Yukon Greenhouse Gas Emission Mitigation Analysis

Phase II: Prioritization of Practical Greenhouse Gas Emissions Mitigation Measures

Submitted to:

Yukon Energy, Mines and Resources
Energy Branch
206 Lowe Street
Whitehorse, Yukon Y1A 1W5

Submitted by:

Paul Kishchuk, MA
Vector Research
203 – 301 Hawkins Street
Whitehorse, Yukon Y1A 1X5
www.vectorresearch.ca
paul@vectorresearch.ca
867.668.3164

Draft 30 November 2018
Final 21 December 2018

Introduction

This report presents an extension of the analysis of contained in the *Yukon Greenhouse Gas Emission Mitigation Analysis Phase I* report completed for the Energy Branch of Yukon Energy, Mines and Resources in September 2018. The Phase I report identified greenhouse gas emission mitigation measures that could potentially be applied in the Yukon context. Both the Phase I report and this Phase II report have been prepared to inform Yukon government officials and partners in the development of an Integrated Yukon Strategy on Climate Change, Energy and the Green Economy.

This Phase II report presents a quantification, through use of reasonable ranges, of the volume of greenhouse gas emissions that could possibly be abated and the cost per tonne (CO_2e) to implement the measures. The quantification is based on the "Practical Greenhouse Gas Emissions Mitigation Measures" table presented on pages 12 to 17 of the Phase I report.

Research undertaken for the Phase II report has demonstrated that much of the work in the greenhouse mitigation arena in Canada has focused on discussion on broad approaches and general policy measures rather than the quantification of specific measures. Fortunately, work completed by the Working Group on Specific Mitigation Opportunities does contain a reasonably comprehensive assessment of an extensive menu of specific mitigation measures. The Working Group on Specific Mitigation Measures was one of four federal, provincial, and territorial (F/P/T) working groups mandated by Canada's First Ministers as part of the Vancouver Declaration on Clean Growth and Climate Change in March 2016.

The results of the working groups' efforts were located in a report titled *Specific Mitigation Opportunities Working Group Final Report* and are the source of data for this report. Drafting of the *Specific Mitigation Opportunities Working Group Final Report* was the result of a collective effort of F/P/T officials from across Canada. The *Specific Mitigation Opportunities Working Group Final Report* captures input from experts, stakeholder groups, the general public and National Indigenous Organizations.

In the tables that follow, greenhouse gas emissions volumes are measured as carbon dioxide equivalent (CO_2e) in megatonnes (Mt), or millions of metric tonnes. The reductions in CO_2e emissions were estimated over a 15-year time horizon ending in 2030, to correspond with Canada's commitment to the international community that it will reduce emissions to at least 30% below 2005 levels by 2030.

Potential greenhouse gas emission reductions are grouped into one of three categories:

Major opportunities: > 10 megatonnes of CO_2e emissions by 2030

Significant opportunities: 5 to 10 megatonnes of CO_2e emissions by 2030

Minor opportunities: < 5 megatonnes of CO_2e emissions by 2030

The lower bound of potential greenhouse gas emission reductions identified the by Specific Mitigation Opportunities Working Group was used to assign the potential opportunities to the three categories above.

As the work of the Specific Mitigation Opportunities Working Group focused on Canada's commitment to reduce greenhouse gas emissions, the estimates of the potential greenhouse gas emission reductions assembled by the working group are national-level estimates. Yukon Environment's Climate Change Secretariat has confirmed that estimates of potential greenhouse gas emission reductions have yet to be calculated and assembled for the Yukon. Notwithstanding the national-territorial difference in scale, the reduction estimates provide a relative indication of the potential for reductions.

