PGgRc®

PASTORAL GREENHOUSE GAS
RESEARCH CONSORTIUM

5 year Science Progress Report | 2002-2007

DEVELOPING SOLUTIONS TO REDUCE NEW ZEALAND AGRICULTURAL EMISSIONS

Foreword

This publication gives an overview of the research activity undertaken by the PGgRc to mitigate non-CO_2 agriculture greenhouse gases (GHG). It covers the period from 2002 - 2007 and also indicates at a strategic level the future science directions for the consortium.

The opening section gives background to the consortium and the wider climate change issues that are being addressed by its activity. The remaining sections are organised into research discipline areas profiling the broad approach that has been taken to gain understanding of the complex biology that produces methane and nitrous oxide from our pastoral grazing systems. Each section commences with an introduction that identifies the research covered and the following pages detail specific projects of work, completed over the last 5 years. Corresponding authors are referenced on each project page, should the reader require more information.

We have produced this review as we complete our initial research contract with the New Zealand Government and embark on a second five year contract as a consortium. It is our intention that it will be of value to researchers, policy makers, farmers and the wider industry as a reference document.

The contents of this booklet are the result of many people's efforts, from the Directors of the consortium (past and present) who, with the initial consortium manger Dr Julie Iommi, collectively set this programme in motion, through to the many scientific staff who have contributed their knowledge and skills in the last 5 years. All should feel proud of their efforts and are to be thanked for their continued support of what is a big challenge and opportunity for New Zealand agriculture.

We hope that you find this document useful, and if you want to know more about our activities please contact us.

Mark Aspin | Consortium Manager

Chairman's introduction1

The Pastoral Greenhouse Gas Research Consortium (PGgRc) is a partnership between the pastoral industries and the Foundation for Research Science and Technology (FRST). Formed in 2002 to reduce methane emissions from ruminant animals, the PGgRc began rebuilding New Zealand's research capabilities and human capital in the field of rumen science. Since 2003 the consortium's membership and science focus has expanded to incorporate nitrous oxide research. This is the fourth annual report on the investment by the pastoral sector into the mitigation of agricultural greenhouse gases and represents the end of the first 5 years of funding and the beginning of the next 5 year funding period.

The significance of greenhouse gas research has continued to escalate in the last 12 months both nationally with the announcement of an all encompassing Emissions Trading Scheme and globally via the release of the Stern and IPCC Reports. Agriculture is a key driver of New Zealand's economy and a significant contributor to its greenhouse gas profile. As such agricultural greenhouse gas mitigation is a key focus of New Zealand to meet its Kyoto Protocol objectives.

The members of PGgRc believes that it is well placed after 5 years to continue to provide a "centre of excellence" for pastoral based agricultural greenhouse gas mitigation research in New Zealand and globally. In April 2006, the research commissioned by the PGgRc and the governance of the consortium was reviewed by FRST. The panel of internationally recognized experts described the PGgRc activities as "World leading research, with excellent productivity for money expended. The consortium represents the biggest single integrated programme globally responding to issues around livestock greenhouse emissions". This was an extremely satisfying result for the consortium and gives it a sound base for the next 5 years and beyond.

Over the next five years the PGgRc will continue to develop ruminal methane and nitrous oxide mitigation solutions while additionally focusing on whole farming systems to provide pragmatic as well as technological mitigation solutions that target both methane and nitrous oxide. With the prospects of further expansion, the PGgRc is progressively moving towards researching and developing whole farming systems that are equally productive but incorporate mitigation strategies to significantly lower greenhouse gas emissions and adverse environmental effects. Such farms will serve as model model-farms to promote the adoption of more carbon-conscious farm systems across the industry.

The PGgRc is the cornerstone investment by New Zealand in mitigating agricultural greenhouse gas emissions. PGgRc has a broad research focus with many promising leads to reduce greenhouse gas emissions. We may be a small country at the edge of the world, but we are proud to be at the centre of pastoral greenhouse gas emission mitigation and for those who share our vision of the future we would be happy to collaborate.

Mark Leslie | Chairman PGgRc

NEW ZEALAND PASTORAL GREENHOUSE GAS RESEARCH CONSORTIUM (PGgRc) DIRECTORY

The PGgRc is an unincorporated Joint Venture operating through its agent company Pastoral Greenhouse gas Research Limited.

