INFO SHEET GRAPHIC

TURKSTRA CHAIR IN URBAN ENGINEERING

UNIVERSITY OF WATERLOO
FACULTY OF ENGINEERING
Department of Civil & Environmental Engineering

STATUS ON SUSTAINABILITY | ENERGY

Sustainable energy is the balanced approach to meeting the 'Trilemma' of Energy Security, Energy Equity, and Environmental Sustainability. While closely related to renewable energy, which can be rapidly replenished, sustainable energy goes further to ensure that current energy usage does not compromise future generations' ability to meet their energy needs. It also aims to reduce greenhouse gas emissions and contribute to social and economic development (IPCC, 2012; IRENA and ILO, 2022; Johns Hopkins, 2021; WEC, 2022).

TRENDS IN ENERGY

GLOBAL TRENDS

FOSSIL FUEL DEPENDENCE:

- As of 2020, fossil fuels have accounted for over 80% of the global energy supply since the 1950s (IEA, 2020).

GROWTH OF NATURAL GAS:

- Natural gas is expanding more rapidly than any other fossil fuel, with an annual growth rate of 1.1%, outpacing the growth of liquid fossil fuels at 0.6% and coal at 0.4% (EIA, 2019).

FASTEST GROWTH OF RENEWABLE ENERGY:

- Renewable energy is the fastest-growing sector in global energy with electricity generation increasing at an annual rate of 3.6% and overall consumption increasing at 3% from 2018 to 2050, while nuclear energy trails with a 1% annual growth rate (EIA, 2019).

NUCLEAR ENERGY'S AMBIGUOUS FUTURE:

- Nuclear energy contributes approximately 25% of the world's clean electricity, trailing only hydropower, yet its future is clouded by contentious issues such as cost, safety, waste management, and proliferation risks (Bowen & Guanio, 2023; WNA, 2023).

RISING GLOBAL ENERGY CONSUMPTION AND SECURITY CHALLENGES:

- In 2022, global primary energy consumption rose by 1%, reaching 3% above pre-COVID 2019 levels, even as energy security was compromised due to ongoing supply chain issues and geopolitical conflicts like the Ukraine crisis (Energy Institute, 2023).

TRENDS IN CANADA

- In 2019, Refined Petroleum Products constituted 40% of Canada's energy consumption, followed by natural gas at 36% and electricity at 16% (CER, 2023).

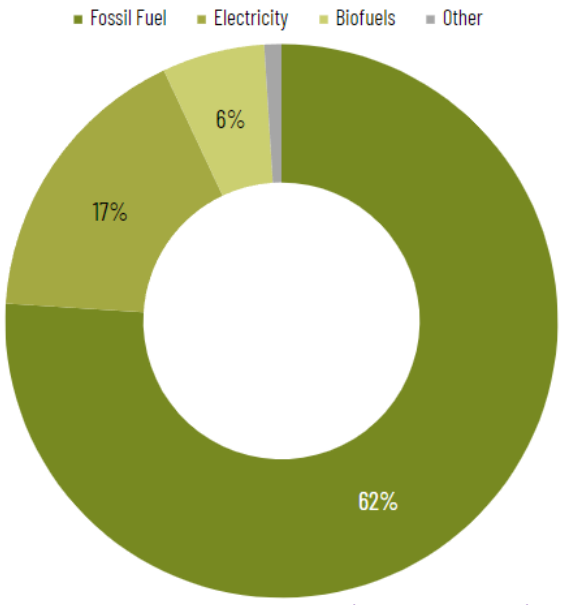

Figure 1. End-Use Fuel Demand in 2019 (CER, 2023; NRC, 2021)

- In Canada, 13,486 petajoules (PJ) of primary energy covers all sectors and transformation processes, while secondary energy is for final consumers; some fuels are also used as non-energy feedstock.

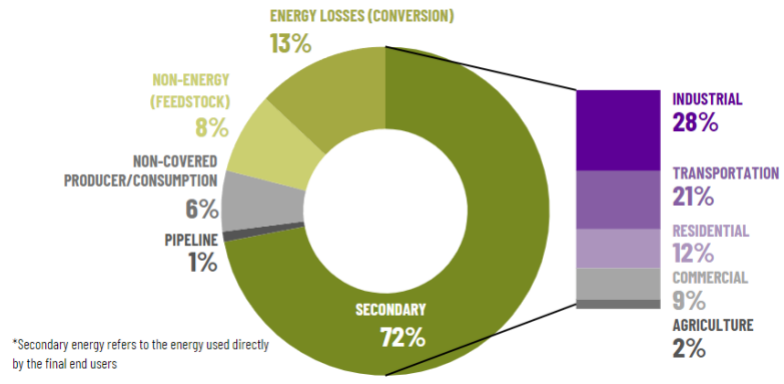

Figure 2. Primary and Secondary Energy Use by Sector, 2018 (NRC, 2021)

