

Marginal Abatement Cost Curve (MACC) Analysis Report

Assessing GHG Emission Reduction Strategies for Transitioning to Work-from-Home Operations

Group 4

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1 Problem Set Scope

Assess the marginal abatement cost (MAC) of various projects to reduce greenhouse gas (GHG) emissions for an office worker realigning their operations as they transition to a work-from-home strategy.

In the report, CO₂e stands for CO₂ equivalent.

2 Methodology

This analysis employs Marginal Abatement Cost Curve (MACC) to evaluate potential savings, costs, and CO₂e reductions of various projects until December 31, 2023. The starting date aligns with each project's implementation plan, while the proposal date (February 12, 2024) is considered as the immediate implementation date.

Implementation costs are adjusted by the savings in year 0 (2024), and CO₂e reductions in year 0 are also calculated separately based on the implementation date.

The hurdle rate in this analysis is 8%.

3 Current Scenario

Current Scenario Information						
Electricity	%	Total(kWh)	Price(\$/kWh)	CO ₂ e (t/kWh)	Cost(\$)	CO ₂ e (t)
Total	100%	8760	0.16	1.10E-04	1401.6	9.64E-01
Lighting	20%	1752	0.16	1.10E-04	280.32	1.93E-01
Cooling	40%	3504	0.16	1.10E-04	560.64	3.85E-01
Heating	Natural Gas(m3/d)	Days	Total (m3)	Price(\$/m3)	Cost(\$)	CO ₂ e (t)
	7	365	2555	0.75	1916.25	4.8
Transportation	Distance(/trip)	No. of Trip	Total Distance(km)	Price(\$/trip)	Cost(\$)	CO ₂ e (t)
Car			15000		2500	5.2
Flight	1000	10	10000	300	3000	2.2
Annual Total					8817.85	1.32E+01

4 Project 1 Lighting

All existing lights are 60W. Replace all lights with 9W LED equivalent. The entire replacement cost will be \$375. Cost saving is immediate and will not decline from implementation to end of 2030.

4.1 Calculation

- The reduction rate for electricity usage in lighting is 85% ($=1-(9W/60W)$).
- The implementation date is February 12, 2024. Therefore, for the year 0, the saving and CO2e reduction are for the portion from that day to the end of 2024 (323 days).

Project1 Calculation								
Category	Current Electricity	Reduce Rate	Save (kWh)	Price(\$/kWh)	Save (\$)	CO2e (t/kWh)	Current CO2e (t)	Reduced CO2e (t)
Lighting	1752	85%	1489.2	0.16	238.272	1.10E-04	1.93E-01	1.64E-01
Starting Date	End of 2024	Days in year 0	Saving in year 0	Reduced CO2e in year 0 (t)				
2024-02-12	2024-12-31	323	210.8544	1.45E-01				

4.2 Results

Project1				
Lighting	Implement Cost (\$)	Annual Saving (\$)	Reduced CO2e (t)	Adjusted Implement Cost (\$)
	375	238.272	1.64E-01	164.1456

5 Project 2 Air travel

Air travel: Eliminate 60% of air travel. This will require an investment of \$7000 per employee to upgrade their home office technology for proper customer meetings/presentations. This can be implemented immediately.

5.1 Calculation

- The reduction rate for air travel is 60%.
- The implementation date is February 12, 2024. Therefore, for the year 0, the saving and CO2e reduction are for the portion from that day to the end of 2024 (323 days).

Project2 Calculation					
Category	Reduce Rate	Current Cost (\$)	Annual Saving (\$)	Current CO2e (t)	Reduced CO2e (t)
Flight	60%	3000	1800	2.2	1.32
Starting Date	End of 2024	Days in year 0	Saving in year 0	Reduced CO2e in year 0 (t)	
2024-02-12	2024-12-31	323	1592.876712	1.17E+00	

5.2 Results

Project2				
Air travel	Implement Cost (\$)	Annual Saving (\$)	Reduced CO2e (t)	Adjusted Implement Cost (\$)
	7000	1800	1.32	5407.123288

6 Project 3 Electric vehicles

Electric vehicles: Due to a long-standing relationship with Nissan Canada and electrical vehicle incentives, the company has access to Nissan Leaf vehicles at a cost of \$32,000 per vehicle. The vehicle's 160 kWh battery results in a driving distance of 360 kilometers. The electric vehicles require less maintenance resulting in savings of \$100/month. Vehicles will be charged with electricity purchased from the grid at the employee's homes. The customer territory of each sales rep will not require them to charge the vehicle elsewhere. Nissan Canada has offered to accept all current employee vehicles on June 30 as part of the deal (ie. saving will start July 1 will not decline from implementation to end of 2030).

