BACKGROUND

In response to a federal government initiative to voluntarily achieve a 30 per cent reduction in greenhouse gas emissions from nitrogen fertilizer application by 2030, Fertilizer Canada took the initiative to organize a virtual dialogue on May 12-13 focused on the role that the 4R Nutrient Stewardship program can play in reducing farm nitrous oxide emissions while growing agricultural exports.

Fertilizer Canada would like to thank officials from Agriculture and Agri-Food Canada, Environment and Climate Change Canada, farm leaders, research scientists and members of the fertilizer industry for assisting in the development of the agenda, presenting and participating in the discussion. The following report attempts to summarize the discussions and capture key outcomes.

KEY TAKEAWAYS

Canadian farmers are not overapplying nitrogen fertilizer. Canadian farmers use nitrogen (N) efficiently compared to their competitors in Europe. In countries where over application of N has been the norm, reducing N rates will not reduce yield. Canada is not one of those countries.

Nutrient use efficiency in Canada exceeds the world average and ranges between 66% and 78%. Canada is accomplishing this while also increasing productivity as a net positive contributor to world food security. The opportunity to improve nitrogen use efficiency is smaller in Canada than it is in other places in the world.

Emission reductions based on reduced rates alone will be expensive and economically painful on the farm. Implementation of intermediate 4R practices increases crop productivity and farmer profit, while also significantly reducing emissions, compared to a 30% N rate reduction that only has marginal impacts on intensity of emissions, and negatively impacts farmer profits.

- The difference in profit between a per acre emissions reduction based on a 30% reduction in nitrogen rate and implementation of intermediate 4R practices is approximately $41 per acre.

Barriers to farmer adoption of 4R Nutrient Stewardship practices:

- **4R Nutrient Stewardship is field-specific, not farm-specific.** There is a lot of complexity to a specific fertilizer program for each field at an advanced level. Farmers need to understand how implementing more advanced practices will improve their bottom line.
- **Source: yield effect for inhibitors and controlled release products are less obvious.** The economic benefit is smaller than the environmental benefit and farmers are not being paid for that environmental benefit. A mechanism at the national level (carbon credits |protocols) is required to reward farmers for the societal benefits they provide.
- **Rate optimization: There is a need to provide farmers with better decision-making support tools.** Requires a concerted multi-stakeholder effort to develop, validate and verify N rate decision support in-season. Require addressing risk management and better predictions of plant N needs at the farm level.
- **Timing & Placement: advanced practices require larger capital investments in equipment** – incentives required both from the marketplace and carbon market opportunities.
- **Technology: a need for widespread rural availability of broadband for equipment**. Also, progress in digital tools on farm will advance uptake, which may not be widely available nor accessible (tech transfer is needed by the industry).

- **Regulatory: there are multiple initiatives across government focused on climate change that have cumulative impacts** and are not reflective of what's happening on the ground. Farmers must be considered as partners. Increased integration of 4R Nutrient Stewardship across these initiatives is required as a practical way to achieve goals across the agriculture industry.

Engagement in risk: The motivation is to positively change the environmental practices of 200,000 farmers across Canada. These are small and medium enterprises who are engaging in a lot of risk to their operations and need assurance in the value. When considering challenges in terms of risk and the requirements for certainty from government, the Government of Canada should share in some of that risk with Canadian farmers and agri-retailers who are investing on-farm to advance sustainable practices.

N_2O reductions are achievable with 4R Nutrient Stewardship: A combination of 4R practices will allow us to achieve the greatest efficiencies and the greatest reductions.

There is a right source solution. Inhibitors work to reduce direct and indirect GHG emissions by 20% to 40%.

- Nitrification inhibitors and controlled release coatings exceed their value to the farmer in terms of improvements to yield and nitrogen use efficiency. As a best case, an Ontario corn farmer could expect a 2% increase in yield from the use of a nitrification inhibitor, a 10% nitrogen use efficiency increase, and a 30% reduction in emissions of nitrous oxide. The value to society of the emission reduction is $41/acre (with carbon valued at $170 per tonne of CO_2eq). An arbitrary 30% reduction could result in an 8% yield loss and $55/acre profit loss.
- Current use of these products in the Fertilizer Use Survey for Ontario (2020) shows 13% of corn farmers - a significant start and something that we can increase.

Challenges & opportunities - National Inventory Report (NIR): If the NIR is being used to assess performance towards the federal emission reduction target by 2030, then it is not fit for purpose at this time to be used as target tracking.

- The NIR requires a complete, consistent, historical farm management activity data set to update inventory estimates (less emphasis on 1990 – now 2005).
- This data does not exist. There is a need to understand what a reasonable level of reliable or proxy data is.
- Authoritative information based on mature science: defined as information that has scientific consensus and is published to inform the methodologies.
    - NERP Reduction modifier development during the Ontario-Quebec protocol adaptation process: PhD soil scientists across Canada (including AAFC) reached over 80% consensus on appropriate emission reduction factors for Canada following the ISO 14064:2 principles and process. These were conservative estimates of reduction factors of 15% to 35%.
    - A published synthesis of the research studies for inclusion of 4R Nutrient Stewardship and modified reduction factors must be agreed upon in the NIR.
- Acquiring adjustments under IPCC rules is not easy to implement. However, IPCC 2019 guidelines do allow for EEF recognition in the national GHG inventory. Some EEFs (nitrification inhibitors and controlled-release coatings) have a consistent effect on reducing emissions from nitrogen fertilizer under a range of conditions and thus generalizable.
- The challenge is acquiring field-level data. A cooperative approach with industry and provincial/federal governments to collect farm activity data is needed. Modeling will need to be considered in order to address this challenge. The creation of a research database for modellers is required.