- Canada's crude oil and lease condensate production is projected to increase by an astounding 123%, contributing to a 5.3 million barrels per day rise by the year 2050. This surge is largely attributed to the development of oil sands, especially as global oil prices gradually increase and easily accessible resources deplete (EIA, 2019).
- Canada's natural gas production is expected to reach 6.8 trillion cubic feet (Tcf) by 2050, marking a nearly 20% increase. Along with the United States and the Middle East, Canada will account for about half of the natural gas consumption associated with oil and natural gas extraction activities from 2018 to 2050 (EIA, 2019).

TRENDS IN ONTARIO, CA

- In 2019, 92% of Ontario's electricity came from zero-carbon sources: nuclear (59%), hydroelectricity (24%), wind (8%), and solar (1%), with the bulk of its generating capacity in southern Ontario and key hydro stations in the Ottawa and Moose River Basins (CER, 2023).
- Operating since the early 1990s, the four CANDU 850 reactors at Darlington nuclear power plant fulfill approximately 20% of Ontario's electricity demand (OPG, 2023; WNA, 2023).
- By 2014, Ontario phased out coal-fired electricity, which once contributed 25% to its energy mix in 2003, leading to a significant reduction in greenhouse gas emissions, with 2020's emissions at just 6% of Canada's total from power generation (CER, 2023; Ontario, 2023).
- In 2019, Ontario's energy demand was 3,150 PJ, with the industrial sector leading at 35% of the demand, followed by transportation (30%), residential (19%), and commercial (16%); it ranked second in Canada's total energy use and ninth per capita (CER, 2023).

TRENDS IN WATERLOO, ON

- In the Waterloo Region, residential energy use accounts for 40%, industrial for 31%, and commercial for 29%, with households primarily consuming electricity and natural gas (WRCE, 2022).

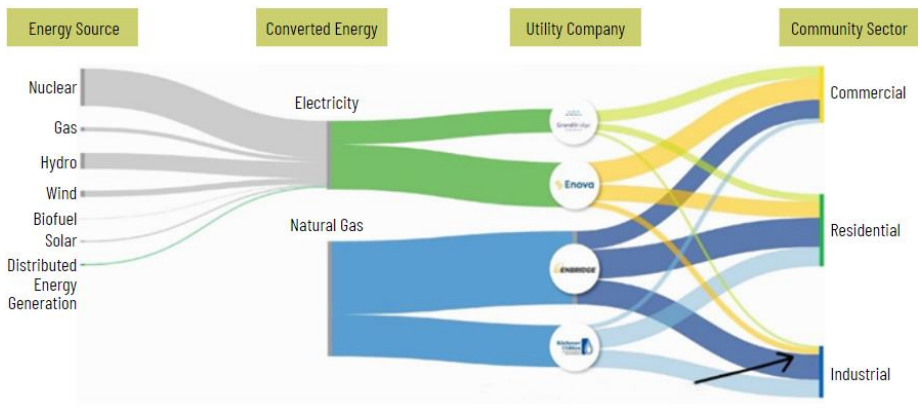

Figure 3.Sankey diagram showing energy flows from generation to consumption in Waterloo Region (WRCE, 2022)

- Only 0.8% of electricity is locally generated in the area, far below the target of 43% (WRCE, 2022).

UNIVERSITY OF WATERLOO RESEARCH

- The University of Waterloo Laboratory for Emerging Energy Research explores advanced energy solutions, focusing on nanotechnology-enhanced biofuel combustion and nanostructure applications in energy production and storage (University of Waterloo, 2023a).
- Focused on complex energy issues, the Waterloo Institute for Sustainable Energy (WISE) emphasizes multidisciplinary research and real-world problem-solving. Partnering with the Karlsruhe Institute of Technology, WISE co-leads the Affordable Energy for Humanity (AE4H) initiative, aiming to enhance global access to affordable, clean energy (WISE, 2023).
- The Power and Energy Systems Group stands as a prominent North American research entity, extensively covering areas from active power filters to microturbine-based power generation, showcasing broad expertise in power engineering research and solutions (University of Waterloo, 2023e).
- The Wind Energy Group concentrates on comprehensive research in wind turbine aerodynamics, aeroacoustics, and energy conversion, including aspects like wind resource assessment, blade design, and off-grid hybrid wind systems, ensuring efficient and environmentally friendly wind energy development (University of Waterloo, 2023f).
- The Green Energy and Pollution Control Research focuses on advancing nanoaerosol measurement, nanofiber fabrication for efficient air filtration, and innovative simultaneous absorption of NOx and SO_2, prioritizing environmental and health safety (University of Waterloo, 2023d).
- The Fuel Cell and Green Energy Lab focuses on understanding and improving green energy conversion technologies, specifically analyzing and modelling Polymer Electrolyte Membrane Fuel Cell materials and processes, and characterizing biodiesel fuel spray droplet formation (University of Waterloo, 2023c).
- The Materials Interface Foundry focuses on several areas, including Climate and Environment Research, aiming to address global sustainable energy challenges and related issues of food, water, and security (University of Waterloo, 2023b).