The estimates of the cost per tonne of CO_2e to implement the emission reduction measures are categorized according to five ranges:

- less than $0 per tonne of CO_2e (implying a positive payback by 2030)
- $0 to $50 per tonne of CO_2e
- $50 to $100 per tonne of CO_2e
- $100 to $250 per tonne of CO_2e
- more than $250 per tonne of CO_2e

The results of the quantification of the volume of greenhouse gas emissions that could possibly be abated and the cost per tonne (CO_2e) to implement the measures is presented in Tables A and B below. Table A presents a summary snapshot of the potential greenhouse gas emission reductions in megatonnes of CO_2e by 2030 and the corresponding estimated cost per tonne of CO_2e. Table B presents the potential mitigation measures with descriptions organized according to the estimated cost per tonne of CO_2e to implement the measure.

The first letter of the identifier for each measure indicates the sector:

- B = Buildings
- C = Cross-Sector
- E = Electricity
- F = Forest Resources, Light Manufacturing, Construction
- H = Heavy Industry
- T = Transportation
- W = Waste

Table A: Potential GHG Emission Reductions (Mt of CO2e) and Estimated Cost ($ per tonne CO2e)

Estimated GHG Emission Reduction (Mt CO2e) by 2030	Estimated Cost ($ per tonne of CO2e)					
	< 0	0 to 50	50 to 100	100 to 250	>250	not available
Major (> 10 Mt)		E1.2 H3.2	E3.2	H2.2		
Significant (5 to 10 Mt)	B2.3 B6.2 H3.1 W2.1	E1.1 F4.1	E3.1 E6.2			
Minor (< 5 Mt)	B2.1 B4.1 B4.3 B5.1 B5.2 B5.3 B7.1 B7.2 B7.3 T6.1 T7.4 T7.5 T8.1 T8.2	B1.1 B2.2 B3.1 E6.1 F1.1 F2.1 H5.1 T5.1 T5.3 W1.1 W3.1 W4.1	E6.3 F3.1 T1.3 T3.1 T4.1 T6.2 T8.4 T8.5	E4.1 E4.2 E4.3 H2.1 T1.1 T2.1 T4.2 T4.4 T5.2 T7.1 T7.2	B6.1 T4.3 T4.5	
not available						B4.2 B8.1 B8.2 C1.1 C2.1 C4.1 C4.2 C4.3 H1.1 T1.2 T2.2 T2.3 T2.4 T7.3 T8.3

Table B: Potential Mitigation Measures and Descriptions by Reduction Potential and Estimated Cost

Potential Greenhouse Gas Emission Reduction (megatonnes of CO_2e) at an Estimated Cost of:	less than $0 per tonne of CO_2e
Significant (5 to 10 Mt)	B2.3 introduce regulations and loan programs to reduce energy use by requiring moderate retrofits at time of home sale or permit application.
	B6.2 introduce incentive or loan programs to reduce emissions by fuel switching of space and water heating from oil/propane to less GHG intensive alternatives.
	H3.1 introduce financial incentives such as grants, tax measures and low interest loans to accelerate the use of computerized energy management systems that improve energy efficiency.
	W2.1 introduce education and incentive programs to reduce increasing percentages of avoidable food waste to reduce emissions at all stages of the food production supply chain including transport.
Minor (< 5 Mt)	B2.1 financial incentives to reduce low rise housing energy use via voluntary shallow retrofits (e.g., LED lights, weather stripping).
	B4.1 introduce financial incentives for retrofitting to reduce emissions in existing buildings.
	B4.3 introduce energy disclosure regulations to reduce emissions in existing buildings.
	B5.1 introduce financial incentives and retrofitting requirements to improve the energy efficiency of equipment and appliances in existing buildings.
	B5.2 support the adoption of minimum efficiency standards through market transformation initiatives and incentives.
	B5.3 support the introduction of minimum standards and labelling with incentives.
	B7.1 impose regulations requiring electricity and natural gas utilities to offer enhanced billing to facilitate reduced energy use.
	B7.2 introduce regulations and incentives to reduce peak electricity demand through time of use rates or by providing utilities control over household thermostat settings.
	B7.3 introduce financial incentives or rebates to install adaptive thermostats in existing homes.
	T6.1 incentives for information technology-enabled freight logistics and supply chain systems.
	T7.4 offer employees incentives for car sharing.
	T7.5 require employers to implement transportation demand management measures (e.g., charge all employees for parking and rebate parking fees to employees that do not use parking spaces).
	T8.1 implement road use pricing based on vehicle kilometres traveled.
	T8.2 institute pay-as-you-drive (PAYD) insurance policies that cost more the higher the number of kilometres driven.