6.1 Calculation

- The saving has two parts: one is the difference between traditional car's cost and EV's cost for the same distance; the other is the maintenance saving 100\$/month.
- The implementation date is July 1, 2024. Therefore, for the year 0, the saving and CO2e reduction are for the portion from that day to the end of 2024 (183 days).

Project3 Calculation					
Total Distance(km)	Total Electricity (kW)	Price(\$/kWh)	Cost(\$)	CO2e (t/kWh)	CO2e (t)
15000	6666.666667	0.16	1066.666667	1.10E-04	7.33E-01
Maintainace Fee Sa	Months	Saving(\$)			
100	12	1200			
Starting Date	End of 2024	Days in year 0	Saving in year 0	Reduced CO2e in year 0 (t)	
2024-07-01	2024-12-31	183	1320.273973	2.24E+00	

6.2 Results

Project3				
Electric Vehicle	Implement Cost (\$)	Annual Saving (\$)	Reduced CO2e (t)	Adjusted Implement Cost (\$)
Fuel	32000	1433.333333	4.47E+00	30679.72603
Maintainace		1200		
Total	32000	2633.333333	4.47E+00	30679.72603

7 Project 4 Insulation and upgraded heating equipment

Insulation and upgraded heating equipment: At a cost of \$10,000 – the homes of employees can be upgraded to reduce natural gas use from 7 cubic meters per day to 2 cubic meters per day on average (average of 365 days) and reduce electricity for cooling by 75% (again, average of 365 days).

7.1 Calculation

- The saving has two parts: one is due to natural gas usage with reduction rate of 71% (1-2/7); the other is the electricity usage for cooling reduced by 75%.
- The implementation date is February 12, 2024. Therefore, for the year 0, the saving and CO2e reduction are for the portion from that day to the end of 2024 (323 days).

Project4 Calculation								
Category	Current Electricity	Reduce Rate	Save (kWh)	Price(\$/kWh)	Save (\$)	CO2e (t/kWh)	Current CO2e (t)	Reduced CO2e (t)
Cooling	3504	75%	2628	0.16	420.48	1.10E-04	3.85E-01	2.89E-01
	Current Natural Gas	Reduce Rate	Save (m3)	Price(\$/kWh)	Save (\$)	CO2e (t/kWh)	Current CO2e (t)	Reduced CO2e (t)
Heating	2555	71%	1825	0.75	1368.75	1.10E-04	4.8	3.428571429
Starting Date	End of 2024	Days in year 0	Saving in year 0	Reduced CO2e in year 0 (t)				
2024-02-12	2024-12-31	323	1583.346	3.29E+00				

7.2 Results

Project4				
Insulation	Implement Cost (\$)	Annual Saving (\$)	Reduced CO2e (t)	Adjusted Implement Cost (\$)
	10000			8416.654
Cooling		420.48	2.89E-01	
Heating		1368.75	3.43E+00	
Total	10000	1789.23	3.72E+00	8416.654

8 Project 5 Eliminate flying completely

Eliminate flying completely: The VP, Sales hosts a quarterly planning meeting with her team. She would still like to do so in-person as it is beneficial for team morale. The employees are willing to drive-in for this meeting. Charging is available at the office for the same price per kWh and with the same GHG intensity. However, employees will need range extending batteries installed in their vehicles. You are able to source compatible batteries for \$6500 each (installed) that will ensure that employees only need to charge at their home or at the office.