Science update to the 4R Climate Smart Protocol BMPs: The 4R Research community has offered to provide ECCC and AAFC with a separate session to review the latest science update for the Protocol (based on the Ontario-Quebec process).

- Research into integrated BMPs for in-field verification of N_2O reductions is expensive and rare. Much more abundant in peer-reviewed literature is the impact of separate BMPs (source, rate, time and place) on N_2O emissions.
- A consensus approach, following the ISO 14064:2 principles and process, based on conservative assessments of what the latest science is on each of the 'R's' is valuable, especially when the bar is set at 80% consensus of the participating independent N_2O scientists.
- Nitrous oxide is emitted into a global pool. At least 8 published peer-reviewed global meta-analyses confirm an average efficacy for nitrification inhibitors to reduce emissions by 20% to 40%.
- Activity Data requirements for improved NIR (trajectory towards Tier III)
    - Farm environmental management surveys (FEMS) do not collect all the needed activity data.
    - Fertilizer Use Survey - Industry has filled the gap with commodity groups through the Fertilizer Use Survey. There is a wealth of information to start to be able to incorporate into an improved NIR and can lend itself to modelling.
    - Fertilizer Shipments to Agricultural Markets (Statistics Canada) – an issue was noted that data for small provinces are often suppressed owing to privacy requirements.
    - 4R Nutrient Stewardship Plans
- Low-hanging fruit - recommendations outlined for reduction modifiers:
    - Source: nitrification inhibitors: 35% at advanced is a conservative estimate - need to synthesize the literature and obtain a peer reviewed publication on the efficacy of 4R implementation in Canada for reducing greenhouse gas emissions.
- Opportunity for further research: to identify the specific conditions in which one timing/placement combination is preferred over another.
    - Placement: Split application recommendation is 15% in emission reductions
    - Time: 30% emissions reduction relative to spring pre-plant application
- Integration:
    - Fundamental to integrate N_2O reduction with soil organic carbon changes.
    - Integration of crops and animals - ensure practices encourage the utilization of manure, rather than displacing it with fertilizer.

Challenges & opportunities - protocol development: data needs to be grounded in publicly available, peer-reviewed research studies / methodologies to be able to clearly identify that the reductions being generated from the protocol are quantifiable, verifiable, and additional.

- While it is preferred to have Protocol development utilize the same methodology as the NIR, it is not required to be identical. Ideally, the two can be reconciled for offset projects to be visible in the inventory estimates, but it is understood that is a process that will take time to accomplish. Protocol development allows us to be nimbler and reflect what is happening on the ground sooner.
- Peer-reviewed studies are required to validate that the reduction modifiers that are used for the 4R program at various levels are supported by scientists to be the appropriate percentages.
- Barriers to getting peer-reviewed publications: Time is the biggest factor and field experiments need to take place over several seasons with suites of practices put together which is expensive and rarely achieved in practice.

- ECCC is maintaining a database of all published studies and will share this database for researchers to identify gaps and provide relevant studies. Possibility of providing ECCC with unpublished research to date to be classed in a different category (provincial government researchers, non-academic - funded by farmers or provincial governments). This could be a priority for a CAN-Net- N_2O.
- 4R Climate Smart Protocol: verification requirements and the evidence required for proof of practice | meeting the requirements of the protocol are substantial.
- Using the dynamic baseline approach on average with $35 / tonne (after negotiations and administrative costs) it's about $5/acre return on average.
- There are multiple carbon pilots on the ground today in Canada which are testing and trying to find solutions to pain points and seeing how digital technology can be better applied.

Defining "common practice"

- Under the 4R Climate Smart Protocol, banding and no-till are practices that would not affect the baseline or the base application of 4Rs under a system of basic, intermediate and advanced management. Building a documented 4R Plan according to the requirements of the protocol and with an Accredited Professional Advisor is a key eligibility criteria for the protocol. In practice, most growers don't soil test or conduct N balance calculations on every field in every year. So practice change is required even at the basic level. The 4R's required by the protocol represent a higher level of management that produces environmental benefit more than improved yield, especially at intermediate and advanced levels.
- Need to be careful not to punish early adopters of practices. If we are too quick to assume that improved N management is becoming "common practice" then there is no incentive for the majority to adopt the practice. It is important to focus on the broader system and consider all nutrients.

Data collection: there is an opportunity for implementation via crop input suppliers considering the desired reach of 200,000 Canadian farmers. The majority of farmers use a Certified Crop Advisor (CCA), whether independent or connected to a crop input supply business. It is important that this data entry point focus on working towards digital ag data capture vs manual entry to bring it to scale. This could be effective for informing the NIR, but also protects the privacy of farmers. A common methodology across Canada is important to enable digital implementation at scale as private companies make investments into digital infrastructure to enable farmers to participate in a carbon market.

ACTIONABLE OUTCOMES

1. Support farmer adoption of 4R Nutrient Stewardship by utilizing the more than 1,700 Certified Crop Advisors (CCAs) across Canada who provide rigorous, science-based agronomic advice to farmers in Western Canada, Ontario and the Atlantic provinces. CCAs are the most significant extension resource for Canadian farmers. The 4R Nutrient Stewardship program has always operated on the basis that in order to guarantee appropriate implementation of 4R practices and document emission reductions, 4R implementation on-farm is best through a Plan written by CCA that has completed 4R training. Canadian Agri-retailers across Canada are participating in Designation and Certification programs to ensure this is the case.

