Modeling renewable energy integration in Canada's remote communities

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Canada

Canada's Northern and Remote Communities

Northern and remote communities

- Not connected to the North American electrical grid nor to the natural gas pipeline network
- Long-term settlement (5 years or more) with at least 10 dwellings
- 220K people living in 280 remote, off-grid communities, roughly 190 use diesel as primary energy source
- Extreme location & climate lead to high energy costs and deterioration of buildings & infrastructure
- Logistical and financial challenges associated with reliable and affordable electricity & heat
- Diesel electricity generation is dispatchable, reliable and established, and has relatively low capital investment cost; however, diesel generators are aging, in need of investments, and have concerns over oil spillages and air pollution
- Heating consumes 2-3 times more diesel fuel than electricity

2030 Diesel Transition

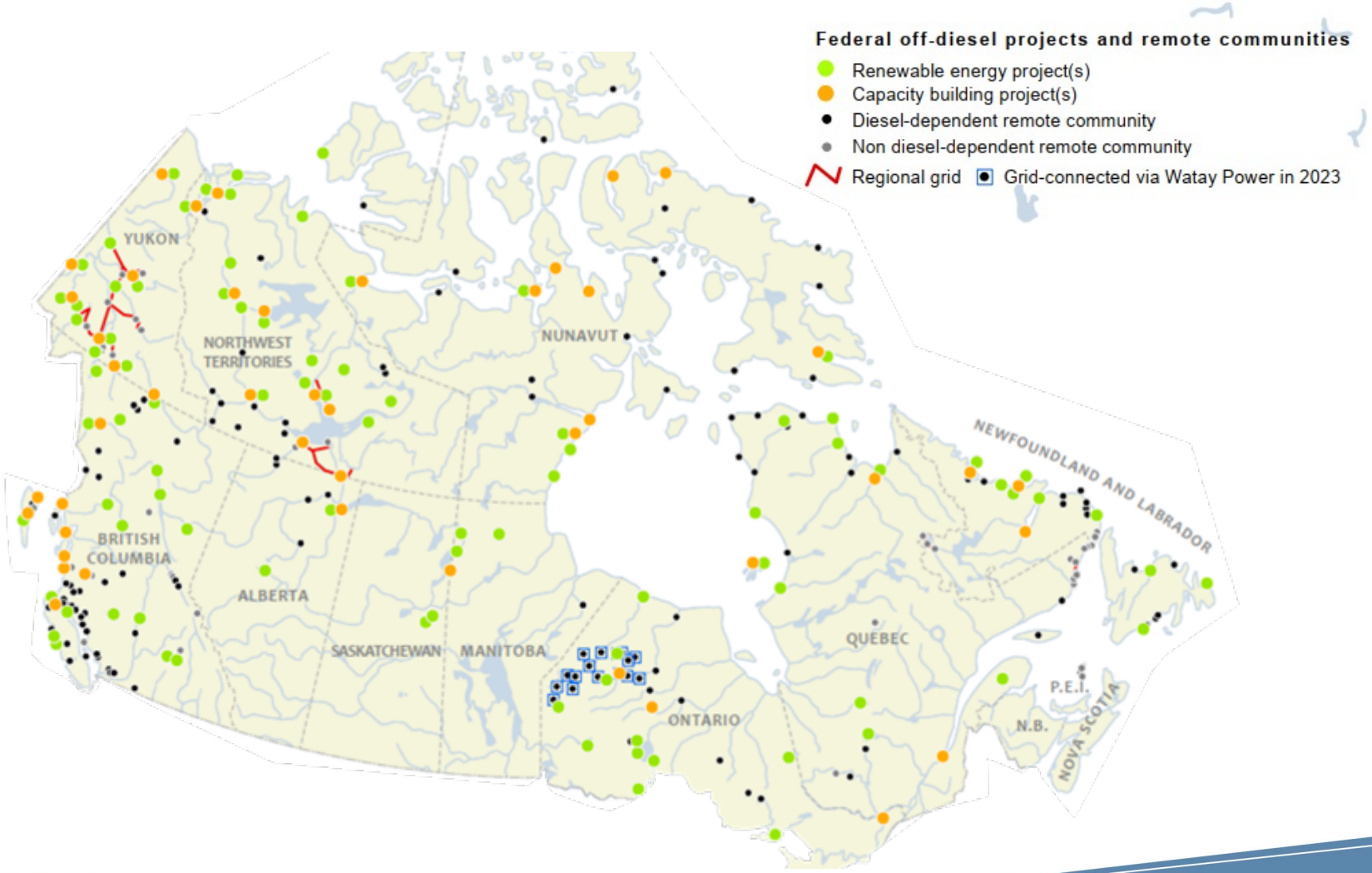
Context Factors

200 COMMUNITIES ARE RELIANT ON DIESEL IN EVERY JURISDICTION

380 MILLION LITRES OF DIESEL ARE USED ANNUALLY IN CANADA!

Success Factors

- Community capacity, engagement and ownership
- Sustained source of easily accessible funding
- Project partnership between PTs, utilities and communities