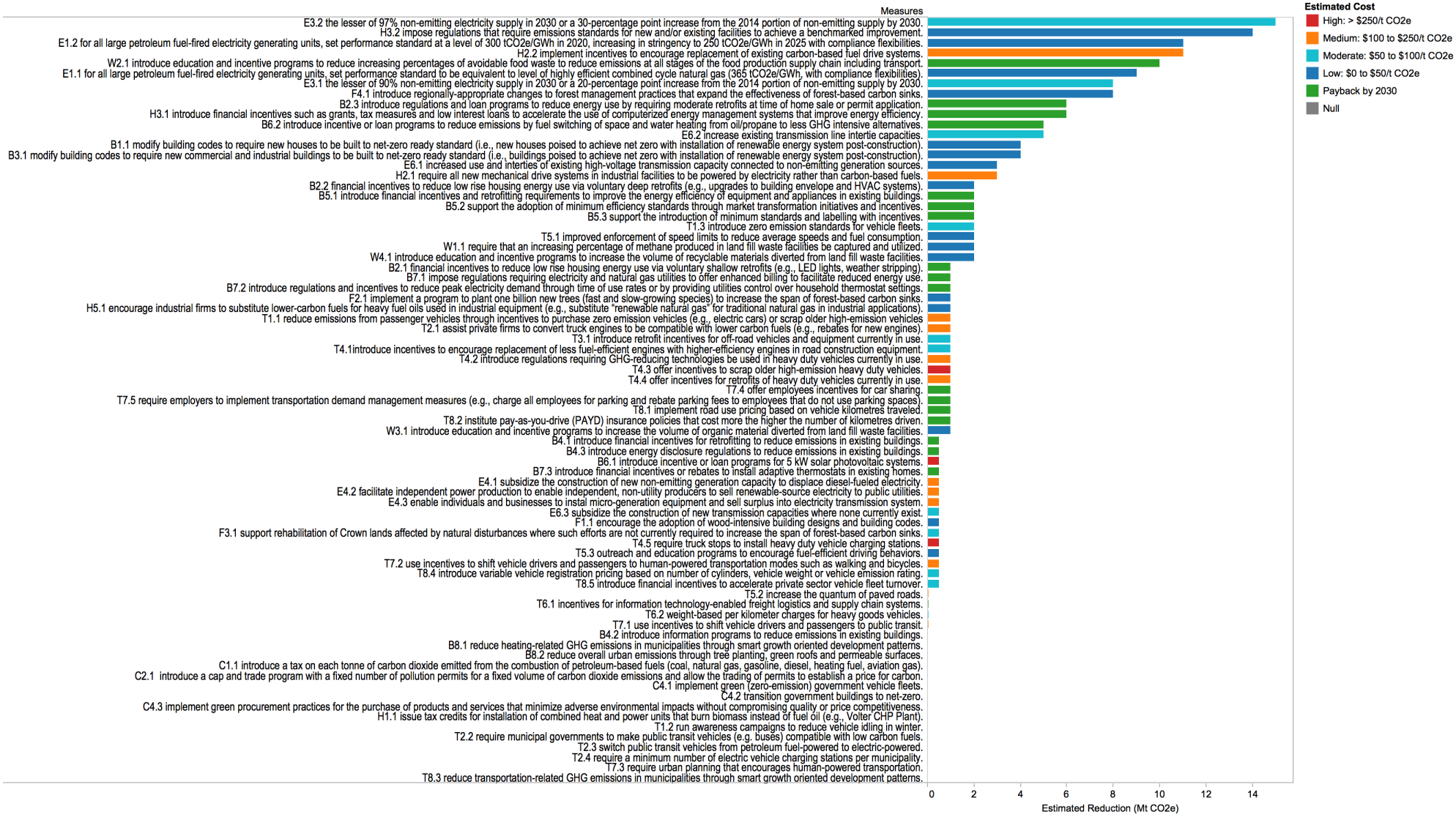
Potential Greenhouse Gas Emission Reduction (megatonnes of CO_2e) at an Estimated Cost of:	$0 to $50 per tonne of CO_2e
Major (> 10 Mt)	E1.2 for all large petroleum fuel-fired electricity generating units, set performance standard at a level of 300 tCO2e/GWh in 2020, increasing in stringency to 250 tCO2e/GWh in 2025 with compliance flexibilities.
	H3.2 impose regulations that require emissions standards for new and/or existing facilities to achieve a benchmarked improvement.
Significant (5 to 10 Mt)	E1.1 for all large petroleum fuel-fired electricity generating units, set performance standard to be equivalent to level of highly efficient combined cycle natural gas (365 tCO2e/GWh, with compliance flexibilities).
	F4.1 introduce regionally-appropriate changes to forest management practices that expand the effectiveness of forest-based carbon sinks.
Minor (< 5 Mt)	B1.1 modify building codes to require new houses to be built to net-zero ready standard (i.e., new houses poised to achieve net zero with installation of renewable energy system post-construction).
	B2.2 financial incentives to reduce low rise housing energy use via voluntary deep retrofits (e.g., upgrades to building envelope and HVAC systems).
	B3.1 modify building codes to require new commercial and industrial buildings to be built to net-zero ready standard (i.e., buildings poised to achieve net zero with installation of renewable energy system post-construction).
	E6.1 increased use and interties of existing high-voltage transmission capacity connected to non-emitting generation sources.
	F1.1 encourage the adoption of wood-intensive building designs and building codes.
	F2.1 implement a program to plant one billion new trees (fast and slow-growing species) to increase the span of forest-based carbon sinks.
	H5.1 encourage industrial firms to substitute lower-carbon fuels for heavy fuel oils used in industrial equipment (e.g., substitute "renewable natural gas" for traditional natural gas in industrial applications).
	T5.1 improved enforcement of speed limits to reduce average speeds and fuel consumption.
	T5.3 outreach and education programs to encourage fuel-efficient driving behaviors.
	W1.1 require that an increasing percentage of methane produced in land fill waste facilities be captured and utilized.
	W3.1 introduce education and incentive programs to increase the volume of organic material diverted from land fill waste facilities.
	W4.1 introduce education and incentive programs to increase the volume of recyclable materials diverted from land fill waste facilities.