2. Participate in the 4R Climate Smart Task Force – ECCC and AAFC participation is requested in the recently developed 4R Climate Smart Taskforce. This group consists of representatives with expertise in offset protocol development, greenhouse gas validation and verification, sector-based best management practices, and relevant academic research. Our industry has proactively constructed this group of experts to help address and answer concerns which currently challenge prioritization of the 4R Climate Smart Protocol.

3. Incorporate 4R practices into the National Inventory Report (NIR) – Canada's NIR provides a good estimate of N_2O compared to the rest of the world. However, the NIR will be difficult to use to assess performance against the federal emission reduction target to 2030, unless it's improved through calculating emission reductions resulting from differences in 4R nitrogen management which we know reduce N_2O emissions. Advancing integration of 4R Nutrient Stewardship into the NIR is necessary to ensure that progress can be monitored appropriately. It is also fundamental to integrate N_2O reductions with soil organic carbon increase, and crops and animals. Improvements in industry and farmer buy-in could be achieved through increased outreach, collaboration and communication on how the NIR is derived and opportunities for improvements.

4. Collaborate with industry on farm activity data – Government has indicated new science is being prepared to implement in the next couple of years which is fundamental for fertilizer use. Industry is requesting collaboration on these publications and as well as new opportunities for 4R meta-analysis. Fertilizer Canada will work with research scientists, farmers, ECCC, AAFC (Sustainability Metrics Team) and Statistics Canada on identifying what better activity data we could create and contribute to – including the Fertilizer Use Survey.

5. Compile peer-reviewed research – The challenge for regulators in operating an offset system is the requirement for peer-reviewed research. To provide more certainty, research scientists will work towards a published synthesis of the research studies for inclusion of 4R Nutrient Stewardship and modified reduction factors. ECCC will provide the research community with access to the database of published studies to identify gaps and pull together published and non-published studies as well as meta-analysis supporting various practices for the 4Rs. In order to address the challenge of acquiring field-level data, modeling would need to be considered and the creation of a research database for modellers is required.

6. Support for public-private partnerships advancing 4R research and tools
N_2O Network (CAN NET N_2O): tangible results will need to be achieved through collaboration within the agri-food system - including farmers, industry, processors, retailers, and governmental and university researchers. This effort would focus on farmer-driven research to validate the efficacy for various enhanced efficiency products for N_2O reductions and targeted funding for field-scale 4R Climate Smart protocol demonstrations in the Prairies, Central and Atlantic regions through the Living Labs program.

Cool Farm Tool: Fertilizer Canada and Antheis group put forward a proposal to AAFC in 2019 to adapt the Cool Farm Tool for Canadian farming systems, but did not receive funding. The projected cost of the pilot was $200,000 invested from industry and $1M from government funding. The Government should reconsider support for this tool as the agricultural community seeks to validate its sustainable practices and define progress towards government goals. A common methodology across Canada is important to enable digital implementation at scale.

7. Ensure policy is reflective of Canadian agriculture – Need for clarification from AAFC if the intention is to reduce nitrogen rates or GHG emissions from nitrogen application, and whether a total emissions reduction could be achieved without cutting nitrogen rates. Focus should be on sustainable intensification - reducing the carbon footprint per tonne of grains and oilseeds to ensure Canadian farmers can continue to feed the world with sustainably-grown crops. Many recent policies and investments by the federal government support sustainable intensification. The Clean Fuel Standard, for example, has the co-benefit of reducing emissions intensity in liquid fuels while creating a significant demand for growers to sell more crop, as demonstrated by three recently-announced canola crush plants in Saskatchewan totalling nearly five million tonnes in annual capacity. The federal government, through the Canada Infrastructure Bank, has also earmarked $1.5-billion to

increase irrigated acres in the Prairies. With new active cropland, sustainable intensification must be the objective in order to ensure the competitiveness and export potential of Canadian growers.

The concept of sustainable intensification has also been endorsed by the United Nations through FAO's Climate-Smart Agriculture strategy. The government's stated intention to pursue an absolute emissions reduction of 30% is out of step with this global direction and will effectively put a cap on the total emissions allowable from fertilizer at 30% below 2020 levels. As the yield of Canadian crops is directly linked to proper fertilizer application this creates a ceiling on Canadian agricultural productivity well below 2020 levels.

- Chris Forbes, Deputy Minister, AAFC (CAPI "The Big Forum" Webinar Series - timestamp: 12:08PM "…we are starting with engagement with producers, Fertilizer Canada, and the science community about how we can best meet this target. I would say the imperative is to find a way to do both - reduce fertilizer use without impairing the competitiveness of the sector."
- Additionally, the Crops and Horticulture Division, as well as the Minister's office, has indicated to Fertilizer Canada and farm organizations in initial consultations, that the target was set not through extensive modelling exercises on what was achievable, but rather through an iterative process, identifying potential opportunities and a desire to align with international jurisdictions - specifically the EU, whose strategy is a 20% reduction in fertilizer use.

