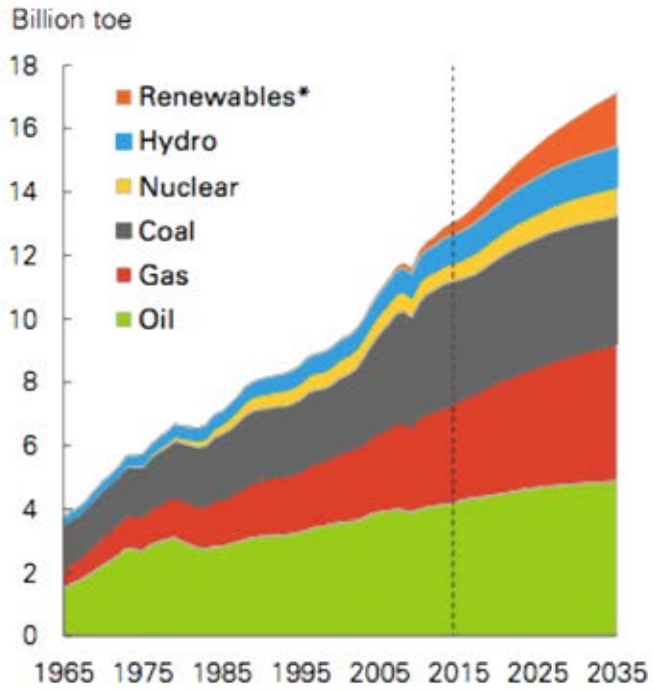
While renewable energy projects have no global warming emissions associated with generation, there are other issues. [30]. Environmental impact associated with solar and wind farms are loss of habitat as well as flying animal deaths. However, a recent National Wind Coordinating Committee (NWCC) concluded that these impacts are relatively low and do not pose a threat to species populations, as shown in the figure. Hydroelectric reservoirs cause flooding which destroys forest and wildlife habitat. [31]. [32] Nuclear reactors create radioactive wastes such as uranium mill tailings and used reactor fuel. These materials can remain radioactive and dangerous to human health for thousands of years. Although the amount of waste produced is relatively low, the issue faced is that there is no long-term solution to dispose of this material [33].



Breakdown of Energy Production

Renewable energy will continue to face immense challenges before it will be able to attain global pro-

minence due to a lack of reliability and integration costs [34]. The current energy consumption mix can be seen in the image on the next page. The graphic details renewable energy's 3% share in primary energy in 2015, as well as the forecasted valuillustrating a rapid increase in the consumption of renewable energy until 2035. These forecasts however, are greatly controversial due to the current energy mix and the dominance of fossil fuels; McKinsey research projects that fossil fuels will remain the principal source of energy until 2050 because of the reliability of fossil fuels and the extensive investments made within this sector. [34] In order to help enhance the adoption of renewable energy generation, it is necessary to implement policies to prevent the continued investment into and use of fossil fuels while supporting renewable energy. [35]



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