SUSTAINABILITY DIMENSIONS

ENVIRONMENTAL IMPACT

- Globally, 78% of GHG emissions are from energy use and production, increasing to 81% in Canada, influenced by the nation's extreme climates, vast geography, and dispersed population (NRC, 2021).

ECONOMIC IMPACT

- In 2020, Canada's energy sector contributed 8.1% ($168 billion) to the nominal GDP, with a direct impact of 5.8% ($121 billion) from petroleum (3.9%), electricity (1.8%), and others (0.2%), and an indirect impact of 2.3% ($48 billion) (NRC, 2021).

SOCIAL IMPACT

- In 2020, Canada's energy sector supplied 845,500 jobs (4.7% of total employment), with 293,000 direct and 552,500 indirect roles. This includes a 1.6%

direct energy employment contribution, and 3.1% indirect, with around 15,000 off-reserve Indigenous employees (NRC, 2021).

RELEVANCE TO UNITED NATIONS SUSTAINABLE DEVELOPMENT GOAL (UN SDG)

(United Nations, 2023)

7 AFFORDABLE AND CLEAN ENERGY

7.1: Ensure universal access to modern energy services.
7.2: Increase global renewable energy use.
7.3: Double the improvement rate in global energy efficiency.
7.a: Boost global cooperation for clean energy access and investment.
7.b: Expand sustainable energy infrastructure and technology in

11 SUSTAINABLE CITIES AND COMMUNITIES

11.6: Reduce cities' environmental impact per person, noting the indirect benefit of sustainable energy in enhancing air quality and managing waste

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

12.2: Promote sustainable, efficient natural resources use, indirectly emphasizing responsible energy management and consumption

13 CLIMATE ACTION

13.1: Enhance climate resilience, indirectly linked to energy through the vital role of sustainable, renewable sources in mitigating climate change impact

TOWARDS SUSTAINABILITY

INNOVATIONS IN PRACTICE

Canada is actively pioneering numerous initiatives for substantial innovation and advancement in the energy sector (CERIN, 2021; NRC, 2023b).

- On-road Transportation Decarbonization: Canada's Energy Innovation Program promotes the use and development of low-emission vehicles and more efficient transportation, focusing on medium and heavy-duty vehicles.
- Carbon Capture, Utilization, and Storage: Canada is actively funding and promoting research and development in carbon capture, utilization, and storage to advance the commercial viability of these crucial technologies.
- Clean Fuels and Industrial Fuel Switching: Canada is enhancing clean fuel use, focusing on electricity, hydrogen, and biomass in various sectors to notably reduce industrial CO_2 emissions.
- Canadian Emissions Reduction Innovation Network: A nationwide network in Canada, aims to hasten the progress and application of technologies reducing methane emissions in the oil and gas sector, aiming for effective emission management and regulatory compliance.

POLICY AND REGULATIONS

- Canada's Pan-Canadian Framework aims to cut emissions by 40-45% by 2030, working towards net-zero by 2050 (Environment and Natural Resources, 2018; Environment and Natural Resources, 2022a).
- Canada's Renewable Fuels Regulations require fuel producers and importers to maintain an average of 5% renewable content in gasoline and 2% in diesel and heating oil to reduce greenhouse gas emissions (Environment and Natural Resources, 2018).
- Canada's Clean Fuel Regulations aim for a 15% cut in fuel carbon intensity by 2030, incentivizing the adoption of hydrogen, biofuels, and other low-carbon fuels, backed by a $1.5 billion Clean Fuels Fund (Environment and Natural Resources, 2022b).
- Canada's Energy Efficiency Act requires dealers to ensure that energy-using products meet national standards and are properly reported and labeled before inter-province shipment or importation (NRC, 2023a).

FUTURE PROJECTIONS

- To achieve net-zero emissions by 2050, Canada is focusing on reducing emissions from transportation, which make up 22% of the country's total emissions, aiming to benefit public health, the environment, and the economy (NRC, 2023b).