PARTICIPANTS

Karen Proud, President & CEO, Fertilizer Canada
Clyde Graham, Executive Vice President, Fertilizer Canada
Cassandra Cotton, Vice President, Policy & Programs, Fertilizer Canada
Catherine King, Vice President, Public Affairs, Fertilizer Canada
Daniel Kelter, Senior Manager, Government Relations, Fertilizer Canada
McKenzie Smith, Director, Stewardship & Regulatory Affairs, Fertilizer Canada
Kelsey Hill, Manager, Nutrient Stewardship, Fertilizer Canada
Ryan Greer, Hill & Knowlton Strategies

Brian Kenyon, Yara
Cheyne Ogilvie, Richardson
Emily Pearce-Rayner, Nutrien
Michelle Nutting, Nutrien
Andrew Gajadhar, K+S
Amanda Lindgren, K+S
Tyler Hopson, Mosaic
Adam Herges, Mosaic
Darcie Park, CF Industries
Simon North, Cargill

Tom Bruulsema, Plant Nutrition Canada
Dan Heaney, CCA 4R, Pag, Random Cross Consulting
Karen Haugen-Kozyra, Viresco Solutions
Mario Tenuta, University of Manitoba (4R Research Chair)
Claudia Wagner Riddle, University of Guelph
David Burton, Dalhousie University

Lauren Donihee, Executive Director, Crops and Horticulture Division, AAFC
Linda Diaz, Deputy Director, Crops and Horticulture Division, AAFC
Alexandre Lefebvre, Director, AAFC
Cinthia Braidwood, Climate Change Policy Analyst, AAFC
Lucy Clearwater, Senior Analyst, Environment Science Policy Integration, AAFC
Marie-France Gagnon, Senior Policy Analyst, AAFC
Regina Palamar, Sector Specialist, Crops and Horticulture Division, AAFC
Stefan Schneider, Sector Specialist, AAFC
Jordan Taft, Senior Policy Analyst, AAFC
Ward Smith, Scientist - Study leader in Agroecosystem Modelling, AAFC
Shabtai Bittman, Research Scientist, AAFC
Craig Drury, Research Scientist, AAFC
Reynald Lemke, Research Scientist, AAFC (Saskatoon Research Centre)
Dan MacDonald, Physical Scientist, Landscape and Land Use Analysis, AAFC
Chang Liang, Agricultural Scientist, AAFC

Jackie Mercer, Senior Program Engineer - Environment and Climate Change Canada
Douglas MacDonald, Manager, Physical Science, Agriculture Forestry and Other Land Use, ECCC
Amanda Bambrick, Senior Offset Policy Advisor, ECCC
Megan Baskerville, Environmental Program Officer, ECCC

Mark Walker, Canadian Canola Growers Association
Warren Ward, Canola Council
Keith Currie, Canadian Federation of Agriculture
Frank Annau, Canadian Federation of Agriculture
Erin Gowriluk, Grain Growers of Canada
Branden Leslie, Grain Growers of Canada

APPENDIX

PRESENTATION HIGHLIGHTS

It is only through the collaboration of scientists, farmers, industry and government that we will be able to make progress towards reducing greenhouse gas emissions while sustaining Canadian agricultural economic growth. 4R Nutrient Stewardship is an innovative solution to support the government's agricultural goals of reducing greenhouse gas emissions and increasing the efficiency of agricultural practices for enhanced food production. Through 4R Nutrient Stewardship, agriculture can positively contribute to, and achieve tangible and verifiable results.

4R Nutrient Stewardship – Quantifying the Impacts (McKenzie Smith, Fertilizer Canada): 4R Nutrient Stewardship provides a science-based framework for implementing, validating, and communicating sustainable fertilizer management in Canada. This presentation focused on providing an overview of the 4R framework and the results on impact and uptake of the program.

- The concept is simple, but the implementation is knowledge-intensive and site-specific.
- Highlights of implementation of 4R Nutrient Stewardship in Canada:
    - Fertilizer Use Survey: In 2019, the survey indicated that 67% of Canadian farmers are aware of 4R Nutrient Stewardship and 51% of Canadian farmers believe they are implementing a basic level of 4R BMPs. Only 6% have a 4R plan and only 5% of farmers are qualifying under the 4R Climate Smart Protocol. There is an opportunity to further incentivize and encourage increased adoption.
    - Validated: The 4R Nutrient Stewardship program operates on the basis that in order to guarantee appropriate implementation of 4R practices and document emission reductions, 4R implementation on-farm needs to be done through a plan written by a professional agrologist with 4R training (CCA 4R Specialty exam). Fertilizer Canada has set a target of 30 million acres through the fertilizer use survey by 2025 but also a target of achieving 15 million 4R validated acres by 2025. Reached 4 million acres to date and have a 2021 goal of 6 million acres.
    - The 4R Climate Smart Protocol (based on NERP in Alberta) is focused on improving nitrogen management practices while reducing greenhouse gas emissions and other N losses. Only farms implementing a verified plan developed by a Professional Agrologist with 4R Training allows for documentation of emission reductions.
        - 4R Climate Smart protocol has support of numerous farmer organizations. If implemented across Western Canada alone we would expect to see 2-3 MT CO_2e. Protocol practices are more specific, not necessarily higher level.
- Barriers to adoption: behaviour change takes time. Farmers take on a lot of risk in adopting new practice change and need assurance in the value. This takes time for development, research over multiple years and on-farm demonstration, refinements to practices and quantifying the impacts (economic and environmental), getting buy in, validating activity on farm, etc.
    - Investment: more advanced practices require larger investments in things like equipment and more expensive products. The 4Rs are field-specific, not farm-specific. There is a lot of complexity of having a specific fertilizer program for each field at an advanced level. Farmers need to understand how implementing more advanced practices will improve their bottom line – financial incentives.
    - Technology barriers: there is a need for widespread rural availability of broadband for equipment.