Context and Motivation

Research questions:

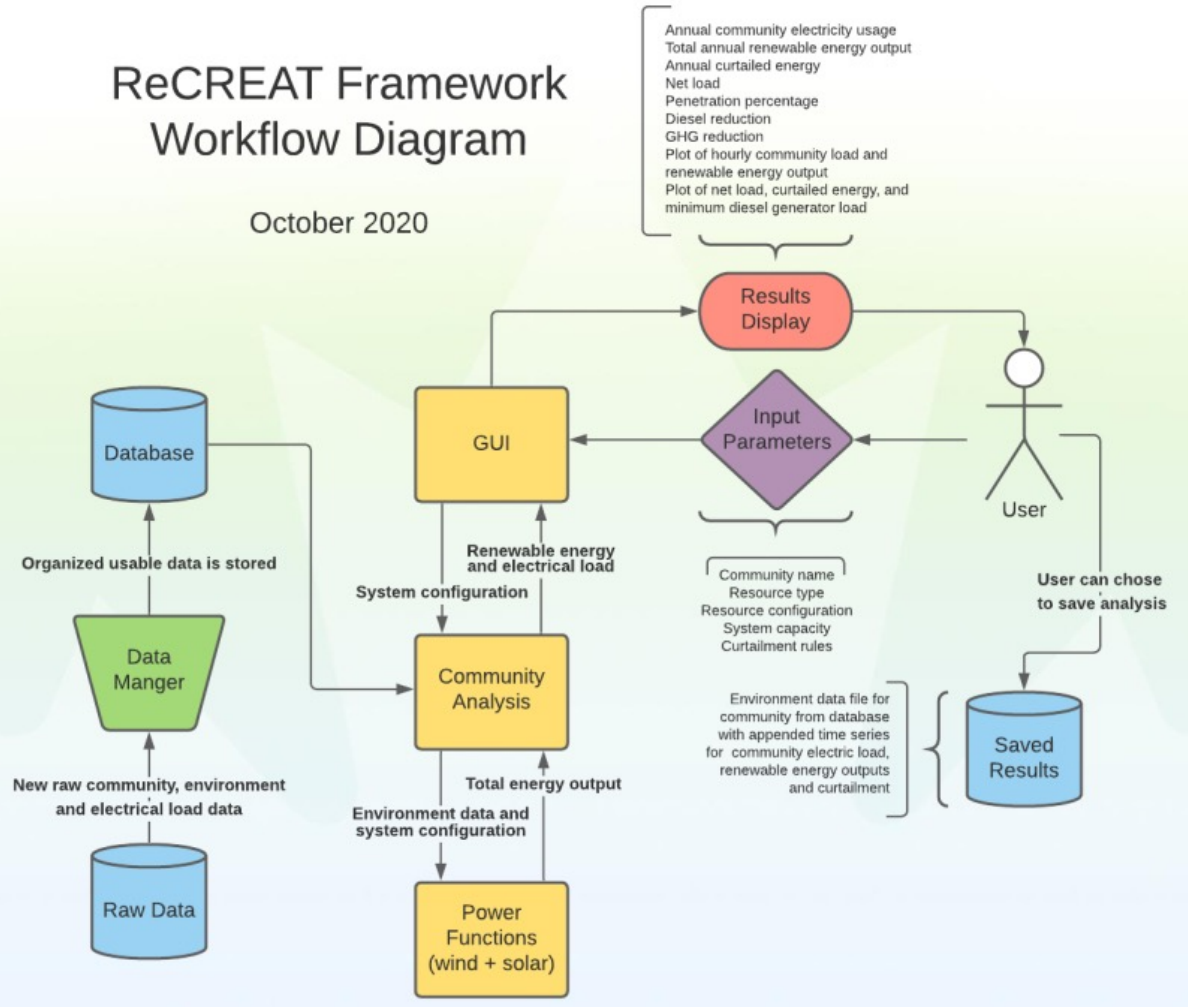
- What are reasonable expectations for Renewable Energy in remote communities?
  - What resources are locally available – solar, biomass, wind, hydro, etc.?
  - What level of RE generation is possible before impacting existing diesel systems?
  - What do high RE penetration systems look like? How do multiple generation types integrate?
  - How to inform discussions with Utilities? Provinces? Territories? Communities?

