L'Institut PEMBINA

Fondation David Suzuki

LES SOLUTIONS SONT DANS NOTRE NATURE

Réductions marquées, croissance solide :
Analyse économique démontrant que le Canada peut assurer sa prospérité économique tout en faisant sa part pour prévenir les changements climatiques dangereux

Le 4 décembre 2008

Introduction

Si la planète est pour éviter des changements climatiques dangereux, la climatologie nous indique que les pays industrialisés doivent réduire leurs émissions de gaz à effet de serre (GES) de 25 % à 40 % par rapport à leurs niveaux de 1990 d'ici 2020.

Étant donné les coûts extrêmement élevés d'un réchauffement incontrôlé de la planète – pour les populations, pour l'environnement et pour l'économie –, il est important de comprendre comment réduire les émissions à une telle échelle. En parallèle, l'actuel ralentissement économique nous permet de nous assurer que les investissements privés et publics visant à redresser l'économie sont consacrés à des solutions d'énergie propre dont les émissions de GES sont beaucoup plus faibles.

L'Institut Pembina et la Fondation David Suzuki ont donc mandaté M.K. Jaccard and Associates Inc. (MKJA) pour mener une étude de modélisation économique afin d'établir les politiques gouvernementales qui permettront au Canada d'atteindre une cible de réduction des GES conforme aux conclusions climatologiques : réduction des émissions de 25 % par rapport à leurs niveaux de 1990 d'ici 2020.[*] À titre comparatif, le gouvernement du Canada cible actuellement une réduction des émissions de GES de l'ordre de 3 % par rapport aux niveaux de 1990 d'ici 2020.[1]

À notre connaissance, il s'agit de la première étude publiée qui fait état d'un ensemble de politiques visant à permettre au Canada d'atteindre la cible de réduction fondée sur des données scientifiques de 25 %.

L'ensemble de politiques modélisées reflète le consensus d'experts qui soutiennent qu'un plan national efficace du point de vue climatique et économique pour réduire de façon considérable les émissions de GES doit combiner :

[*] Nous sommes très reconnaissants à l'endroit du Groupe Financier Banque TD pour son généreux soutien de ce projet. La Banque TD s'intéresse à faire la promotion d'une saine analyse des interactions entre l'environnement et l'économie. Pour l'instant, la Banque TD ne soutient aucune cible de réduction des GES particulière pour le Canada.

- une politique qui fixe un prix considérable pour les émissions à l'échelle globale de l'économie (un « prix du carbone »); et
- des règlements complémentaires et des investissements publics pour développer l'infrastructure verte et l'utilisation de technologies propres.

Nous présentons ci-dessous les résultats préliminaires de cette modélisation illustrant les effets économiques projetés de l'atteinte de la cible. Les détails sont fournis dans deux sections subséquentes :

- les politiques gouvernementales fédérales et provinciales dont la mise en œuvre permettrait de réaliser les réductions des émissions de GES requises et les politiques que nous avons modélisées;
- l'origine et l'importance de cibles fondées sur des données scientifiques aux efforts canadiens et internationaux de lutte contre les changements climatiques.

Le rapport détaillé de modélisation économique produit par MKJA[2] se trouve à la suite de ce document sommaire. Il s'agit du rapport préliminaire d'un projet de modélisation économique en cours, dans le cadre duquel l'Institut Pembina et la Fondation David Suzuki se pencheront également sur les politiques nécessaires pour atteindre l'actuelle cible de réduction des émissions de GES du gouvernement du Canada.

Résultats de la modélisation économique

L'analyse menée par MKJA démontre que si le Canada se dote de solides politiques gouvernementales fédérales et provinciales, il réussira à atteindre une ambitieuse cible de réduction des émissions de GES fondée sur des données scientifiques d'ici 2020 sans compromettre la croissance soutenue de l'économie, le rehaussement de la qualité de vie dont bénéficient les Canadiens et la création soutenue d'emplois d'un bout à l'autre du pays.