ACKNOWLEDGEMENTS

The project is funded in part by the Sustainability Action Fund (SAF) at the University of Waterloo. The project proposal "Status on Sustainability Infosheets and Infographics" was awarded funding by the University of Waterloo Sustainability Office in 2023 and selected by the President's Advisory Committee on Environmental Sustainability (PACES).

REFERENCES

Bowen, M., & Guanio, K. (2023). A critical disconnect: Relying on nuclear energy in decarbonization models while excluding it from climate finance taxonomies . (). US: Center on Global Energy Policy, Columbia University SIPA.

CER. (2023). Provincial and territorial energy profiles – canada. Verkregen van https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html

CERIN. (2021). Canada emission reduction innovation network. Verkregen van https://www.cerinprojects.ca/

EIA. (2019). International energy outlook 2019 with projections to 2050. (). Washington, DC 20585: U.S. Energy Information Administration, U.S. Department of Energy.

Energy Institute. (2023). Statistical review of world energy. (). London, UK: Energy Institute, KPMG and Kearney.

Environment and Natural Resources. (2018). Federal renewable fuels regulations: Overview. Verkregen van https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/renewable/overview.html

Environment and Natural Resources. (2022a). Canada's climate plans and targets. Verkregen van https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview.html

Environment and Natural Resources. (2022b). What are the clean fuel regulations? Verkregen van https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/about.html

IEA. (2020). World energy outlook 2020. (). France: International Energy Agency.

IPCC. (2012). Renewable energy sources and climate change mitigation. (). NY, USA: Cambridge University Press.

IRENA and ILO. (2022). Renewable energy and jobs - annual review 2022. ().International Renewable Energy Agency, Abu Dhabi and International Labour Organization, Geneva.

Johns Hopkins, S. (2021). Renewable energy vs sustainable energy: What's the difference? Verkregen van https://energy.sais.jhu.edu/articles/renewable-energy-vs-sustainable-energy/

NRC. (2021). Energy factbook 2021 -2022. (). Canada: Natural Resources Canada.

NRC. (2023a). Energy efficiency regulations. Verkregen van https://natural-resources.canada.ca/energy-efficiency/energy-efficiency-regulations/6845

NRC. (2023b). Energy innovation program. Verkregen van https://natural-resources.canada.ca/science-and-data/funding-partnerships/opportunities/grants-incentives/energy-innovation-program/18876

Ontario. (2023). The end of coal. Verkregen van https://www.ontario.ca/page/end-coal#:~:text=Ontario%20enshrined%20its%20commitment%20in,to%20generate%20electricity%20in%200ntario.

OPG. (2023). Darlington nuclear station. Verkregen van https://www.opg.com/power-generation/our-power/nuclear/darlington-nuclear/

United Nations. (2023). Sustainable development - the 17 goals. Verkregen van https://sdgs.un.org/goals

University of Waterloo. (2023a). Emerging energy research. Verkregen van https://uwaterloo.ca/emerging-energy-research-laboratory/

University of Waterloo. (2023b). Energy and climate research -materials interface foundry climate and environment research. Verkregen van https://uwaterloo.ca/materials-interface-foundry/materials-interface-research/energy-and-climate-research

University of Waterloo. (2023c). Fuel cell and green energy lab. Verkregen van https://uwaterloo.ca/fuel-cell-green-energy-lab/research

University of Waterloo. (2023d). Green energy and pollution control research lab. Verkregen van https://uwaterloo.ca/green-energy-pollution-control-research-lab/research-0/nanofiber-electrospinning

University of Waterloo. (2023e). Power and energy systems group. Verkregen van https://uwaterloo.ca/power-energy-systems-group/

University of Waterloo. (2023f). Wind energy research. Verkregen van https://uwaterloo.ca/wind-energy-research/

WEC. (2022). World energy trilemma index 2022. (). England and Wales: World Energy Council and Oliver Wyman.

WISE. (2023). Waterloo institute for sustainable energy. Verkregen van https://wise.uwaterloo.ca/

WNA. (2023). World nuclear performance report 2023. (). England and Wales: World Nuclear Association.

WRCE. (2022). WR community Energy 2022 progress report: Energy transition pillars. (). Waterloo, ON, Canada: WR Community Energy.

AUTHORS Tamanna Kabir
GRAPHIC DESIGNER Javier Fierro
CONTRIBUTORS
PEER REVIEWERS Brandon Schupp, Dr. James Craig
PROJECT OWNERS Dr. Nadine Ibrahim, Dr. Dwarak Ravikumar