- Regulatory barriers: multiple initiatives across government focused on climate change (ie: clean fuel standard) that have cumulative impacts and are not considering farmers as partners (stick vs carrot). If farmers were considered a partner, government would get quicker uptake and less push back. It has to be practical, implementable and economical. The more 4R Nutrient Stewardship can be integrated into initiatives going forward as a practical way to achieve them, there would be much better uptake.

4R Research Results: Three 20-minute presentations provided an opportunity for 4R Research experts to present latest research findings as it relates to improved nitrogen management. Presentations highlighted the potential GHG reduction impacts from 4R towards the federal target goal and identified the opportunities based on research outcomes.

Dr. Claudia Wagner Riddle, University of Guelph

- Only through collaboration of scientists, farmers, industry and government that we are actually going to make a difference and address the challenge
- Promising mitigation strategies were evaluated at the field scale providing evidence for potential of GHG emissions through use of inhibitors at approx. 40%
- Emphasized that it is this combination of practices (source, rate, timing, placement) that will have the greatest impact.
  - In-season application with rate adjustment
  - In-season application with inhibitors
  - Injection with rate adjustment (to avoid trade-offs with ammonia loss)
- Soil biogeochemical models coupled to economic optimization models provided estimates for various emission reduction scenarios
- Results indicate significant reductions in N_2O emissions with increased profits based on matching N requirements to plant needs.
- In practice, this would require addressing risk management and better predictions of plant N needs at the farm level. DMDC model approach is not exactly what farmers can do at the farm level. Analysis shows that there is potential for a reduction of rate in terms of on average. There is a need to provide farmers with better decision-making support tools better in terms of deciding on a yearly basis.

Dr. David Burton, Dalhousie University

- A combination of 4R practices are going to allow us to achieve the greatest efficiencies and the greatest reductions.
- Challenge in Atlantic Canadian system: production of french fries - marketable yield ideal for fry production.
- Challenge: there is a dramatic reduction in GHGs, but at a cost. Research showed a slight reduction in the marketable yield and increased cost associated with enhanced efficiency fertilizer. In terms of the tonnes of CO2 produced, it's about $200 - $220 a tonne.
- Opportunity for more precise measurement to address efficiencies based on soil supply. There is high variation in the soil nitrogen supply capacity: Measuring nitrogen balance inputs versus outputs isn't a direct measurement of what's happening within a field.

Dr. Mario Tenuta, University of Manitoba | 4R Research Chair

- N_2O reductions are achievable with 4R Nutrient Stewardship - combinations of 4Rs achieve the best and consistent reductions.

  - Inhibitors work to reduce direct and indirect emissions
  - Placement works to reduce emissions
  - Timing has variable effects because of weather
- New generation of smart fertilizers and product chemistries - enhanced efficiency fertilizers have been an important industry innovation and one of the most exciting areas in research right now.
- General reductions across the board - Research found that when banding *and* use an EEF saw a reduction in N_2O emissions of at least 40%.
- Emission intensity - counting reductions based on yield relative to end emissions was almost 60% (six sites in Manitoba, different years on farmer fields)
- Challenge: yield effect is less obvious. Rather fine tuning yields, but massive reductions in GHGs. We need to find a mechanism at the national level and carbon credits | Protocols will be important to create that incentive.
- Need integration – a broad Canadian network of research Canada, academia, farmers, and industry, and proposing a CAN-Net- N_2O to get us together and find mechanisms in which we can work together. A need to foster development of next generation nitrogen fertilizers. Both private and public partners.
- Need to include 4R practices in the NIR with highlighted research and demonstrated practices to reduce N_2O.
- NIR inclusion: processes that are required to adhere to with a high level of scrutiny. Currently, Canada operates with a tier two approach for emission estimates and there is room for improvement but need a published synthesis of the research studies for inclusion of 4R Nutrient Stewardship and modified reduction factors must be agreed upon in the national inventory report.
- Barriers to 4R integration into the National Inventory Report:
  - Authoritative information based on mature science: defined as information that has scientific consensus and is published to inform the methodologies.
    - PhD soil scientists across Canada (including AAFC) have reached consensus through a very rigorous process that the 4Rs directionally were a significant opportunity to reduce N_2O emissions. These were conservative estimates of reduction factors of 15% to 35%.
  - Reliable, historic activity data: There is now less emphasis on 1990 – the important year now is 2005 and understanding the practices either through private means or through public means as long as they have the ability to validate it. This data does not exist. There is a need to understand what would be a reasonable level of reliable or proxy data.
- Protocols: Peer-reviewed studies required to validate that the reduction modifiers that are used for the 4R program at various levels are supported by scientists to be the appropriate percentages.
- Collection: activity data should be collected by certified crop advisors. CCA's develop a plan with the farmer and they're working with that farmer, but as a result of that, they report acres to Fertilizer Canada via aggregated scale to a larger data collection process. This could be effective because we need to feed the national inventory report, but we also do need to do it in a way that protects the privacy of the farmers.
- Opportunity for implementation via crop input suppliers considering the desired reach of 200,000 farmers The majority of farmers in this country use a Certified Crop Advisor, whether it's an independent or connected to a crop input supply business.
- Missing further understanding of rate effects in combinations with 4Rs, 4Rs with cultural practices, 4Rs and indirect N_2O emissions.

