An Attempt at Comparatively Ranking Negative Emission Techniques for Canadian Deployment

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Summary

This paper develops a ranking matrix based on the investigation of roughly 10 prospective negative emission techniques (NETs) found in literature. The intent of creating a standardized matrix is to give policymakers and corporations alike the ability to separate the ever-growing field of NETs that are looking for investment. The ten techniques including but not limited to direct air capture (DAC), bioenergy with carbon capture and sequestration (BECCS), biochar, enhanced rock weathering (ERW), and forestry techniques are summarized then compared for common defining factors. The common factors identified are described in further detail, including potential limitations to the public data and how one can determine which are the most important in specific applications. Each NET researched was then applied to the matrix, as well as a set of elimination criteria, to gain an understanding of which prospective technique would be best for immediate deployment in Western Canada. DAC and BECCS returned the best grades, while also fitting the elimination criteria set out, and are recommended for immediate investment. While afforestation, biochar, and magnesium oxide (MgO) looping did not score as well individually, they are viewed to have potential for deployment if utilized in combination with one another to minimize environmental impacts.

Theory / Method / Workflow

Utilizing prior NET assessment literature along with individual NET proposal or assessment documents, ~15 individual CDR methodologies were researched. Following this research, ten common characteristics of assessment were observed throughout which became the metrics for our ranking system. Seven broad CDR methods were then identified which include forestry techniques, biochar, bioenergy carbon capture sequestration, direct air capture, enhanced weathering, ocean fertilization, and soil carbon sequestration. Within these broad methods, ten specific NETs were identified to have great potential while also having a broad range of application. Although these ten specifically will be ranked once the matrix is created, the intent is that any number of NETs can be ranked through the tool provided enough data is present for the user. For this reason, we did not go into detail on each individual technique but summarized each briefly.

In order to effectively rank the prospective NETs, common attributes assessed in other peer-reviewed papers (Fuss et al., 2018; McLaren, 2012; Rueda et al., 2020) were compiled. Each of the metrics represent specific questions that policymakers or governing bodies may have during their own selection or project bidding processes. Each of the categories are summarized with justifications, then given a grading range, which can be seen in the table below.

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Table 3 - *NET Ranking Matrix and Metric Descriptors*					
	Undesirable	Subpar	Satisfactory	Good	Excellent
Metric	1	2	3	4	5
Potential (GtCO2/year)	<0.5	0.5 - 1.5	1.5 - 2.5	2.5 - 3.5	>3.5
Average Cost ($USD/tCO2)	>$225	$175 - 225	$125 - 175	$75 - 125	<$75
Maturity (TRL)	TRL 1-2	TRL 3-4	TRL 5-6	TRL 7-8	TRL 9
Timeliness	Slow	-	Medium	-	Fast
Storage Permanence	Cycling	-	Open	-	Closed
Measurability	Low	-	Medium	-	High
Environmental Side-effects	Many environmental concerns	-	Both positive and negative impacts	-	Benefits outweigh negatives
Controllability	Unpredictable and inability to halt process	-	Takes considerable effort to control	-	Can be shutdown on request
Social Impacts & Perception	Negative impacts and perception	Mixed; leaning negative	Neutral	Mixed; leaning positive	Positive impacts and perception

Results, Observations, Conclusions

Each of the 10 prospective NETs was run through the ranking matrix and sorted by percent grade. The preliminary rankings below showed a clear preference towards the direct capture engineered methods, as DACCS and BECCS, along with magnesium oxide looping, scored very well, and the natural methods did not. We believe this derives from the engineered methods having the ability to control and measure their output, whether that be a direct CO2 stream or a measurable by-product. There is thought that while this directly impacts two of the metrics; other categories get boosted indirectly.

Table 4 - *Grading results for each NET with final sorting by ranking*										
NET	Potential	Cost	TRL	Time	Store	Measure	Enviro	Control	Social	Score
DACCS-LT	5	4	4	5	5	5	3	5	4	89%
DACCS-HT	5	3	4	5	5	5	3	5	4	87%
BECCS-MSW	4	2	4	5	5	5	4	5	4	84%
MgO Looping	4	4	3	3	5	5	3	5	3	78%
BECCS-CC	4	3	4	3	5	5	2	5	3	76%
Soil Carbon Seq	4	5	5	3	3	3	5	3	3	76%
ERW	5	3	4	3	3	3	4	3	4	71%
Biochar	2	5	3	3	3	3	4	3	4	67%
Af/Reforestation	3	5	5	1	3	1	5	1	5	64%
Ocean Fert	1	1	3	3	5	3	1	5	1	51%

Before final conclusions were to be made, the goal of this report was to create a regional assessment for this grouping of technologies. Five elimination parameters were set to allow for different users to utilize this matrix within their regional or organizational limitations. Drawing from personal experience, our team decided on these parameters by picking characteristics of regions globally that cannot be changed and would hence make some NETs economically unviable. Climate dependency, energy intensity, water requirements, total footprint size, and terrestrial vs ocean-based were the five topics settled on. To apply to Canadian development, low climate dependency was the only must, as intense low temperatures are experienced for much of the year. This requirement eliminated many of the biological capture methods, as techniques such as ERW depend on good agricultural conditions year-round to reach it's max profitability. Upon completion of matrix grading and elimination criteria were applied, DACCS low temp, DACCS high temp, and municipal waste BECCS were the top three recommendations for deployment.

Novel/Additive Information

Although many of the biological capture methods such as afforestation, crop BECCS, and biochar did not score as highly as many of the direct capture methods, there is potential for deployment if they are bundled together. For example, some of the forestry techniques concerns (controllability of wildfires and infestations) can be addressed by utilizing the dead matter as a feed for biochar or a BECCS system.

Additionally, while magnesium oxide looping is not viewed as quite ready for deployment, there is opportunity for investment in further research and development. When grouped with other direct capture methods such as DACCS and BECCS, this method has shown potential to be the most economically viable if it's efficiency and land use are better developed. We believe that the infancy of this NET led to the lower grading from our matrix and if revisited in the coming years could result in recommendation for use.

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Although there were no financial or otherwise compensation creating bias in the writing of this paper, the creation of this matrix using multi-criteria decision analysis was completed using the authors' prior experience through education and work experience. This implies that while each of these criteria were viewed as the most important in our ranking method, others could view them differently and thus create other ranking methods which has been seen in other peer-reviewed publications.

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