8.1 Calculation

- This project is based on project 2 and 3, that means the cars have already been changed to EVs and 60% air travels have been reduced and the home office technology has been upgraded.
- The saving is the difference between air travel and EV travel of four trips (1000km each).
- The implementation date is July 1, 2024 same as EV project. Therefore, for the year 0, there are only two seasonal meeting which is 50% of annual 4 meetings. The saving and CO2e reduction in year 0 are 50% of regular.

Project5 Calculation							
Flight	Reduce Rate	Current Cost	Save (\$)	Current CO2e (t)	Reduced CO2e (t)		
	40%	3000	1200	2.2	0.88		
Car	Add Distance(km)	Electricity(kWh)	Price(\$/kWh)	Cost(\$)	CO2e (t/kWh)	Current CO2e (t)	Add CO2e (t)
	4000	1777.777778	0.16	284.4444444	1.10E-04	0	1.96E-01
Starting Date	End of 2024	Year 0 Saving rate (Saving in year 0	Reduced CO2e in year 0 (t)			
2024-07-01	2024-12-31	50%	457.7777778	3.42E-01			

8.2 Results

Project5				
Eliminate flying comp	Implement Cost (\$)	Annual Saving (\$)	Reduced CO2e (t)	Adjusted Implement Cost (\$)
	6500	915.56	6.84E-01	6042.22

9 MACC

9.1 Results from projects

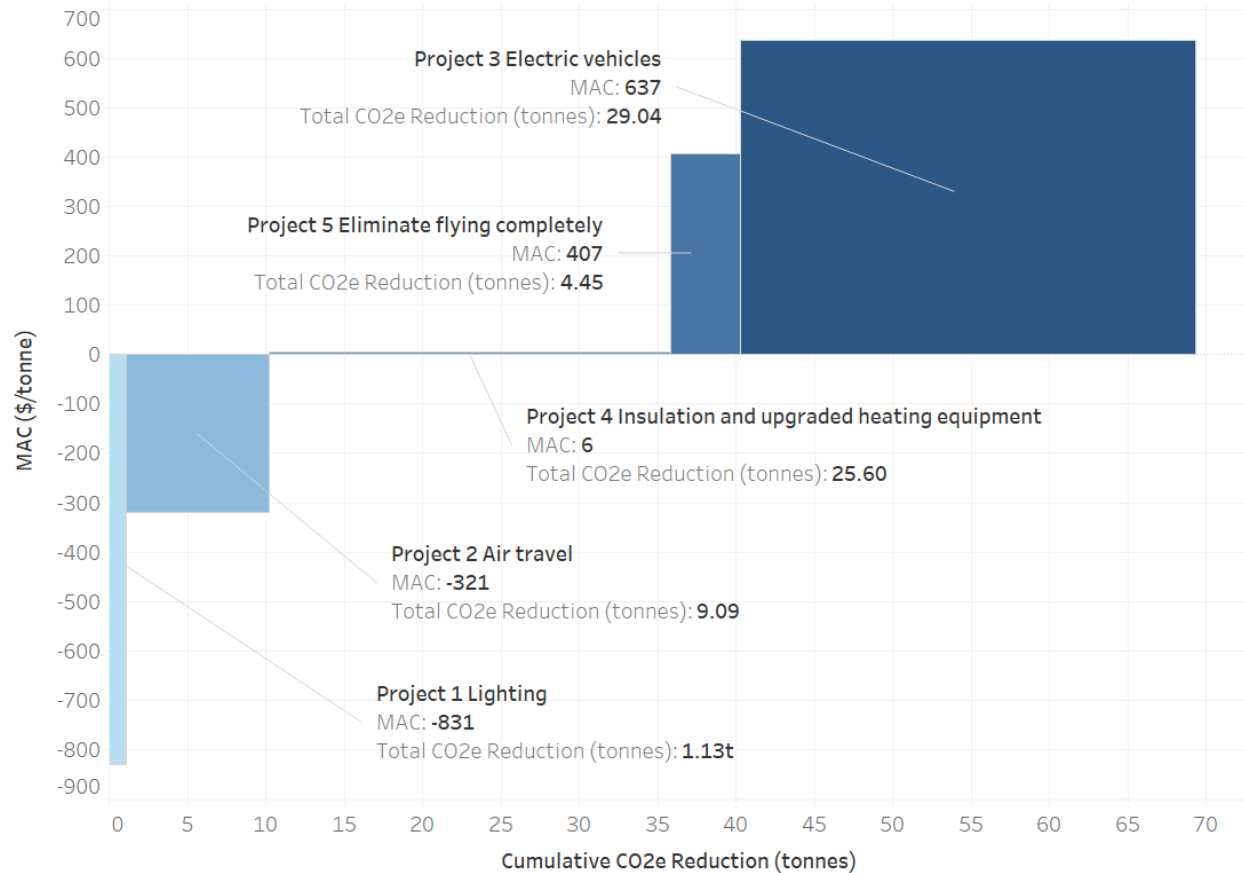
Project Name	Implement Cost	Adjusted Implement Cost	Annual Savings	Annual CO2e Reduction (tonne)	Year 0 CO2e Reduction (tonne)	Total CO2e Reduction (tonne)	CO2e Reduction Rate
Project 1 Lighting	\$375.00	\$164.15	\$238.27	1.64E-01	1.45E-01	1.13E+00	1.24%
Project 2 Air travel	\$7,000.00	\$5,407.12	\$1,800.00	1.32E+00	1.17E+00	9.09E+00	10.03%
Project 3 Electric vehicles	\$32,000.00	\$30,679.73	\$2,633.33	4.47E+00	2.24E+00	2.90E+01	32.04%
Project 4 Insulation and upgraded heating equipment	\$10,000.00	\$8,416.65	\$1,789.23	3.72E+00	3.29E+00	2.56E+01	28.24%
Project 5 Eliminate flying completely	\$6,500.00	\$6,042.22	\$915.56	6.84E-01	3.42E-01	4.45E+00	4.91%
Project 2 + 3 + 5	\$45,500.00	\$42,129.07	\$5,348.89	6.47E+00	3.75E+00	4.26E+01	46.98%