Economics and the Farmer (Dr. Dan Heaney, CCA 4R, Pag, Random Cross Consulting): This presentation provided an overview of a basic modeling exercise based on the potential impacts of a 30% total emissions reduction target vs the impact of 4R nutrient stewardship adoption holistically based on the 4R Climate Smart Protocol.

- Overall, Canadian farmers are not overapplying N. Canadian farmers spend a lot of money on fertilizer inputs (almost $6B a year in Canada) – they are sensitive to getting it right.
- Canada is a net positive contributor to world food supply
    - Canada exports more than half of what it produces, and farmers are not heavily subsidized. This is important because the European Union is one of the regions we're being benchmarked against in terms of emissions and nitrogen use. The EU feeds themselves handily, but they're not a contributor to the world food supply and world food security.
- Canadian emission intensity is relatively low. On a gross scale in Canada, we put down about 60 kilograms of nitrogen per H.
- Emission reductions based on reduced rates alone will be expensive and economically painful on the farm.
- Three scenarios outlined for canola: impact on both crop productivity and the associated emissions.
    - baseline scenario
    - 30% reduction scenario
    - Optimistic 4R-type scenario
- Implementation of intermediate 4R practices increases crop productivity and farmer profit, while also significantly reducing emissions, compared to a 30% N rate reduction that only has marginal impacts on intensity of emissions, and negatively impacts farmer profits. While implementing a total emissions reduction strategy based solely on reduced use of nitrogen fertilizer will reduce emissions, the analysis suggests that adoption of an intermediate suite of 4R practices reduces the emissions intensity by almost double. While the price of the crop remains the same, as these are set by market forces, cropping system productivity for each model changes significantly. The difference in profit between a per acre emissions reduction based on a 30% reduction in nitrogen rate and implementation of intermediate 4R practices is approximately $41 per acre.
- To provide further context to cumulative costs of just over $2 billion to canola farmers, in 2020 canola farm cash receipts were $10.2 billion.
- Banding – substantial capital investment in equipment and those capital investments aren't going to happen without some incentives both from the marketplace and perhaps from things like carbon market opportunities.
- There are two different groups of data needs.
    - NIR: requires complete, consistent historical data set in order to update inventory estimates.
    - Carbon markets Bureau: offsets and emissions trading section has a different need for data. In order to develop protocols, they need to be grounded in publicly available, peer reviewed research studies, methodologies, data to be able to clearly identify that the reductions that are being generated from the protocol are quantifiable, verifiable, and additional.
- While it is preferred to have Protocol development utilizing the same methodology as the NIR, it doesn't necessarily need to be identical. Ideally, the two can be reconciled for offset projects to be visible in the inventory estimates, but it is understood that is a process that will take time to accomplish.
- Protocols need to establish a baseline for a project and a quantification approach to demonstrate that the new activity as implemented is generating emission reductions. There is more flexibility to develop

quantification methods that make sense. 4R incorporation into the NIR will take more time, but protocol development will allow us to be more nimble and actually reflect what industry is doing sooner.

- ECCC doesn't have a good appreciation for what has been done to date that would support the development or the improvement of protocols. Understanding what studies have been done - published and unpublished - would be a helpful first step. From there - gaps can be identified – perhaps AAFC is doing work that supports some of the unpublished studies. ECCC is maintaining a database of all of the published studies. Possibility of providing ECCC with unpublished research to date to be classed in a different category (provincial government researchers, non-academic - funded by farmers or provincial governments). ECCC to share their database and see amongst the researchers to identify gaps and provide relevant studies. This could be a priority for a CAN-Net- N_2O.
- Part of the frustration for the farmer is that policies are not reflective of what's happening on the ground. 4R Nutrient Stewardship is the right concept that can be practically applied going forward, because when you're talking about 250 different crops that we grow in this country, on different soils, in different climates, a one size fits all approach isn't going to work. We've got enough data that we can conservatively quantify the reductions. Once you get a couple of million acres involved in a protocol, the aggregation starts to take care of some of the outliers.
- The Fertilizer Use Survey is a great source of information that may help fill the gap. From 2014, approx. 1000-1500 farmers across Canada (Prairies and Ontario primarily - canola and corn), all source, rate, time and place practices with additional operational on farm data.

Carbon as a Farm Commodity: The 4R Climate Smart Protocol (Karen Haugen-Kozyra, Viresco Solutions): This presentation provided an overview of the 4R Climate Smart Protocol, its current application in Alberta, its challenges, and the proposed solutions.

- Currently in NERP version 2.0 in Alberta.
- In 2014, a protocol validation study was undertaken to determine what the barriers were to implementation of the first version (2010).
- Pain points for NERP V.2:
    - Baselines (conventional – 3-year historic vs dynamic)
    - Whole Farm Enterprise
    - Yield issues (dry matter, residue N)
    - Soil testing vs N balance (Post harvest assessment)
    - Updated 4R tables and science
    - Landowner sign-off
- Protocol adaptation process (ON-QC) 2017 – 2019 - Considered the Western climate initiative offset policy criteria and the ISO 14064:2
- Mandate was also to build something that fit all of Canada as if based on the national emissions inventory.
    - Year-long extensive scientific literature review was used to guide and inform a workshop. Over 80% consensus was gained on appropriate emission factors following the ISO 14064:2 principles and process.
    - Set a high bar in terms of gaining alignment on the science and were conservative on the estimates for specific BMPs (harder to find studies on fully integrated BMPs).