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Climate change, greenhouse gases and pastoral agriculture

Globally, attitudes towards the human role in climate change have shifted and now it is widely accepted that human activities are altering the composition of the atmosphere to such an extent that the planetary energy balance has been altered. The accumulation of greenhouse gases (GHG) such as carbon dioxide is causing our planet to retain more solar radiation, trapping more of the energy that previously would have been emitted back into space.

The "greenhouse effect" is caused by atmospheric molecules such as water vapour (H_2O) and carbon dioxide (CO_2) absorbing infrared energy emitted by the warm earth. Without the heat absorbed by these gases the Earth would be an inhospitable 33°C colder. However, although atmospheric warming is vital for life, since the industrial era human activities have increased the concentration of these gases, by increased emissions and land-use changes that have dramatically depleted the Earth's ability to sink carbon in forests, soil and the ocean. The subsequent increase in the atmospheric absorption of energy is commonly referred to as 'anthropogenic global warming'.

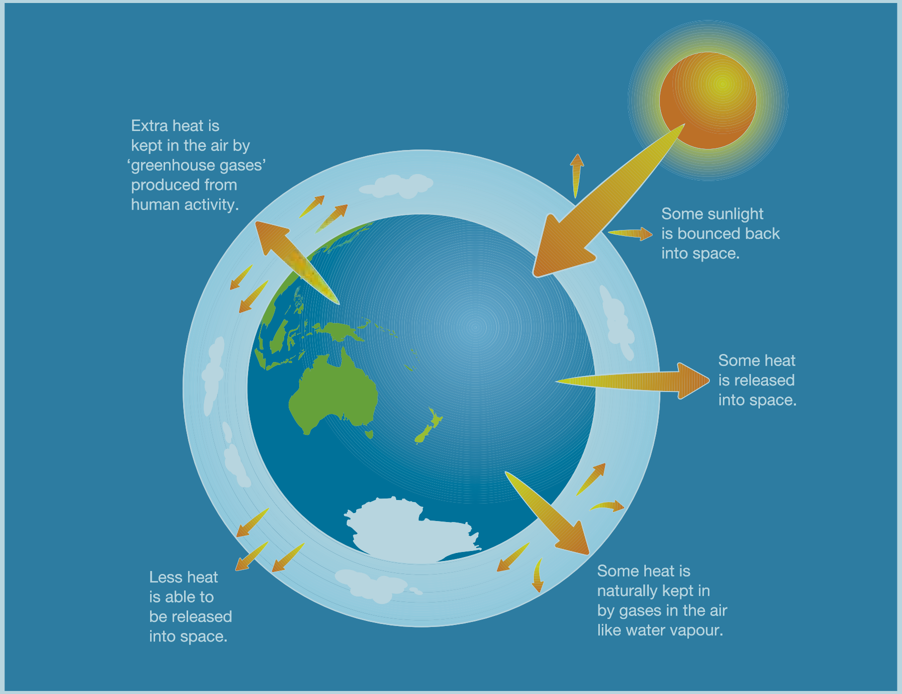
The most significant human emitted 'greenhouse gases' are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Carbon dioxide is emitted from fossil fuel use (coal and oil) and cement production which has reintroduced carbon stores, formed over millions of years, back into the atmosphere. The clearing of forests and draining of wetlands has significantly reduced the biosphere's ability to sequester carbon. Methane is emitted from fossil-fuel related sources, pastoral agriculture and rice cultivation, biomass burning and landfills. Anthropogenic nitrous oxide emissions are from agriculture (fertilizers and animal waste) and the industrial production of nitric and adipic acids. The different gases behave differently and for comparison the relative effects of the different gases are standardized to the equivalent effects of carbon dioxide (CO_2e).

The effects of greenhouse gases are expressed as the *global warming potential* (GWP). Methane's GWP is current set at 21 CO_2e, meaning that the long term effect of one molecule of methane has equivalent magnitude to 21 carbon dioxide molecules. Nitrous oxide's GWP is 310 CO_2e and CFCs have GWPs ranging between 10,000 and 100,000 CO_2e. The GWP reflects the molecule's atmospheric chemistry, the ability to absorb energy and persistence of the molecule. Both nitrous oxide and methane are much less chemically active and persistent than CFCs and hence have lower GWPs.