Potential Greenhouse Gas Emission Reduction (megatonnes of CO_2e) at an Estimated Cost of:	$50 to $100 per tonne of CO_2e
Major (>10 Mt)	E3.2 the lesser of 97% non-emitting supply in 2030 or a 30% increase from the 2014 portion of non-emitting supply by 2030.
Significant (5 to 10 Mt)	E3.1 the lesser of 90% non-emitting supply in 2030 or a 20% increase from the 2014 portion of non-emitting supply by 2030.
	E6.2 increase existing transmission line intertie capacities.
Minor (< 5 Mt)	E6.3 subsidize the construction of new transmission capacities where none currently exist.
	F3.1 support rehabilitation of Crown lands affected by natural disturbances where such efforts are not currently required to increase the span of forest-based carbon sinks.
	T1.3 introduce zero emission standards for vehicle fleets.
	T3.1 introduce retrofit incentives for off-road vehicles and equipment currently in use.
	T4.1introduce incentives to encourage replacement of less fuel-efficient engines with higher-efficiency engines in road construction equipment.
	T6.2 weight-based per kilometer charges for heavy goods vehicles.
	T8.4 introduce variable vehicle registration pricing based on number of cylinders, vehicle weight or vehicle emission rating.
	T8.5 introduce financial incentives to accelerate private sector vehicle fleet turnover.
Potential Greenhouse Gas Emission Reduction (megatonnes of CO_2e) at an Estimated Cost of:	**$100 to $250 per tonne of CO_2e**
Major (>10 Mt)	H2.2 implement incentives to encourage replacement of existing carbon-based fuel drive systems.
Minor (< 5 Mt)	E4.1 subsidize the construction of new non-emitting generation capacity to displace diesel-fueled electricity.
	E4.2 facilitate independent power production to enable independent, non-utility producers to sell renewable-source electricity to public utilities.
	E4.3 enable individuals and businesses to install micro-generation equipment and sell surplus into electricity transmission system.
	H2.1 require all new mechanical drive systems in industrial facilities to be powered by electricity rather than carbon-based fuels.
	T1.1 reduce emissions from passenger vehicles through incentives to purchase zero emission vehicles (e.g., electric cars) or scrap older high-emission vehicles
	T2.1 assist private firms to convert truck engines to be compatible with lower carbon fuels (e.g., rebates for new engines).
	T4.2 introduce regulations requiring GHG-reducing technologies be used in heavy duty vehicles currently in use.
	T4.4 offer incentives for retrofits of heavy duty vehicles currently in use.
	T5.2 increase the quantum of paved roads.
	T7.1 use incentives to shift vehicle drivers and passengers to public transit.
	T7.2 use incentives to shift vehicle drivers and passengers to human-powered transportation modes such as walking and bicycles.