In this report, the project time period is from implementation to 2030. The NPV is calculated with adjusted implementation cost and the total CO2e reduction also includes the adjusted value in year 0.

Project Name	NPV	Total CO2e Reduction (tonne)	MAC (\$/t CO2e)	0	1	2	3	4	5	6
				2024	2025	2026	2027	2028	2029	2030
Project 1 Lighting	\$937.36	1.13E+00	-\$831.11	-\$164.15	\$238.27	\$238.27	\$238.27	\$238.27	\$238.27	\$238.27
Project 2 Air travel	\$2,914.06	9.09E+00	-\$320.65	-\$5,407.12	\$1,800.00	\$1,800.00	\$1,800.00	\$1,800.00	\$1,800.00	\$1,800.00
Project 3 Electric vehicles	-\$18,506.14	2.90E+01	\$637.28	-\$30,679.73	\$2,633.33	\$2,633.33	\$2,633.33	\$2,633.33	\$2,633.33	\$2,633.33
Project 4 Insulation and upgraded heating equipment	-\$145.26	2.56E+01	\$5.68	-\$8,416.65	\$1,789.23	\$1,789.23	\$1,789.23	\$1,789.23	\$1,789.23	\$1,789.23
Project 5 Eliminate flying completely	-\$1,809.72	4.45E+00	\$406.78	-\$6,042.22	\$915.56	\$915.56	\$915.56	\$915.56	\$915.56	\$915.56
Project 2 + 3 + 5	-\$17,401.80	4.26E+01	\$408.72	-\$42,129.07	\$5,348.89	\$5,348.89	\$5,348.89	\$5,348.89	\$5,348.89	\$5,348.89

9.2 MACC analysis

Marginal Abatement Cost Curve (MACC)



According to the above MAC curve, project 1 results in the highest financial benefits of \$831 for the company but the potential for CO₂e reduction is only 1.13 tonne which is only 1.24% reduction from the present scenario. Project 2 on the other hand results in 10.03% reduction in CO₂e emissions while allowing the company to pocket an additional 321\$/tonne of reduction. Project 4 costs the company around 5.68\$/tonne of CO₂e reduction but has the second highest potential in reducing the CO₂e emissions by 28% from present values. Project 5 requires the company to spend an additional 407\$/tonne of CO₂e and is the second most expensive project and has limited potential for reducing CO₂e emissions, accounting for only 4.91% reduction from the current scenario. The implementation of project 5 also mandates the implementation of projects 2 and 3. Project 3 is the most expensive project to implement, costing the company 637\$/tonne of CO₂e, but it also has the highest potential in reducing CO₂e emissions by 29.04 tonnes which is a 32.05% reduction from current levels.