As the atmospheric energy (heat) balance changes, circulation patterns of the atmosphere and oceans change. These large scale patterns drive our weather, leading to changes in extreme events (e.g., storms and floods), as well as affecting local mean temperature, rainfall patterns and water availability. Without any action the scenarios outlined in the IPCC 4th Assessment Report have a high probability of occurring, and the economic consequences outlined in the Stern report are likely to follow. The New Zealand (and global) economy is vulnerable to environmental change and to maintain the current standard of living we must take a precautionary approach, and proactively implement measures to reduce greenhouse gas emissions throughout the economy.

In addition to climate induced effects on land, sea level rise will have dramatic consequences like the flooding of major low-lying economic centres, such as London, New York or Auckland. Repair and maintenance costs associated with more frequent attrition of transport and other infrastructure by storm events will place greater demands on public resources. Although primary production will need to prepare for more frequent drought and flood events, soil losses or pestilence (as problem species migrate in response to changing conditions), a changed climate may also provide opportunities to take advantage of, such as different crops and forages, and biofuel stock production.

The effects of climate change will be ongoing for decades. Current levels of greenhouse gases and predicted emissions in the next few years already commit us to a changing climate. Hence we need to take steps to both mitigate greenhouse gas emissions, and also to adapt to the climate change we are committed to. Climate change is a challenging and complex issue but there is action we can take and it is more likely that the cumulative results of many small actions across a range of activities that will make a significant difference. Research is providing alternatives to reduce the impact of our current activities and with the implementation of an emissions trading scheme there is an economic incentive intended to drive the adoption of more *carbon-conscious* business practices.



Sources of greenhouse gases from pastoral agriculture

The two greenhouse gases associated with pastoral agriculture are methane and nitrous oxide. The majority of methane is belched (eructed) from ruminant animals where the gas is a by-product of rumen fermentation. Methane can diffuse into the blood stream and some methane is exhaled but the majority is eructed from the rumen directly. Additionally, but to a lesser extent, methane is emitted from the anaerobic decomposition of dung.

Nitrous oxide is formed as part of the nitrogen cycle when soil conditions are anaerobic. The most prevalent conditions for nitrous oxide emission are generally in winter when soil moisture and water tables are high. Nitrous oxide can be formed by two different groups of soil bacteria, one group oxidizes ammonium ions and nitrous oxide is formed as the bacteria cycle nitrogen from ammonium to nitrate. Nitrous oxide can also form as other bacteria reduce nitrate to nitrogen gas, forming nitrous oxide during the course of the transformation.

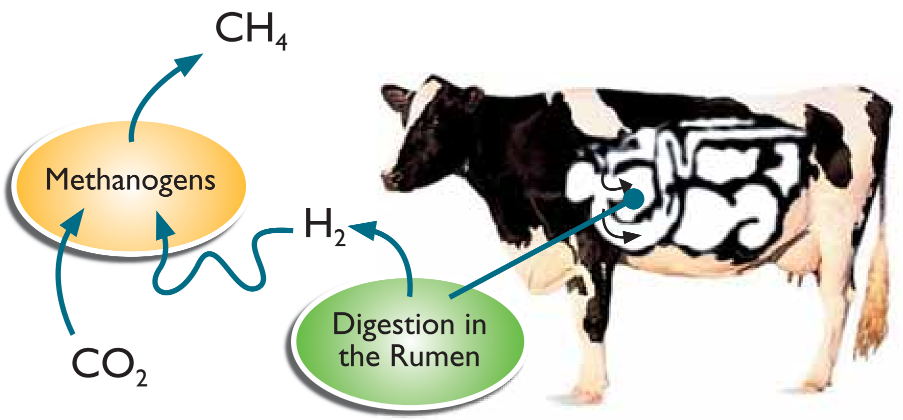
Methane

Methane is produced as a by-product of the digestion of forage. The rumen is the first stage of a ruminant's digestive tract. Forage is chewed up and swallowed with copious quantities of saliva. Once in the rumen the forage is subjected to the action of numerous species and types of micro-organisms, such as fungi, bacteria, protozoa and Archaea-bacteria. Ruminants can return partially digested material to the mouth for further chewing that mechanically breakdowns the forage into a mushy pulp.