Potential Greenhouse Gas Emission Reduction (megatonnes of CO_2e) at an Estimated Cost of:	> $250 per tonne of CO_2e
Minor (< 5 Mt)	B6.1 introduce incentive or loan programs for 5 kW solar photovoltaic systems.
	T4.3 offer incentives to scrap older high-emission heavy duty vehicles.
	T4.5 require truck stops to install heavy duty vehicle charging stations.
Potential Greenhouse Gas Emission Reduction (megatonnes of CO_2e) at an Estimated Cost of:	**not available**
not available	B4.2 introduce information programs to reduce emissions in existing buildings.
	B8.1 reduce heating-related GHG emissions in municipalities through smart growth oriented development patterns.
	B8.2 reduce overall urban emissions through tree planting, green roofs and permeable surfaces.
	C1.1 introduce a tax on each tonne of carbon dioxide emitted from the combustion of petroleum-based fuels (coal, natural gas, gasoline, diesel, heating fuel, aviation gas).
	C2.1 introduce a cap and trade program with a fixed number of pollution permits for a fixed volume of carbon dioxide emissions and allow the trading of permits to establish a price for carbon.
	C4.1 implement green (zero-emission) government vehicle fleets.
	C4.2 transition government buildings to net-zero.
	C4.3 implement green procurement practices for the purchase of products and services that minimize adverse environmental impacts without compromising quality or price competitiveness.
	H1.1 issue tax credits for installation of combined heat and power units that burn biomass instead of fuel oil (e.g., Volter CHP Plant).
	T1.2 run awareness campaigns to reduce vehicle idling in winter.
	T2.2 require municipal governments to make public transit vehicles (e.g. buses) compatible with low carbon fuels.
	T2.3 switch public transit vehicles from petroleum fuel-powered to electric-powered.
	T2.4 require a minimum number of electric vehicle charging stations per municipality.
	T7.3 require urban planning that encourages human-powered transportation.
	T8.3 reduce transportation-related GHG emissions in municipalities through smart growth oriented development patterns.