Objective:

- Develop a rapid, simplified analysis of potential RE options for Canadian remote communities based on public resource data and RE generation options
  - Use hourly time series over representative year to understand community load and RE variability
  - Identify opportunities for detailed analysis and support investment decisions

Remote Community Renewable Energy Analysis Tool (ReCREAT)

Rapid energy analysis tool dedicated to Canadian remote communities



Remote Community Renewable Energy Analysis Tool (ReCREAT)

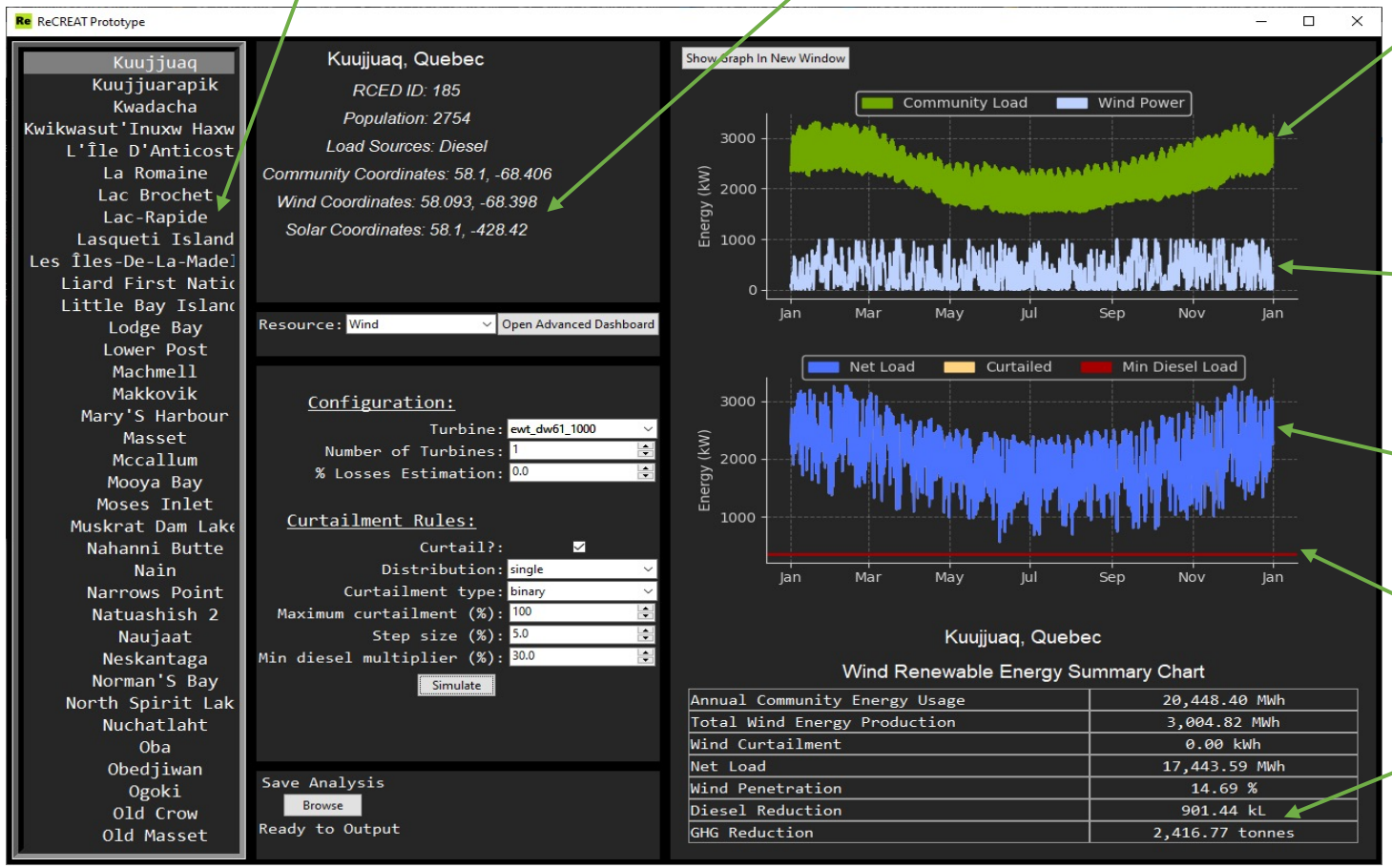
Rapid energy analysis tool dedicated to Canadian remote communities

Analyzing potential range of RE technologies

- Starting with wind and solar
- Modelled annual hourly wind/solar data
- Real and modelled community load data
- Energy storage module in development

RE system configuration analysis

- Desktop application built in Python
- Supports initial considerations
- Not for detailed design
- Limited to internal use for now



Community-level Results

Which communities can achieve different levels of renewable electricity penetration without storage based on electricity demand and local wind/solar resource?