L'analyse indique que l'application générale d'une tarification élevée des émissions de GES à l'ensemble de l'économie, combinée à de solides règlements complémentaires et investissements publics, permettra au Canada de réduire ses émissions de 25 % par rapport à leurs niveaux de 1990 d'ici 2020. Le prix des émissions est fixé à 50 $ la tonne[3] en 2010, puis augmente progressivement d'année en année pour atteindre 125 $ la tonne en 2015 et 200 $ la tonne en 2020. (Le prix anticipé des émissions au-delà de 2020 a aussi des répercussions sur des décisions prises antérieurement : dans le cadre de cette analyse, le prix continue d'augmenter au-delà de 2020 pour atteindre 300 $ la tonne d'ici 2030.)

Maintien d'une croissance économique soutenue

L'analyse démontre que l'ensemble des politiques modélisées – incluant un prix du carbone relativement élevé – permet de maintenir une croissance économique soutenue au Canada.

Dans un scénario de « maintien du *statu quo* », le PIB du Canada devrait croître de 22,0 % entre 2011 et 2020. La mise en œuvre de notre ensemble de politiques réduirait légèrement la croissance du PIB à 19,2 % ou 19,3 % au cours de la même période. Autrement dit, entre 2011 et 2020, l'économie enregistrerait une croissance annuelle moyenne de 2,2 % si le *statu quo* était maintenu et de 2,0 % si le Canada prenait les mesures nécessaires pour atteindre une cible de réduction des émissions de GES fondée sur des données scientifiques.

Cette modeste réduction du rythme de l'expansion économique perd toute importance par rapport aux pertes projetées du PIB dans un scénario de maintien du *statu quo*. Dans son rapport de 2006 sur l'économie des changements climatiques, l'ancien économiste en chef de la Banque mondiale, Sir Nicholas Stern, évalue que les coûts et les risques de changements climatiques non contrôlés totaliseraient l'équivalent d'une perte de PIB mondial d'au moins 5 % jusqu'à 20 % ou plus.[4]

En vertu des politiques modélisées, la majorité des secteurs économiques enregistreraient une augmentation de leur production de 2005 à 2020 près des hausses prévues dans un scénario de maintien du *statu quo*. Seuls deux secteurs de production de combustibles fossiles – raffinage du pétrole et production de gaz naturel – verraient leur production absolue diminuer. Dans une étape subséquente de ce projet, nous avons l'intention de modéliser des politiques visant à limiter l'irrégularité interrégionale des impacts économiques.

Maintien de la croissance de l'emploi

Notre ensemble de politiques maintient une croissance soutenue de l'emploi dans presque tous les secteurs de l'économie canadienne. Dans un scénario de maintien du *statu quo,* la main-d'œuvre totale devrait croître de 6,4 % entre 2011 et 2020; nos politiques permettront une croissance variant entre 6,2 % et 6,4 % (en fonction d'hypothèses concernant les partenaires commerciaux du Canada). En termes absolus, un nombre net de plus de 1,16 million de nouveaux emplois seraient créés au Canada entre 2011 et 2020 tout en atteignant la cible de réduction des émissions de GES fondée sur des données scientifiques. Seuls les secteurs de la production de combustibles fossiles – extraction de pétrole brut, raffinage du pétrole, production de gaz naturel et exploitation du charbon – et de la production d'électricité enregistrent des réductions absolues du nombre d'emplois. Notre ensemble de politiques prévoit un maintien de l'augmentation des salaires, quoiqu'à un rythme quelque peu moins rapide que si le *statu quo* était maintenu.

Principales possibilités de réduction des émissions

L'analyse précise les principales technologies qui devront être déployées pour atteindre d'importantes réductions de la pollution causée par les GES au Canada. Les plus importantes de ces technologies sont :

- captage et stockage du dioxyde de carbone produit par les installations industrielles et les centrales électriques;
- réduction des émissions « fugitives » provenant de l'industrie pétrolière et gazière et des sites d'enfouissement;
- accroissement de l'efficacité énergétique à l'échelle de l'économie (par ex., véhicules et bâtiments);
- augmentation de la production d'énergie renouvelable (par ex., l'énergie éolienne représente 13 % de l'électricité produite en 2020 par rapport à moins de 1 % aujourd'hui);
- remplacement de combustibles fossiles par l'électricité (par ex., pour chauffer les bâtiments).