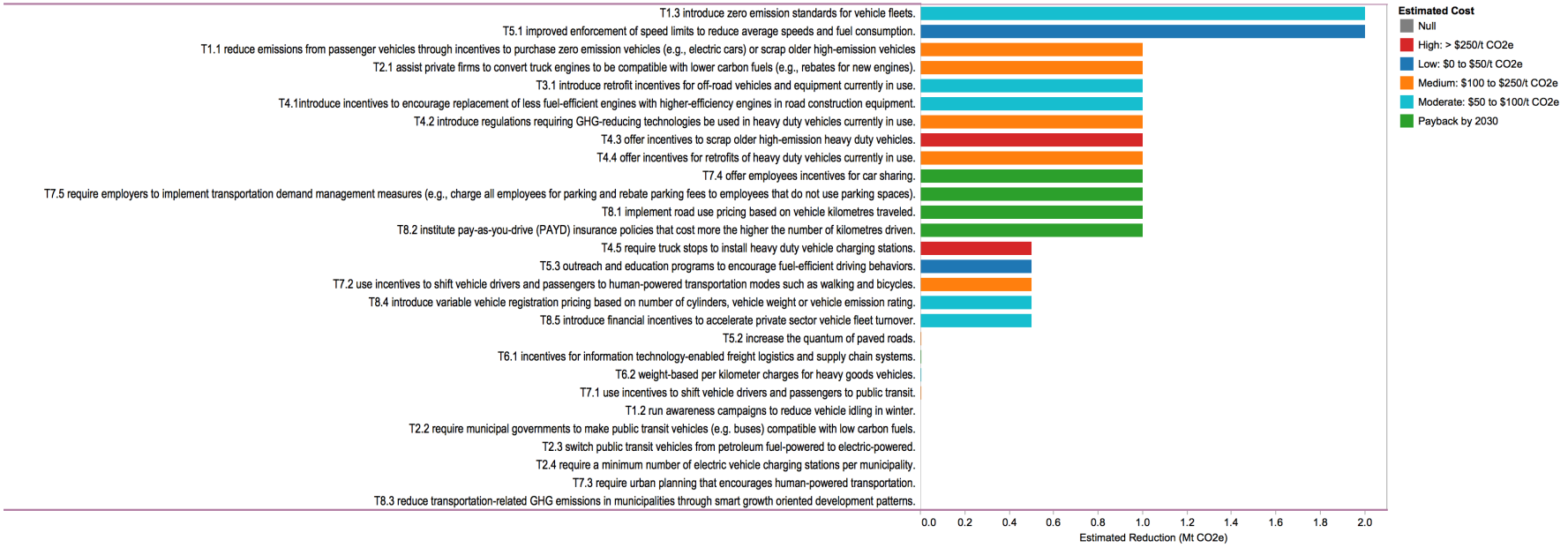
The bar chart on the following page summarizes the estimated reduction in greenhouse gas emissions (Mt CO_2e) and the estimated cost ($ per tonne CO_2e) across all sectors

Estimated Reduction in Greenhouse Gas Emissions (Mt CO2e) and Estimated Cost ($ per tonne CO2e)



As noted earlier in this paper, the estimated reductions in greenhouse gas emissions and estimated costs are national-level estimates. The next step in identifying mitigation measures suitable for introduction in the Yukon is to have a closer look at the potential measures at the sectoral level. In the charts which follow, the mitigation measures are grouped by sector and are ordered according to the extent to which the sector contributed to the Yukon's overall volume of greenhouse gas emissions in 2016. Criteria specific to each sector which can be used to adapt the national-level estimates for the Yukon context are suggested and are intended to seed a facilitated discussion of Integrated Yukon Strategy on Climate Change, Energy and the Green Economy partners in February 2019. The sector-by-sector quantification is based on the "Practical Greenhouse Gas Emissions Mitigation Measures" table presented on pages 12 to 17 of the Phase I report and, as such, does not include the two sectors which contributed 1% or less to Yukon's overall greenhouse gas emission in 2016 – agriculture and oil & gas.