5% Solar Penetration | 10% Solar Penetration | **15% Solar Penetration** | 20% Solar Penetration | 25% Solar Penetration | Solar Summary | Solar Cheaper than Diesel | 5% Wind ..

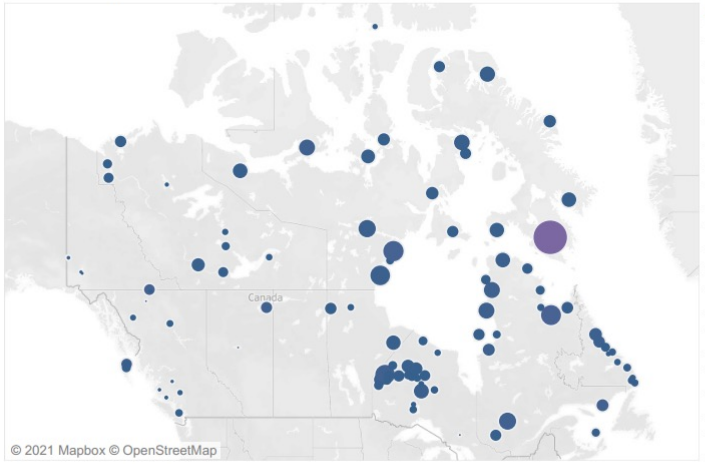
Solar Stats

# of communities possible	101
15% total capacity (kW)	84,571
15% total cost ($) - DRAFT	678,333,600
15% diesel savings (kL)	23,909
15% GHG emission reduction (tonnes)	64,100

Province
All

Indigenous category
All

Solar Map



Community name
- Aklavik
- Akulivik
- Anahim Lake
- Arctic Bay
- Armstrong
- Arviat
- Aupaluk
- Baker Lake
- Barren Lands
- Bearskin Lake
- Beaver Creek
- Big Bar
- Biscotasing
- Black Tickle
- Bob Quinn Lake
- Boulder Bay
- Brochet
- Burwash Landing
- Cambridge Bay
- Cape Dorset
- Cartwright
- Charlottetown
- Chesterfield Inlet
- Chipewyan Lake

Diesel savings (kL)
0 — 20,000

5. | 10% Wind Penetration | 15% Wind Penetration | 20% Wind Penetration | **25% Wind Penetration** | 30% Wind Penetration | 35% Wind Penetration | 40% Wind Penetration | 45 % ..

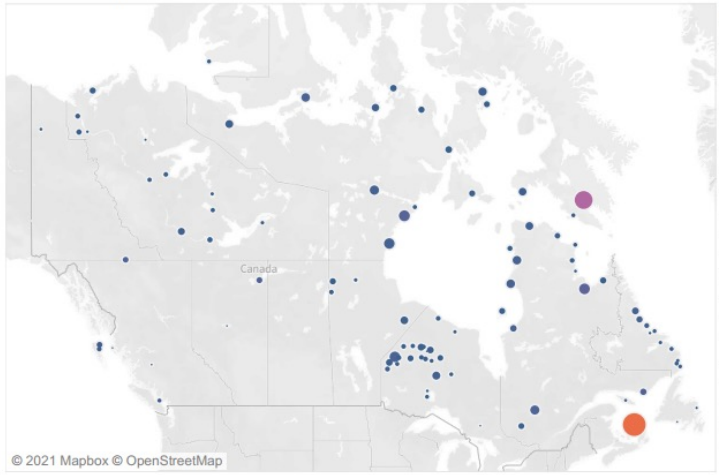
Wind Stats

# of communities possible	99
25% total capacity (kW)	79,300
25% total cost ($) - DRAFT	679,775,000
25% diesel savings (kL)	57,378
25% GHG emission reduction (tonnes)	153,831