Outre l'imposition d'un prix sur les émissions de GES, nos politiques prévoient plusieurs mesures réglementaires pratiques qui aideront à soutenir notre qualité de vie et notre prospérité économique. Par exemple, des réductions considérables des émissions sont atteintes simplement en traitant nos déchets différemment une fois qu'ils aboutissent dans les sites d'enfouissement. Plutôt que de laisser le méthane (un gaz à effet de serre très néfaste) s'échapper dans l'atmosphère, notre réglementation prévoit l'obligation de capter le méthane, qui peut être ensuite utilisé pour produire de l'électricité. Dans notre analyse, cette mesure à la fois simple et efficace permettrait au Canada de réduire ses émissions de GES provenant des sites d'enfouissement de 84 % par rapport au maintien du *statu quo*.

Une autre mesure pratique et facilement accessible à laquelle nous avons recours pour réduire les émissions accélère l'application de la technologie des véhicules à haut rendement énergétique aux automobiles qui circulent sur les routes canadiennes. En réglementant une réduction substantielle des émissions d'échappement de GES, les Canadiens économiseront considérablement sur l'essence. L'analyse conclut que les Canadiens économiseront plus de 5,6 milliards de dollars par année en essence d'ici 2020 par rapport au maintien du *statu quo*. (Cette économie est aussi en partie attribuable à une utilisation accrue du transport en commun et à une réduction des distances parcourues.)

Possibilités internationales de réduction des émissions

Les investissements du gouvernement fédéral en projets de réduction des émissions dans les pays moins riches peuvent contribuer à réduire le coût d'atteinte d'une cible nationale de réduction des émissions de GES tout en aidant ces pays à s'attaquer aux changements climatiques. Cela peut passer par l'achat de droits d'émission internationaux comme ceux actuellement offerts par le Mécanisme de développement propre des Nations Unies. Nous avons pris pour hypothèse un prix relativement élevé des droits internationaux (de 100 $ la tonne d'ici 2020) pour assurer que le Canada acquiert des crédits d'une qualité environnementale élevée qui représentent de réelles réductions des émissions.[5]

Dans le cadre de cette analyse, le Canada achète entre 35 et 49 millions de tonnes de réductions internationales annuellement d'ici 2020 (la quantité exacte varie en fonction d'hypothèses concernant les partenaires commerciaux du Canada). Ainsi, en 2020, les émissions de GES *intérieures* du Canada seraient réduites d'entre 17 % et 19 % par rapport à leurs niveaux de 1990. Des réductions internationales combleraient le reste de la cible de 25 %.

Recettes

Une tarification des émissions de GES produirait des recettes considérables pour le gouvernement. Cette analyse démontre que l'établissement du prix au niveau requis pour atteindre une cible de réduction des émissions de GES fondée sur des données scientifiques produirait des recettes gouvernementales de l'ordre de 87 à 89 milliards de dollars par année d'ici 2020. Cependant, la majorité de ces recettes est retournée dans la poche des Canadiens sous la forme de réductions des impôts sur le revenu.

Deux scénarios pour les partenaires commerciaux du Canada

Pour tenir compte des questions de compétitivité internationale, l'analyse examine deux scénarios différents qui permettraient au Canada d'atteindre la cible de réduction des émissions de GES fondée sur des données scientifiques d'ici 2020. Dans le premier scénario, nos partenaires commerciaux membres de l'OCDE mettent en œuvre des politiques de réduction des émissions de GES au moins aussi contraignantes que celles du Canada. Si les principaux partenaires commerciaux du Canada mettent en œuvre des politiques similaires, leurs coûts de production varieront dans une proportion similaire à ceux du Canada, diminuant ainsi la probabilité que les acheteurs de biens canadiens remplacent leurs achats par des biens étrangers équivalents.

Dans le deuxième scénario, les pays membres de l'OCDE (incluant les États-Unis) imposent une tarification des émissions de GES, mais les politiques de réduction des émissions de GES du Canada sont suffisamment plus contraignantes que le pays est considéré comme « agissant seul ». Dans ce scénario, l'analyse démontre un certain déplacement d'activités à dégagement élevé de GES vers d'autres pays. Dans le cas de deux secteurs considérablement touchés (la fonte de métaux et les minerais industriels), nous réussissons à prévenir une baisse de l'activité en retournant une partie des recettes provenant de la tarification des émissions aux producteurs, proportionnellement à leurs niveaux de production.