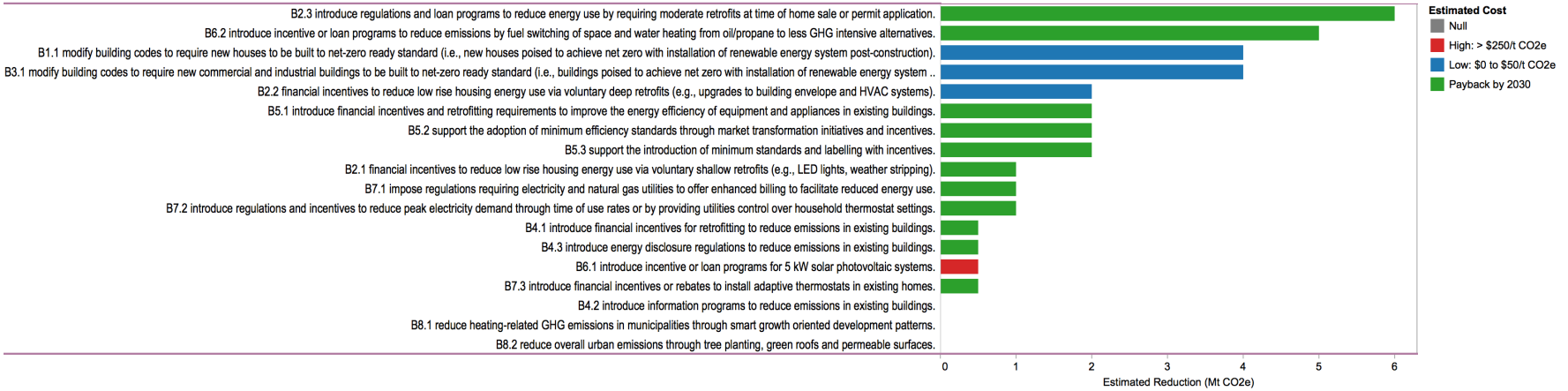
Estimated Reduction in Greenhouse Gas Emissions (Mt CO2e) and Estimated Cost ($ per tonne CO2e)
Transportation [69% of Total Yukon GHG Emissions in 2016]



Transportation Sector – Criteria for Consideration:

As the Yukon is characterized by sparse populations and long distances between communities, mitigation measures involving efficiency increases, as opposed to reducing the numbers of kilometres driven, will be more effective.

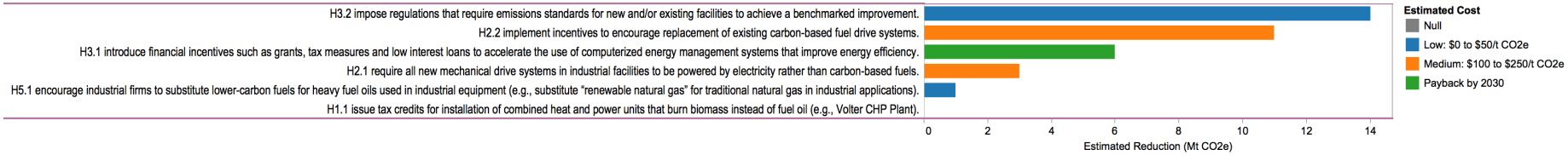
Estimated Reduction in Greenhouse Gas Emissions (Mt CO2e) and Estimated Cost ($ per tonne CO2e)
Buildings [11% of Total Yukon GHG Emissions in 2016]



Buildings Sector – Criteria for Consideration:

Given the Yukon's northern latitude and correspondingly higher heating degree days, measures that reduce the amount of petroleum-derived energy used for space heating will likely be more effective in the Yukon than at the national level.