- 4R Climate Smart Protocol performance levels are more restrictive than the general nutrient stewardship practices. They are designed for a different outcome - not simply better economic performance.
- There are multiple carbon pilots on the ground today in Canada which are testing and trying to find solutions to pain points and seeing how digital technology can be better applied.
- It is very different to be implementing certain practices under a 4R framework vs following a protocol and having a documented 4R plan written and signed off by a professional agronomist – even with "advanced" farmers. Even if a farmer is doing a variable rate application, they haven't necessarily written a 4R nutrient management plan that included **all** of the elements in basic and then moving to intermediate and advanced. I.e.: broadcast and incorporate practices are a good management practice, but they don't qualify for a nitrous oxide emission reduction under the Protocol.
- The verification requirements and the evidence required for proof of practice and meeting the requirements of the protocol are substantial.
- Using the dynamic baseline approach on average with $35 / tonne (after negotiations and administrative costs) it's about $5/acre return on average.
- It is important to note that the science review attempted to summarize the current meta-analysis and published studies that were available at the time. The 35% for nitrification inhibitors vs. 25% for dual inhibitors reflected the various studies available at the time. Those numbers did not reflect studies that included direct comparisons. There is now much better information of dual inhibitors which would support a much larger emissions reduction factor. We also need to rely upon the strong foundation of modelling that has been done within Canada and apply them to project the impact of 4R processes on total N_2O emissions and the effect of variations of weather on those emissions reductions. That modelling can also predict impacts on NH3 and nitrate.

Canada's National Inventory Reporting (Dr. Mario Tenuta, University of Manitoba | 4R Research Chair): In Canada's national inventory, N_2O emissions are not measured directly but rather are estimated based on N inputs. Integration of 4R Nutrient Stewardship into the NIR is necessary to ensure that progress towards a target can be monitored appropriately.

- The NIR is advanced compared to other countries, but how can we improve how things are calculated and make it better – documenting the impacts of 4R management into an emission reduction modifier.
- Low-hanging fruit - recommendations outlined for reduction modifiers that currently aren't part of the NIR:
    - Source: nitrification inhibitors: 35% at advanced as a conservative estimate - need to synthesize the literature on that and get a peer reviewed publication on the use of inhibitors.
    - Placement: Split application recommendation is 15% in emission reductions (spring versus fall is different in East vs West)
    - Time: 30% emissions reduction relative to spring pre-plant application.
- The challenge is to get the field level data – would need to consider modeling.
- N_2O -CAN-Net to tackle improvements to NIR Protocol - academia, government scientists, industry, farmers, conservation groups, working together to tackle improvements in the NIR protocol cooperatively, can it form as a basis for peer-reviewed research summaries and meta-analysis to be published that can be utilized. Support modeling, fill in gaps, provide emission modifiers and factors. Multiple roles to provide the repository and for the information.
- Data requirements for improved NIR (Trajectory is towards field by field (Tier III)
    - Farm management surveys (FEMS) can be limited.

    - Fertilizer Use Survey - Industry has filled the gap with commodity groups through the Fertilizer Use Survey (five years). There is a wealth of information to start to be able to incorporate into an improved NIR and can lend itself to modeling as well.
    - Fertilizer Shipments
    - Nutrient Management / 4R plans
- Peer-reviewed research summaries and meta-analysis (target eco-district research to fill gaps)
- Create research database for modellers \ multi-role of modelling
- Data privacy issues – farm level data needs to be protected.
- Challenge for activity data and matching that to the science. To have more certainty, the science on 4R needs to be published as quick as possible. If the inventory can't get data that is reliable across the country, then it can't implement. It's a complex process. Fertilizer Canada is keen to work with ECCC, AAFC and Statistics Canada on identifying what better activity data we could create and contribute to – including the Fertilizer Use Survey.
- Original development of the baseline under NIR methodology for emission coefficients were based off no till using banded fertilizer and ammonium-based recommended fertilizer rates based on soil test.
- Under the 4R Climate Smart Protocol, banding and no-till are practices that would not affect the baseline or the base application of 4Rs under a system of basic, intermediate and advanced management. Building a documented 4R Plan according to the requirements of the protocol and with an Accredited Professional Advisor is a key eligibility criteria for the protocol. In practice, most growers don't soil test or conduct N balance calculations on every field in every year. So practice change is required even at the basic level. The 4R's required by the protocol represent a higher level of management that produces environmental benefit more than improved yield, especially at intermediate and advanced levels.
- The NIR is very good compared to the rest of the world, however, there is a lot of mystery out there on the part of farmers on how the NIR is derived. For example, an issue is that carbon sinks are reported in a separate category (not reported under agriculture). Is it possible that farmers say NIR over-reports, not because they know how much they emit, but because very little in the NIR is under their control. Trust is built through outreach and interaction. Communication from ECCC and the farming community could be improved.
- We also have to be careful not to punish early adopters of practices. If we are too quick to assume that improved N management is becoming "common practice" then there is no incentive for the majority to adopt the practice.

The Cool Farm Tool (McKenzie Smith, Fertilizer Canada): The Cool Farm Tool was designed to bring the complex science of agriculture and climate change to the field. The Tool has been designed as a farmer-focused, action orientated and interactive greenhouse gas calculator for agriculture that works across the globe and farming systems.