9.3 Thoughts to the question

- **What projects should meet the financial threshold immediately and what percentage of your employees' GHG emissions will that eliminate?**

Criteria: If one project's NPV is greater than zero, that project is seen as meeting the financial threshold immediately (profitable).

Based on this criteria, Project 1 and 2 meet the financial threshold immediately. The respective percentages of employees' greenhouse gas (GHG) emissions eliminated by those projects are as follows (CO2e Reduction Rate):

Projects meet the financial threshold immediately							
Current CO2e (tonne/y)	Year 0 CO2e without project (tonne)	Total CO2e without project (tonne)	Project Name	NPV	Total CO2e Reduction (tonne)	MAC (\$/t CO2e)	CO2e Reduction Rate
1.32E+01	1.16E+01	9.06E+01	Project 1 Lighting	937.36	1.13E+00	-831.11	1.24%
			Project 2 Air travel	2914.06	9.09E+00	-320.65	10.03%

An investment of \$375 in Project 1 can save \$238.27 per year and \$937.36 in NPV by 2030, and an investment of \$7,000 in Project 2 can save \$1,800 per year and \$2,914.06 in NPV by 2030. From the financial point of view, the funds saved by these two projects are far greater than the input funds, especially project 2, which not only saves more funds than the input funds but also reduces the carbon emissions by 9.09 tons, accounting for 10.03% of the carbon emissions reduced.

By implementing Projects 1 and 2, which meet the financial threshold immediately, the company achieves both financial gains and reductions in GHG emissions, aligning with organization's goals and sustainability targets.

- **What projects will fall below the 2030 Government of Canada's proposed \$170/tonne tax? What percentage of your employees GHG emissions will that eliminate?**

Criteria: If the MAC value of a project is less than \$170 per tonne CO2e, then the project is deemed to fall below the proposed \$170/tonne tax.

Based on the criteria, Projects 1, 2, and 4 are expected to fall below the proposed \$170/tonne tax set by the Government of Canada for 2030. Furthermore, the respective percentages of employees' greenhouse gas (GHG) emissions eliminated by these projects are as follows (CO2e Reduction Rate):

Projects fall below the 2030 Government of Canada's proposed \$170/tonne tax							
Current CO2e (tonne/y)	Year 0 CO2e without project (tonne)	Total CO2e without project (tonne)	Project Name	NPV	Total CO2e Reduction (tonne)	MAC (\$/t CO2e)	CO2e Reduction Rate
1.32E+01	1.16E+01	9.06E+01	Project 1 Lighting	937.36	1.13E+00	-831.11	1.24%
			Project 2 Air travel	2914.06	9.09E+00	-320.65	10.03%
			Project 4 Insulation and upgraded heating equipment	-145.26	2.56E+01	5.68	28.24%

• **Do you have a recommended strategy beyond what is presented in the MACC?**

A strategy that we could recommend is for the company to eliminate flying by advising the VP to conduct her quarterly meeting digitally, rather than in person, thus allowing for the company to avoid the extra cost of range extending batteries and power consumption for travelling the extra 4000kms per each salesman while still reaping the benefits. In this case, we can club the scenario with the existing scenario 2 for calculation of MAC.

➤ **Calculation**

The reduction rate for air travel is 100%.

The implementation date is February 12, 2024. Therefore, for the year 0, in 60% air travel, the saving and CO2e reduction are for the portion from that day to the end of 2024 (323 days), and all four seasonal meeting (40% air travel) can be holden virtually.