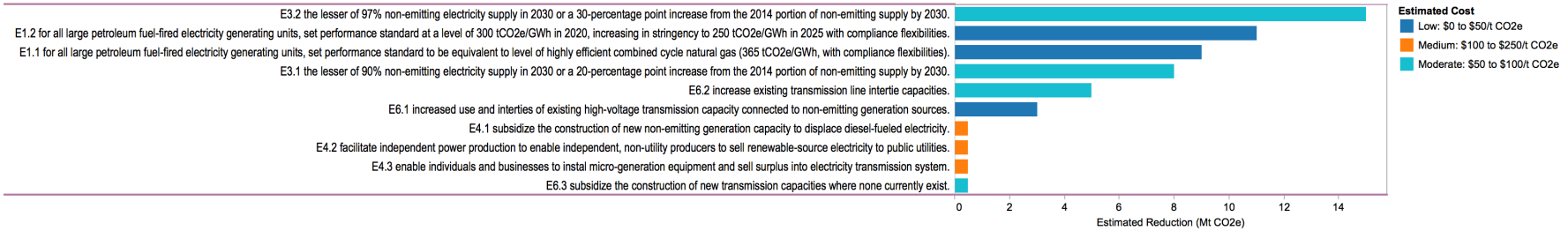
Estimated Reduction in Greenhouse Gas Emissions (Mt CO2e) and Estimated Cost ($ per tonne CO2e)
Heavy Industry [8% of Total Yukon GHG Emissions in 2016]



Heavy Industry - Criteria for Consideration:

Since all machinery used in industrial applications in Yukon is manufactured outside of the territory, Yukon will benefit from efficiency improvements as machinery and equipment are replaced. Measures to encourage accelerated replacement of machinery and equipment will in turn accelerate reductions in greenhouse gas emissions from industrial machinery and equipment.

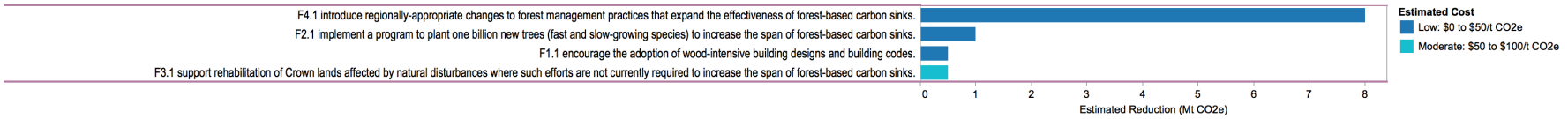
Estimated Reduction in Greenhouse Gas Emissions (Mt CO2e) and Estimated Cost ($ per tonne CO2e)
Electricity [5% of Total Yukon GHG Emissions in 2016]



Electricity Sector – Criteria for Consideration:

Yukon already generates 93% of its electricity from non-emitting fuel sources. As Yukon's electricity transmission system is not connected to electrical grids in neighboring jurisdictions, maintaining and increasing the proportion of electricity generated from non-emitting sources is a challenge to be solved with a Yukon solution.

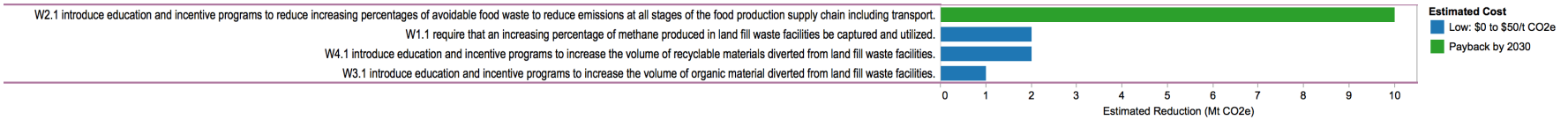
Estimated Reduction in Greenhouse Gas Emissions (Mt CO2e) and Estimated Cost ($ per tonne CO2e)
Light Manufacturing, Construction and Forest Resources [5% of Total Yukon GHG Emissions in 2016]



Light Manufacturing, Construction and Forest Resources – Criteria for Consideration:

Yukon's extensive biomass resources can be substituted for petroleum-based heating fuels imported into the territory.

Estimated Reduction in Greenhouse Gas Emissions (Mt CO2e) and Estimated Cost ($ per tonne CO2e)
Waste [2% of Total Yukon GHG Emissions in 2016]



Waste Sector – Criteria for Consideration:

Yukon has already made significant progress towards diverting recyclable and organic materials from waste facilities.