Ces deux scénarios prennent pour hypothèse que des pays en développement tels que la Chine, l'Inde et le Brésil ont des politiques de réduction des émissions de GES considérablement moins contraignantes.

À propos des modèles économiques utilisés

Cette analyse repose sur les modèles économiques du CIMS et du DGEEM. Le CIMS contient une base de données détaillée des technologies relatives aux émissions de GES. Le modèle simule les choix technologiques des entreprises et des particuliers sur la base d'études de comportements réels. Le DGEEM est utilisé pour étudier des mesures « macroéconomiques » telles que le PIB et le taux d'emploi. Le CIMS a été largement employé par les gouvernements du Canada, de l'Alberta et d'autres provinces.

Modélisation des politiques gouvernementales fédérales et provinciales

Il existe un solide consensus parmi les experts qu'un plan national écologiquement et économiquement efficace pour atteindre des réductions considérables des émissions de GES doit combiner :

- une politique qui impose une tarification suffisamment élevée des émissions de GES à l'échelle globale de l'économie (un système de plafonnement et d'échanges ou une taxe sur les émissions);
- une réglementation et des investissements de fonds publics dans les secteurs où la réaction au prix des émissions est minée par des obstacles ou échecs de marché ou là où il est difficile de tarifer les émissions;
- des mesures visant à protéger les personnes à faible revenu;
- des mesures visant à protéger des secteurs industriels lorsqu'une part considérable de la production et des émissions y découlant serait autrement déplacée vers d'autres pays appliquant des politiques moins contraignantes.[6]

Nous croyons aussi qu'il soit nécessaire de :

- mettre en place des réglementations et/ou investir des fonds publics pour accélérer la réduction des émissions durant la période de transition au cours de laquelle la tarification des émissions sera augmentée progressivement jusqu'à l'atteinte du niveau requis.[7]

Le premier tableau ci-dessous présente l'ensemble de politiques que nous avons modélisées à ce stade-ci du projet et une brève justification de chacune. Toutes ces politiques entrent en vigueur en 2010.[8] La plupart pourraient relever du gouvernement fédéral ou des provinces. Cependant, à notre avis, le gouvernement fédéral a la responsabilité d'assumer la direction de la lutte contre les changements climatiques et la majorité de ces politiques devraient donc être mises en œuvre par le fédéral. Dans le cas de politiques de compétence exclusivement provinciale, il est de notre avis que le gouvernement fédéral doit faire de leur mise en œuvre une condition au transfert de recettes provenant de la tarification des émissions.

Politique	Justification
Prix du carbone : Une politique de tarification des émissions (système de plafonnement et d'échanges ou taxe sur les émissions)[9] couvrant 80 % des émissions nationales. Dans le cas d'un système de plafonnement et d'échanges, les pollueurs paieraient un montant par tonne d'émissions par l'achat de permis d'émission mis aux enchères par le gouvernement. La tarification augmente progressivement au fil du temps.	Les experts s'entendent pour dire que la tarification des émissions représente la plus importante politique pour atteindre des réductions considérables des émissions de GES. La mise aux enchères des permis tient compte du principe pollueur-payeur et produit des recettes pouvant servir à financer d'autres politiques comprises dans l'ensemble. L'augmentation progressive de la tarification permet à l'économie de s'adapter.
Compensations agricoles : L'achat par le gouvernement fédéral de « crédits compensatoires » représentant les réductions des émissions dans le secteur agricole.	Sur le plan administratif, les émissions agricoles sont difficiles à couvrir en vertu d'un système de plafonnement et d'échanges ou d'une taxe sur les émissions. L'achat de crédits est un autre moyen efficace de tarifer ces émissions. Puisque c'est le gouvernement et non le secteur privé qui achète les crédits, la tarification des émissions industrielles ne peut être affaiblie.
Transfert de recettes vers des secteurs ciblés : Le transfert des recettes provenant de la tarification des émissions proportionnellement aux niveaux de production vers des secteurs industriels où une part considérable de la production pourrait autrement être déplacée vers des pays dont les politiques de réduction des émissions de GES sont moins contraignantes.	Il n'y aura peu ou pas d'avantage environnemental si la production et les émissions y découlant sont simplement déplacées ailleurs dans le monde.
Investissements internationaux : L'investissement par le gouvernement fédéral dans des projets de réduction des émissions dans des pays moins riches.[10]	Cela offre au Canada l'option d'atteindre ses cibles de réduction des émissions de GES en partie par l'investissement international, ce qui est plus rentable que l'action purement intérieure et aide des pays moins riches à lutter contre les changements climatiques.
Réduction des impôts sur le revenu : Le transfert des recettes restantes provenant de la tarification des émissions pour réduire les impôts sur le revenu des particuliers.	Cette politique stimulera la création d'emploi et compensera le coût accru de la pollution.