- This tool could be valuable as the agricultural community seeks to validate its sustainable practices and define progress towards government goals.
- Goals
    - Access to improve opportunities for farmers. Accessibility of this globally accepted sustainability metrics calculator in the Canadian marketplace could help enable industry to easily make credible, meaningful and verifiable claims about products and the manner in which they are produced, thus building trust and global recognition of the sustainability of the Canadian cropping sector.

  - Increase carbon credits for farmers across Canada. What farmers want to see in these tools is how do their management practices / changes impact their carbon outcomes - and this is why it should be updated with 4R management practices under the 4R Climate Smart protocol to make it a useful approach in Canada.
  - Potential source of data. The system could capture digital data and download it in a manner that will benefit the farmer for decision support systems, performance metrics, and benchmarking to improve performance and production efficiency.
  - Increase education and awareness on Farms. Additionally, export data could be used to inform the NIR
- A common methodology across Canada is important to enable digital implementation at scale - a barrier is the cost of building different digital infrastructures for each jurisdiction - private companies are building or have built digital tools to enable farmers to participate in the carbon market opportunity.
- The tool is easy to use with direct N_2O emissions broken up into emissions from residues, soils, and fertilizers. It would need to be updated for N_2O emissions levels for Canada and 4R practices.
- These tools, in order to be scaled, have to engaged farmers in some kind of digital on farm management – inputting data manually will not succeed. This is why it is important that the nutrient management consultant be the data entry point and we focus on working towards as much machine entered data coming directly off field monitors as possible and less manual entry.

Eastern Canadian Agriculture & Manure Management (Dr. Tom Bruulsema, Plant Nutrition Canada):
Provided an opportunity to outline the carbon footprint of fertilizer use from an Eastern Canadian perspective, with a focus on corn and the usage of manure as a fertilizer.

- Canada needs to do its part to contribute to world food security.
- Nutrient use efficiency in Canada exceeds the world average.
  - Went from an era of mining the soil in the Prairie's for its nitrogen, to gradually transitioning to a system in which we are maintaining or increasing soil organic matter.
  - Canada's nutrient use efficiency ranges between 66% and 78%. Canada is accomplishing this while also increasing productivity.
  - Western Europe was the leader in productivity in crop yield per acre for many years, however this was achieved with very high levels of nitrogen inputs. Their nitrogen use efficiency went as low as 33%. They have improved their nitrogen use efficiency, but their productivity, the total amount of output of nitrogen coming from their agriculture, has not continued to increase in the last 10 to 20 years. Their current level of nitrogen use efficiency is 61% - where the world average is right now. Canada exceeds that.
  - The opportunity to improve nitrogen use efficiency is smaller here in Canada than it is in other places in the world.
- There is a right source solution. Much discussion surrounding nitrification inhibitors and controlled release coatings and their ability to reduce N_2O emissions. Presented further meta-analysis on this topic as well as a calculation of their societal value in reducing nitrous oxide. Showed how they exceed their value to the farmer in terms of improvements to yield and nitrogen use efficiency. Provided an example of the benefit of inhibitors to yield, NUE and GHG emissions for Ontario grain/corn with some basic assumptions for yields, rates and price (carbon price of $170/tonne).
  - Most probable case that a farmer would expect is a 2% increase in yield from the use of a nitrification inhibitor, a 10% nitrogen use efficiency increase, and a 30% reduction in emissions of nitrous oxide. If you value carbon at $170 a tonne, the value to society is $41/acre.

    - Current use of these products in the Fertilizer Use Survey for Ontario (2020) shows 13% of farmers - a significant start and something that we can increase.
    - An arbitrary 30% reduction would result in an 8% yield loss and $55/acre loss.
- Need to ensure we don't arbitrarily reduce yields and need to bring new land into cultivation which would generate greenhouse gas emissions.
- Nitrous oxide is admitted into a global pool. This is an advantage because it doesn't matter that every farm reduces its emissions. It matters that on average we reduce emissions. So, documenting to the nth degree is not required. What we need is practices that can be expected on average to have a positive contribution to the reduction of emissions and complete a meta-analysis.
- IPCC 2019 guidelines already allow for EEF recognition in the national GHG inventory - "can develop Tier II emission factors specific mitigation options such as the application of EEFs." EEFs have a consistent effect on reducing emissions under a range of conditions and thus generalizable.
- It is fundamental to integrate N_2O reduction with soil organic carbon increase. If we want our cropping systems, whether we use cover crops or whether we use better systems that grow more, nitrogen is needed to support those crops.
- Crops are the ultimate source of carbon going into the soil. We need better decision support tools.
- Integration of crops and animals - nitrogen inputs for Ontario, there are three equal sources: fertilizer, legumes (alfalfa and soybeans) and manure - need to be considering that and ensure we have practices that encourage the utilization of manure, rather than displacing it with fertilizer. Fertilizer Use Survey (2020): 36% were using manure and 8.6% were using some form of biosolids or organic amendments.
- Barriers to adoption:
    - Source: inhibitors and controlled release: the economic benefit is smaller than the environmental benefit and farmers are not being paid for that environmental benefit. Need a mechanism to get farmers rewarded for the societal benefits that they are providing.
    - Rate optimization: Need decision support systems. Requires a concerted multi-stakeholder effort to develop, validate and verify N rate decision support in-season. Integration: Need to integrate N_2O reductions with SOC increase. A need to have crop and animals.
    - Timing & Placement: requirement to invest on the part of the farmer - new equipment.