Essentially the rumen is a fermentation chamber within which hydrogen is produced. Methane is produced by a group of microbes classified as members of Kingdom Archaea, called methanogen, which gain energy by fixing hydrogen gas into carbon dioxide molecules in the anaerobic environment. Methanogen replace the oxygen atoms in carbon dioxide with hydrogen, and form methane. The methane and other gases built up in the rumen are eructed directly from the rumen. A small fraction (approximately 5%) can pass into the animal's blood stream and then leave the body via the lungs on the animal's breath.

Methanogen play an important role maintaining optimum conditions in the rumen. Without methane or any other mechanism to absorb or remove the hydrogen gas, the hydrogen accumulation would be detrimental for the animal and farming productivity. To successfully mitigate enteric methane emissions is a two step process. Firstly a mechanism that inhibits or eliminates the methanogen is needed and secondly an agent (biological or chemical) is required to mop up the hydrogen. Managing ruminal hydrogen is critical to avoid reducing the rumen pH, leading to poor fermentation and lower feed conversion efficiency, and if left unchecked, acidosis and ultimately death.

Another source of methane from animal



agriculture is the anaerobic breakdown of excreta. Methane from animal waste accounts for about 2% of total agricultural emissions. Since the predominant farming system in New Zealand is free-range, the majority of animal waste is deposited back to land directly and hence difficult to abate. The exception to this occurs in dairying systems or more intensive stand-off pads where waste is collected and stored in oxidation ponds from the milking shed or stand-off pad. The waste still emits methane and nitrous oxide as the waste decays under anaerobic conditions but there is a slight reduction. However with the use of manure digestors and/or the pyrolysis of manure much greater reductions in greenhouse gases could be achieved as well as providing a local energy source.

Additionally, animal waste management practices can not only reduce methane emissions but also those of nitrous oxide. Animal waste is normally applied to land soon after collection and depending on the environmental conditions at the time of application; nitrous oxide can be emitted by soil microbes. So by having the capacity to store manure in a sealed anaerobic digestor and to time the application can mitigate both methane (collected and from the waste) as well as nitrous oxide emission from the soil if the nitrogenous material breaks down under conditions that are less favourable for nitrous oxide formation.

The PGgRc research predominantly focuses on enteric methane production through rumen manipulation and the knowledge gained can also be applied to enhance rumen efficiency and increase productivity.

Nitrous Oxide

The New Zealand national greenhouse gas inventory shows that nearly half (48.5%) of New Zealand's total greenhouse gas emissions in 2005 were from the agriculture sector and, of this, N_2O accounted for about one-third (34.9%). The dairy and fertiliser industries are significant contributors to the N_2O emissions. Animal excreta deposited during grazing is the single largest source of N_2O from New Zealand agriculture, producing over 80% of the direct and indirect N_2O emissions. Consortium research for N_2O focuses on three aspects; dairy farm emissions, nitrification inhibitors and hill country farm emissions.

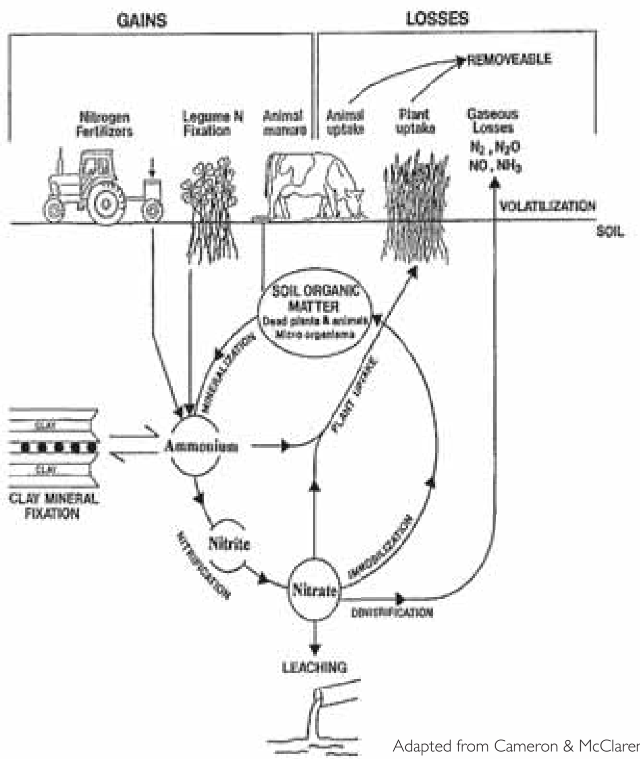
Nitrous Oxide production and emissions from soils