Normes sur les émissions des véhicules : La réglementation des émissions d'échappement de GES des automobiles et des camions légers initialement en ligne avec les normes californiennes, puis resserrée progressivement.	L'efficacité accrue des véhicules est minée par d'importants obstacles de marché. Les normes californiennes sont actuellement les plus contraignantes en Amérique du Nord.
Règlements provinciaux visant à stopper l'étalement urbain	L'urbanisme ne répondra pas efficacement à une tarification des émissions. Le développement urbain de plus forte densité réduira considérablement les émissions provenant des transports et des bâtiments.
Codes du bâtiment : Le relèvement des normes d'efficacité énergétique dans les codes du bâtiment pour les nouvelles constructions résidentielles et commerciales : augmentation de l'efficacité énergétique des maisons neuves de 50 % par rapport aux normes actuelles; construction de nouveaux bâtiments commerciaux conformes à la norme LEED Or; aucun nouveau système de chauffage brûlant des combustibles fossiles en Colombie-Britannique, au Manitoba et au Québec.	L'efficacité énergétique des bâtiments est minée par d'importants obstacles et échecs de marché. La Colombie-Britannique, le Manitoba et le Québec produisent de l'électricité pratiquement sans émissions, laquelle peut servir à chauffer les bâtiments munis de fournaises électriques et/ou de thermopompes.
Normes sur l'efficacité des appareils électroménagers : La réglementation de l'efficacité énergétique des gros électroménagers au niveau des modèles les plus efficaces offerts sur le marché.	L'efficacité énergétique des appareils électroménagers est minée par d'importants obstacles de marché.
Captage obligatoire du carbone : L'obligation de capter et de stocker le dioxyde de carbone émis par toute nouvelle installation de traitement de gaz naturel, centrale thermique alimentée au charbon et exploitation de sables bitumineux.	Dans l'optique de réductions poussées des émissions de GES, nous ne considérons de nouveaux développements de combustibles fossiles acceptables que s'ils captent et stockent le carbone. La tarification des émissions à elle seule est une mesure trop faible pour l'assurer au cours des premières années.
Établissement du coût complet de l'énergie nucléaire : L'obligation que les producteurs d'énergie nucléaire paient le plein coût estimé de la gestion des déchets, la mise hors service et l'assurance.	D'importants coûts ne sont actuellement pas pris en compte dans les décisions d'investir dans l'énergie nucléaire, ce qui mène à de l'inefficacité économique ainsi que de graves problèmes d'environnement et de sécurité. Cette mesure forcera l'industrie nucléaire à concurrencer équitablement les autres producteurs d'électricité.
Réglementation sur l'exhalaison et le torchage : Une réglementation visant à limiter les émissions d'exhalaison et de torchage dans la production pétrolière et gazière.	Il est difficile d'inclure ces émissions dans une politique en matière de tarification des émissions vu qu'elles sont difficiles à quantifier. Des règlements précis sont donc à préconiser.

Réglementation sur le captage de gaz d'enfouissement	Il est difficile d'inclure ces émissions dans une politique en matière de tarification des émissions vu qu'elles sont difficiles à quantifier. Des règlements précis sont donc à préconiser.