Province
All

Indigenous category
All

Wind Map



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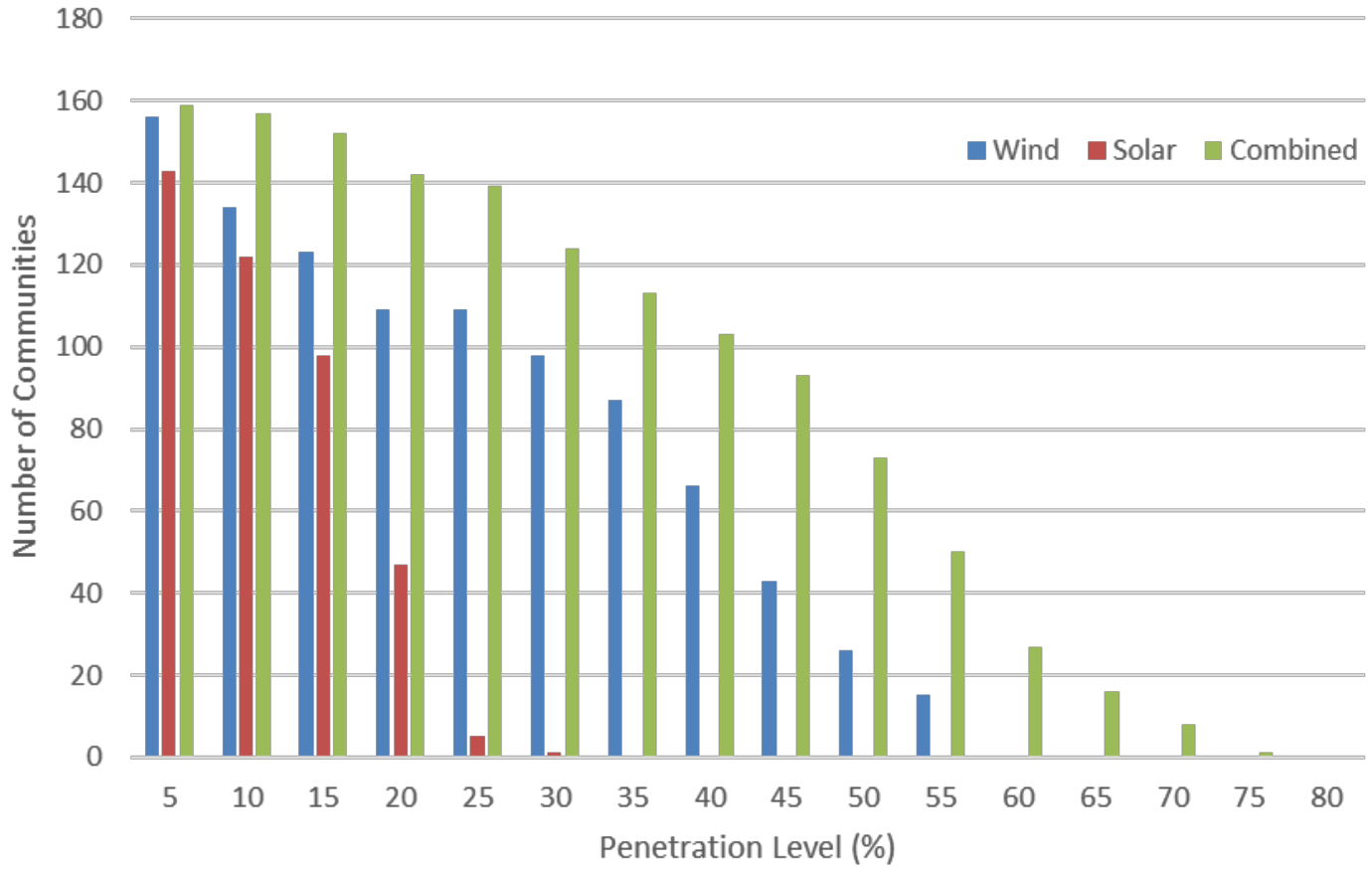
Diesel savings (kL)
0 — 20,000

Aggregated Results

How many communities can achieve different levels of renewable electricity penetration without storage based on electricity demand and local wind/solar resource?



Economics

Levelized cost of energy (LCOE)

Total Lifetime Cost = $\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}$

Total Lifetime Output = $\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}$

LCOE = $\frac{Total\ Lifetime\ Cost}{Total\ Lifetime\ Output}$

LCOE = $\frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$

- I_t = Investment and expenditures for the year (t)
- M_t = Operational and maintenance expenditures for the year (t)
- F_t = Fuel expenditures for the year (t)
- E_t = Electrical output for the year (t)
- **r** = The discount Rate
- **n** = The (expected) lifetime of the power system

Source: University of Calgary Energy Education
https://energyeducation.ca/encyclopedia/Levelized_cost_of_energy

Baseline parameters used in this analysis:

- Consistent annual electricity generation
- Cost of debt = 5%
- Debt fraction = 80%
- Project lifetime = 30 years
- Discount rate = 3%