Soils contribute about 65% of the total N_2O produced by terrestrial ecosystems. N_2O gas is formed in soils during the microbiological processes associated with the nitrogen cycle. N_2O production by nitrifying bacteria may arise either during NH_4^+ oxidation to NO_3^- or during NO_3^- reduction in anaerobic conditions. These processes are affected by a number of soil and climatic factors, such as soil enzyme activities, water-filled pore-space (WFPS), nitrate concentrations, pH and available soil carbon, and the dominant factors vary with the seasons.

The influence of Autumn/Winter rainfall on Nitrous Oxide emissions

A relatively high N_2O emission rate is often observed in late autumn/winter in New Zealand. Active denitrification in winter appears to be associated mainly with high soil moisture content due to frequent rainfall and low evapotranspiration. Field studies have demonstrated the rate of denitrification and N_2O production often remains negligible during dry seasons, but then increases briefly when soil water content increases after rainfall.

Recent PGgRc research has shown that, of the measured variables, soil water-filled pore-space (WFPS) had the strongest influence on the level of N_2O emission. Generally, N_2O emissions from grazed sites were high when the soil WFPS were above 'field capacity', indicating formation of anaerobic sites following rainfall, a fundamental requisite for denitrification. Other studies showed N_2O emissions increased exponentially with increased soil water content above field capacity which support the PGgRc findings. Thus, in winter in New Zealand, when rainfall is prolonged and evapotranspiration is low, the soil moisture regime is favourable for denitrification and N_2O emission.



Adapted from Cameron & McClaren, 1996

PGgRc Research Strategy

The PGgRc is the cornerstone investment by New Zealand in mitigating greenhouse gas (GHG) emissions, although other aligned pastoral industry investments focused on lifting productivity will also contribute toward reductions in GHG. Achieving the technological capacity to achieve these emission reduction goals is vital for a sustainable future for agriculture without detrimentally affecting either productivity or quality.

Farmers wish to invest primarily in research that has a productivity benefit and that in some research programs, the measurement of methane and nitrous oxide emissions may not be necessary to measure productivity gains. The substantial government research investment through the Foundation for RS&T acknowledges the national benefits that are derived from making these measurements in those circumstances.

Rumen ecological management provides the knowledge base for stepwise and sustainable improvement of productivity while reducing methane emission. Additionally, efficient use of fertilizers and nitrification inhibitors provides significant opportunities for reducing nitrous oxide emissions from soil while improving pasture growth and regional water quality. The successful implementation of these strategies, coupled with long-term programs of selective breeding for reduced emission traits (animal and forage) make reducing agricultural emissions a realistic and achievable long-term goal. Given the linkages to other environmental issues, a large number of mitigation options offer multiple co-benefits, for example improving water quality.

PGgRc mitigation strategies need to align with other relevant research activities; focused on adaptation of agriculture to address climate change and meeting the Kyoto Protocol through accurate inventory measurement to ensure baseline emission calculations are sound. This is crucial to ensure future solutions will be recognised internationally in New Zealand's inventory.

The following extract from our June 2007 Business Plan outlines broad directions for the consortium. They were formulated prior to the New Zealand Government announcement on the Emission Trading Scheme on 20 September 2007. They will serve as a benchmark to be revisited and updated as our mitigation research advances.

Goal:

Decrease total agricultural emissions of greenhouse gases by 10% per unit of output in 2013 relative to 2004 (estimated to be a 4Mt reduction in the agricultural GHG emissions as identified in the National Inventory).

Vision:

PGgRc and New Zealand as a world leader in greenhouse gas mitigation solutions for pastoral agriculture.

Mission:

The PGgRc will deliver knowledge and economically viable mitigation practices or products that contribute to New Zealand farmers managing greenhouse gas emissions while increasing productivity.