Recommend Project					
Category	Reduce Rate	Current Cost (\$)	Annual Saving (\$)	Current CO2e (t)	Reduced CO2e (t)
Flight	60%	3000	1800	2.2	1.32
Flight	40%	3000	1200	2.2	0.88
Total	100%		3000		2.2
Starting Date	End of 2024	Days in year 0	Saving in year 0	Reduced CO2e in year 0 (t)	
2024-02-12	2024-12-31	323	2654.794521	1.17E+00	
		4 seasonal meeting	1200	0.88	
		Total	3854.794521	2.05E+00	

➤ **Results**

Recommend Project				
Eliminate flying comp	Implement Cost (\$)	Annual Saving (\$)	Reduced CO2e (t)	Adjusted Implement Cost (\$)
	7000	3000.00	2.20E+00	3145.21

Project Name	Implement Cost	Adjusted Implement Cost	Annual Savings	Annual CO2e Reduction (tonne)	Year 0 CO2e Reduction (tonne)	Total CO2e Reduction (tonne)	CO2e Reduction Rate
Project 1 Lighting	\$375.00	\$164.15	\$238.27	1.64E-01	1.45E-01	1.13E+00	1.24%
Project 2 Air travel	\$7,000.00	\$5,407.12	\$1,800.00	1.32E+00	1.17E+00	9.09E+00	10.03%
Project 3 Electric vehicles	\$32,000.00	\$30,679.73	\$2,633.33	4.47E+00	2.24E+00	2.90E+01	32.04%
Project 4 Insulation and upgraded heating equipment	\$10,000.00	\$8,416.65	\$1,789.23	3.72E+00	3.29E+00	2.56E+01	28.24%
Project 5 Eliminate flying completely	\$6,500.00	\$6,042.22	\$915.56	6.84E-01	3.42E-01	4.45E+00	4.91%
Project 2 + 3 + 5	\$45,500.00	\$42,129.07	\$5,348.89	6.47E+00	3.75E+00	4.26E+01	46.98%
Recommended Project	\$7,000.00	\$3,145.21	\$3,000.00	2.20E+00	2.05E+00	1.52E+01	16.82%

Project Name	NPV	Total CO2e Reduction (tonne)	MAC (\$/t CO2e)	0 2024	1 2025	2 2026	3 2027	4 2028	5 2029	6 2030
Project 1 Lighting	\$937.36	1.13E+00	-\$831.11	-\$164.15	\$238.27	\$238.27	\$238.27	\$238.27	\$238.27	\$238.27
Project 2 Air travel	\$2,914.06	9.09E+00	-\$320.65	-\$5,407.12	\$1,800.00	\$1,800.00	\$1,800.00	\$1,800.00	\$1,800.00	\$1,800.00
Project 3 Electric vehicles	-\$18,506.14	2.90E+01	\$637.28	-\$30,679.73	\$2,633.33	\$2,633.33	\$2,633.33	\$2,633.33	\$2,633.33	\$2,633.33
Project 4 Insulation and upgraded heating equipment	-\$145.26	2.56E+01	\$5.68	-\$8,416.65	\$1,789.23	\$1,789.23	\$1,789.23	\$1,789.23	\$1,789.23	\$1,789.23
Project 5 Eliminate flying completely	-\$1,809.72	4.45E+00	\$406.78	-\$6,042.22	\$915.56	\$915.56	\$915.56	\$915.56	\$915.56	\$915.56
Project 2 + 3 + 5	-\$17,401.80	4.26E+01	\$408.72	-\$42,129.07	\$5,348.89	\$5,348.89	\$5,348.89	\$5,348.89	\$5,348.89	\$5,348.89
Recommended Project	\$10,723.43	1.52E+01	-\$703.26	-\$3,145.21	\$3,000.00	\$3,000.00	\$3,000.00	\$3,000.00	\$3,000.00	\$3,000.00

By avoiding all air travel the company can save a significant amount of 3000\$/year and reduce its carbon emissions by over 15.2 tonnes, 16.82% of the current scenario.

10 Limitations

- It is assumed that there are no maintenance costs associated with the implemented projects, which may not reflect real-world conditions accurately.
- The hurdle rate is set at a fixed rate of 8%, although in reality, this rate may vary depending on various factors and market conditions.