Installed costs

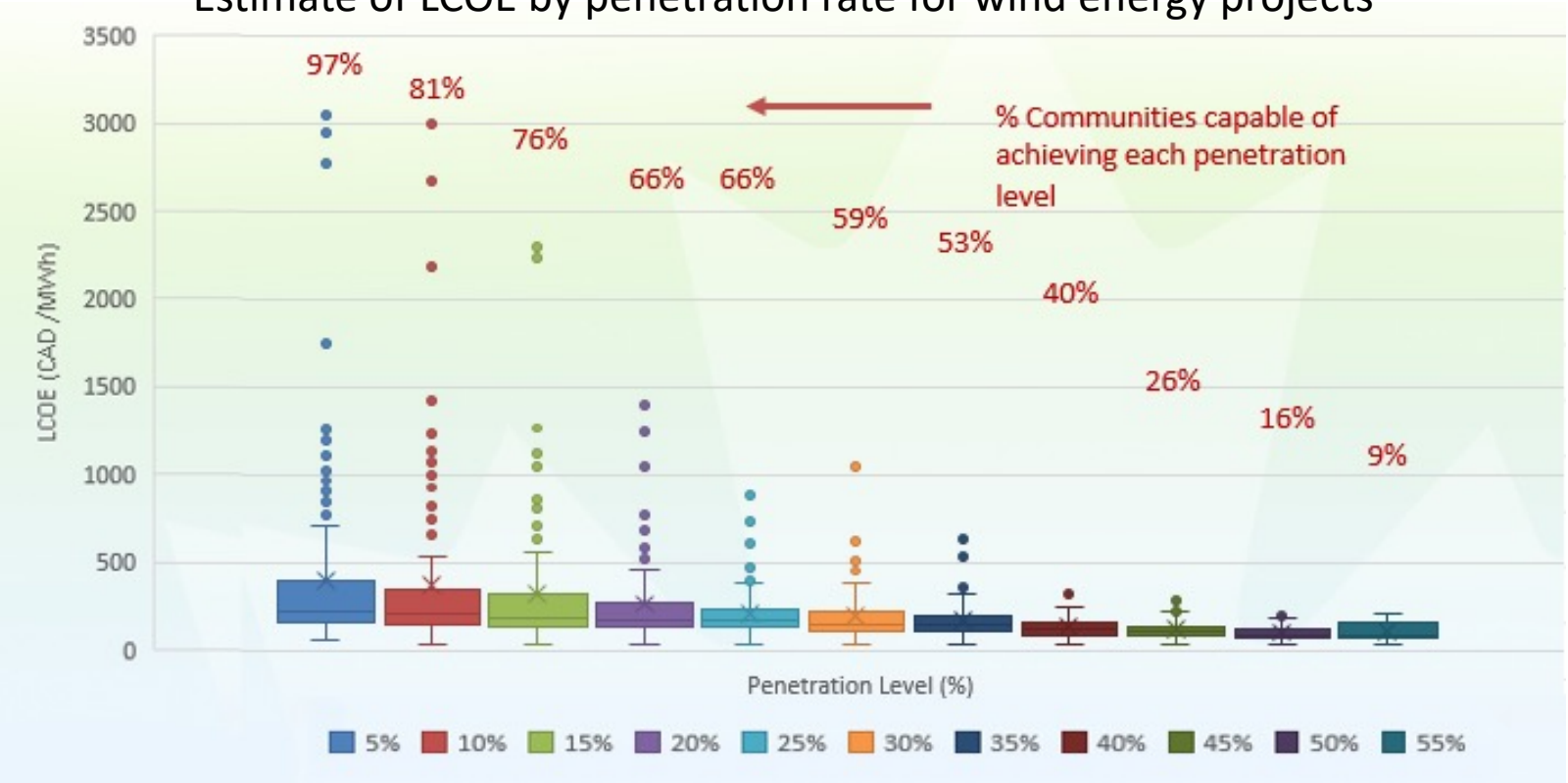
Project size	Project cost ($CAD/kW)	
	Wind	Solar
0 – 300 kW	16,000	28,000
300 kW – 1 MW	10,000	9,000
1 – 3 MW	8,500	6,300
> 3 MW	5,000	3,400

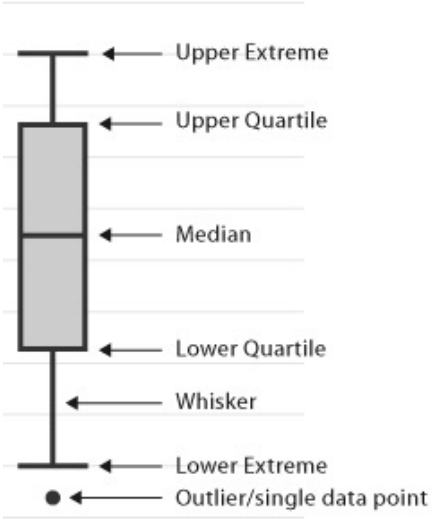
Source: Accepted project proposals into NRCan's Clean Energy for Rural and Remote Community Program (CERRC): https://www.nrcan.gc.ca/reducingdiesel

Economics

How does levelized cost of energy (LCOE) for renewables vary by penetration rate?