Key Targets for 2007-2012:

- *Identified and developed economic on-farm technologies to improve production efficiency for ruminants and decrease total agricultural Greenhouse Gases by 10% per unit of output in 2013 relative to 2004.*
- *By 2013 have 33% of farmers implementing at least one greenhouse gas mitigation technology.*
- *Increased the agricultural sector (farmers and support industries) knowledge of Climate Change and Kyoto.*
- *Established New Zealand and PGgRc as a global leader in agricultural GHG mitigation.*
- *Ensure national coordination of all GHG-related investments between all participants, while also developing further international collaboration and involvement to increase global capability.*
- *Exploited commercial opportunities arising from the science and technologies in a global market.*
- *Contributed to preparing NZ Agriculture to be competitive in a carbon constrained global economy beyond 2012 and adapting to the effects of climate change.*

The UNFCCC and the Kyoto Protocol

"The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

On 9 May 1992, the governments of the world adopted the UN Framework Convention on Climate Change (UNFCCC), taking the first step in addressing one of the most urgent environmental problems facing humankind.

The convention establishes the framework for intergovernmental efforts to address climate change and is the mechanism within which the Kyoto Protocol (KP) was agreed upon. The objective of the UNFCCC is quoted above but the Convention also establishes principles, such as 'equity' and 'common but differentiated responsibilities' such as to recognize the linkage between climate change and economic development.

The Convention recognizes that although climate change is a global issue, the adverse effects threaten developing (Annex 2) nations more because these nations have less technological, economic and institutional capacity to respond.

Thus the balance of equity and responsibility requires industrialized (Annex 1) countries to lead by reducing their long-term emissions and on the richest amongst them to provide financial and technological resources to help developing countries to avoid a development pathway that mirrors the industrialized countries fossil energy consumption to achieve economic growth and instead, to develop along sustainable lines that value adaptation to the threatening adverse effects.

The KP is the mechanism for implementation of emissions reductions. The Protocol supplements and strengthens the Convention with five main elements:

- **Commitments:** legally-binding emissions targets
- **Implementation:** Annex I countries must implement domestic policies and measures to cut emissions. Offers international mechanisms to gain credit for emissions reductions at lower cost abroad than at home:
  - Joint implementation
  - Clean development mechanisms
  - Emissions trading
- **Minimizing impacts of developing countries.** Includes an adaptation fund for those most vulnerable to adverse effects of climate change and to the economic impact of response measures.
- **Accounting, reporting and review:** Rigorous monitoring procedures exist to safeguard the KP's integrity, including an *accounting system*, regular *reporting* by Parties and *in-depth review* of those reports by expert review teams.
- **Compliance:** A *Compliance Committee,* consisting of a facilitative and an enforcement branch, will assess and deal with any cases of non-compliance.

The KP broke new ground with its three innovative implementation mechanisms: joint implementation (JI), the clean development mechanism (CDM) and emissions trading. These aim to maximise the cost-effectiveness of climate change mitigation by allowing Parties to pursue opportunities to cut emissions, or enhance carbon sinks, more cheaply abroad than at home. The cost of curbing emissions varies considerably from region to region as a result of differences in, for example, energy sources, energy efficiency and waste management. It therefore makes economic sense to cut emissions, or increase removals, where it is cheapest to do so, given that the impact on the atmosphere is the same.

Joint implementation (JI)

This allows Annex I Parties to implement emission reduction projects, or increase removals by sinks, in other Annex I countries. The emission reduction units generated can be used by the investing Annex I Parties to achieve their emission reduction targets.

Clean Development Mechanism

Similar to JI, CDM allows Annex I Parties to implement emission reduction projects in non-Annex I countries. The intention is to generate investment in developing countries, especially from the private sector, and promote the transfer of environmentally sound technologies.

Emissions trading

Emissions trading is a 'cap and trade' scheme where the cap amounts to an average of at least 5% reduction from 1990 levels by 2008-2012. Parties that reduce emissions below their target can trade the emission reduction with another Party to reduce their emission liability. The credit for reduced emissions from JI and CDM projects can also be traded through this mechanism.

Protocol Ratification

For the KP to come into force required more than 55 Parties to the Convention to ratify the Protocol, including Annex I Parties accounting for 55% of that group's carbon dioxide emissions in 1990.

In May 2002, Iceland became the 55th Party to ratify the KP but it was not until February 16th, 2005 that the KP came into force following Russia's ratification in November 2004. Russia's ratification represented a cumulative total of 61.6% of emissions from Annex I Parties. By June 2007 175 Parties had ratified the KP, while only two, the USA and Australia, are currently not willing to ratify the KP, and they share the balance: 36.1% of emissions are from the US and 2.1% are Australian.