Estimate of LCOE by penetration rate for wind energy projects





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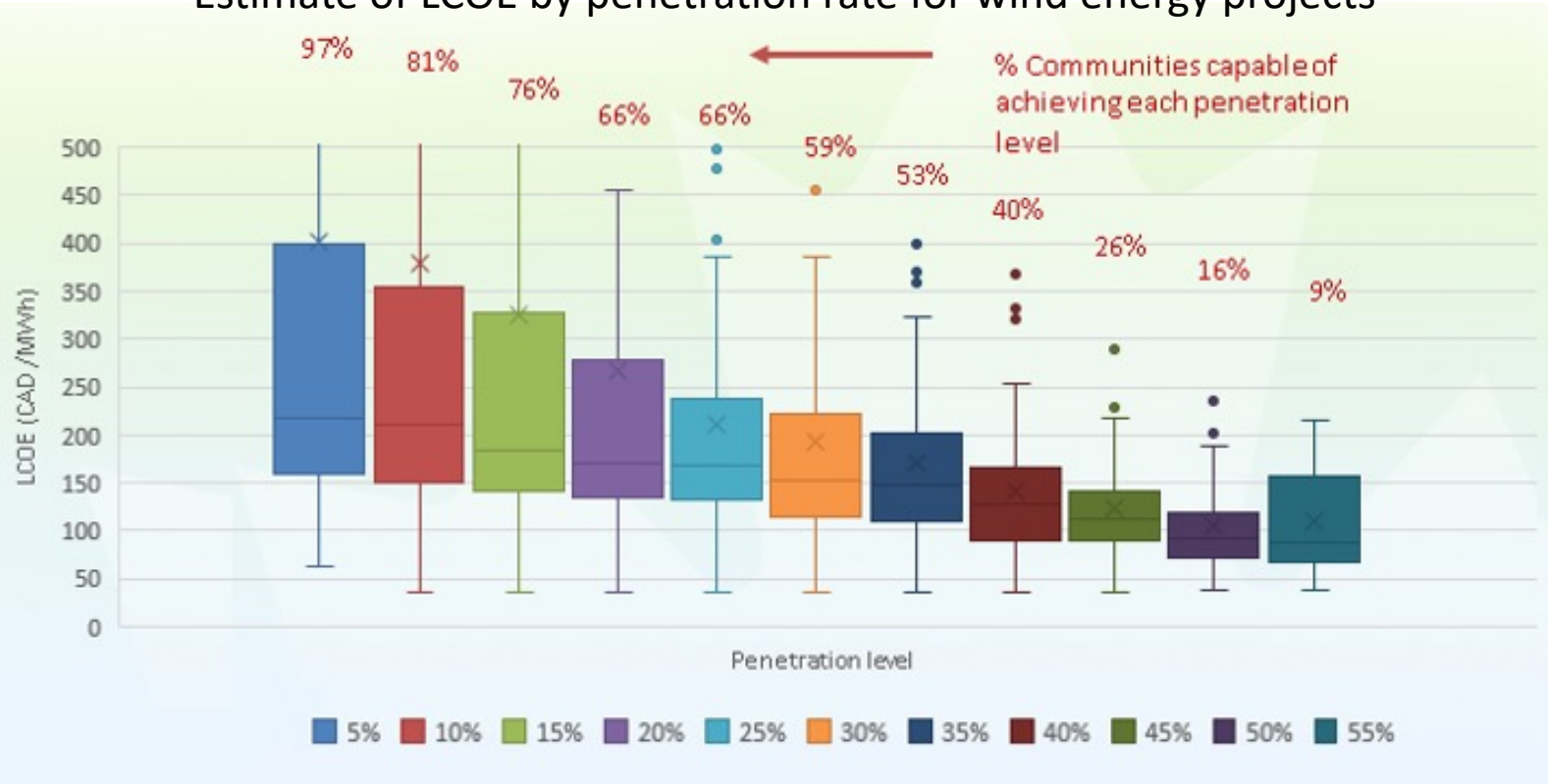


	Lazard* LCOE in the South (CAD/MWh)	ReCREAT LCOE (CAD/MWh)
Wind	$35 – $72	$75 – 225
Solar	$85 – $125	$500 – 1500

2-3x

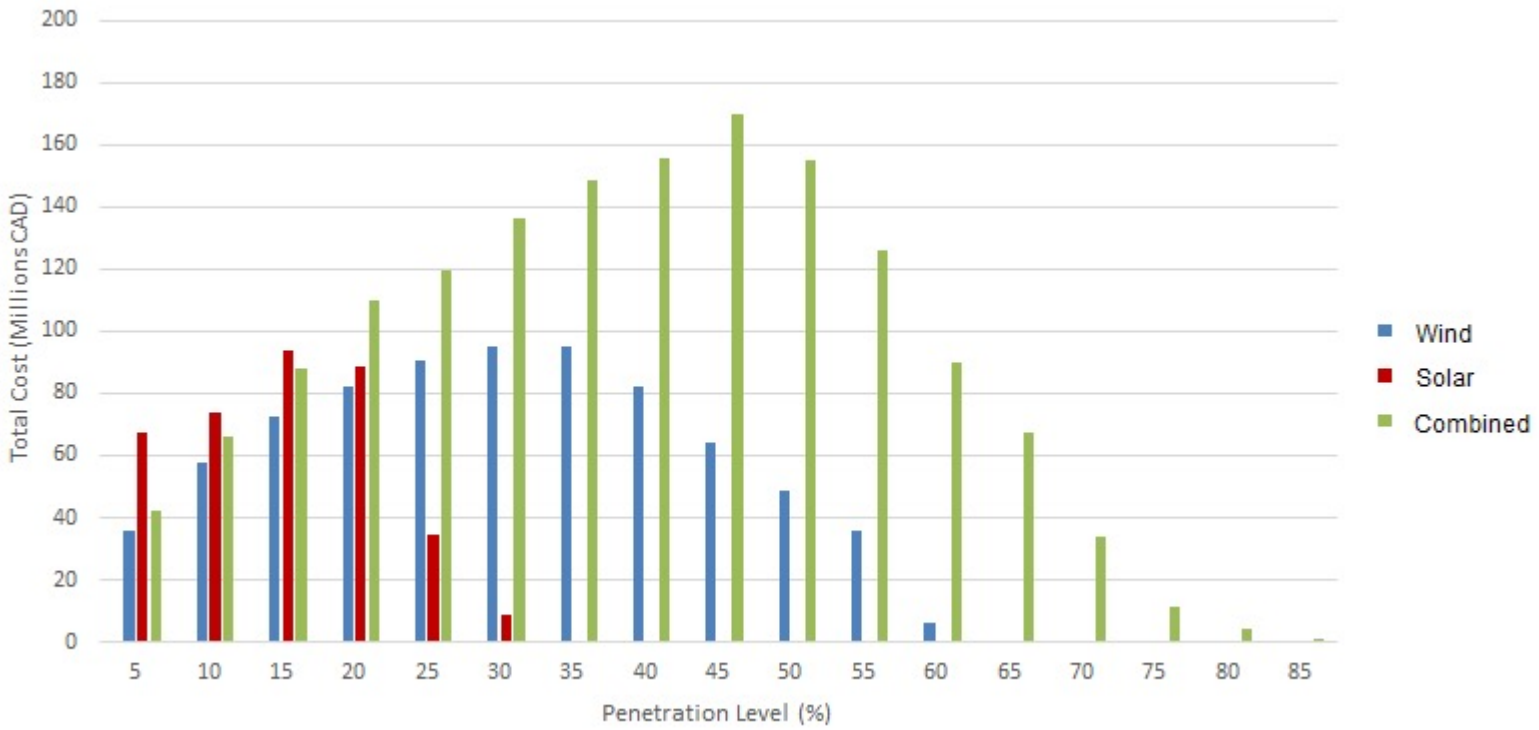
6-10x

Source: https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2020/

**Using average 2020 USD to CAD conversion rate of 1.34

Economics

What is the cost of implementing the highest possible penetration level in each community?



Cost of achieving 20% penetration

	Cost over capable communities (millions CAD)	Extrapolated cost over all 189 Communities (millions CAD)
Wind	82	140
Solar	89	178
Combined	110	133

Conclusions

- Many communities able to achieve over 20% diesel displacement through wind and solar without storage
- Some communities technically capable of achieving >25% through solar and >50% through wind
- Combinations of wind and solar can substantially improve possible penetration
- Wind has generally lower capital cost and LCOE than solar but is more complex in both installation and maintenance and less modular

Future work

- Fine-tune energy and cost results and run sensitivity analyses
- Work towards filling data gaps with more measured data and more accurate estimates
- Add battery electric storage and determine effect on RE penetration and LCOE
- Assess potential of renewable heat technologies including bio-energy to displace heating fuel consumption

Thank you!

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