Au cours d'étapes subséquentes de ce projet, nous comptons modéliser les politiques suivantes :

Politique	Justification
Transfert de recettes aux provinces : Des transferts fédéraux aux provinces de recettes provenant de la tarification des émissions pour réduire l'inégalité des répercussions économiques entre les provinces.	Cela assurera une transition économique sans heurt.
Transfert de recettes aux personnes à faible revenu : Le transfert de recettes provenant de la tarification des émissions à des personnes à faible revenu pour faire en sorte qu'elles ne soient pas pénalisées par les politiques en matière de réduction des émissions de GES.	Seule, une tarification des émissions est une mesure « régressive » (elle représentera un coût relatif [pourcentage du revenu] plus élevé pour une personne à faible revenu que pour une personne disposant d'un revenu plus élevé). Cette situation est généralement décriée comme inéquitable.
Investissements gouvernementaux dans l'infrastructure du transport en commun	Le niveau des investissements dans le transport en commun ne réagira probablement pas efficacement à une tarification des émissions. De meilleurs services de transport en commun pourraient considérablement réduire les émissions imputables aux transports.
Subventions d'améliorations éconergétiques : L'octroi de subventions pour l'amélioration éconergétique de bâtiments résidentiels et commerciaux existants.	L'efficacité énergétique des bâtiments est minée par d'importants obstacles et échecs de marché.
Incitatifs à l'énergie verte : L'octroi de subventions pour la production écologique d'électricité renouvelable (par ex., énergie éolienne et solaire).	La tarification des émissions ne sera peut-être pas assez élevée au cours des premières années pour soutenir le déploiement adéquat de ces technologies.
Réduction de l'impôt des sociétés : Le transfert d'une partie des recettes provenant de la tarification des émissions pour réduire l'impôt des sociétés en plus de l'impôt des particuliers	La réduction de l'impôt des particuliers seulement bénéficie surtout les particuliers et les secteurs à forte main-d'œuvre plutôt que les entreprises et les secteurs à forte intensité de capital.

Il faut souligner que ce projet ne tient pas compte de l'émission ou l'absorption de dioxyde de carbone par les forêts. Réduire les émissions des forêts par la conservation et, le cas échéant, le rehaussement des « puits » (l'absorption de dioxyde de carbone dans l'atmosphère) pourrait aider le Canada à renforcer ses mesures de lutte contre les changements climatiques, puisque les volumes potentiels de dioxyde de carbone sont élevés.[11] Cependant, les modèles économiques que nous avons utilisés ne tiennent pas encore compte des forêts. De surcroît, la majorité des discussions portant sur l'établissement de cibles de réduction des émissions de GES pour le Canada excluent les forêts.

Cibles de réduction des émissions de GES fondées sur des données scientifiques pour le Canada et les pays industrialisés

L'objectif visé par la Convention-cadre des Nations Unies sur les changements climatiques (CCNUCC), laquelle a été ratifiée par pratiquement tous les pays de la planète, est d' « empêcher toute perturbation anthropique dangereuse du système climatique », autrement dit, d'éviter des changements climatiques dangereux. Cet objectif doit représenter la principale motivation de tous les pays, dont le Canada, à établir des cibles de réduction de la pollution causée par les GES.

Il existe maintenant un large consensus qu'un réchauffement moyen de la planète de plus de 2 ºC par rapport au niveau préindustriel constituerait un changement climatique dangereux. La Déclaration scientifique sur le climat de Bali, signée en 2007 par plus de 200 éminents climatologues de la planète, énonce que le « principal objectif » du prochain accord mondial sur le climat doit être de contenir le réchauffement à un maximum de 2 °C.[12] Plusieurs pays, dont l'ensemble des pays de l'Union européenne, ont fixé comme plafond absolu un réchauffement de 2 °C.

L'éminent scientifique américain du climat James Hansen affirme qu'un réchauffement planétaire au-delà de ce seuil serait « excessivement dangereux »"[13] étant donné que la dernière fois que la planète a connu un tel réchauffement sur une période prolongée (il y a trois millions d'années de cela), la fonte des glaces avait fait augmenter le niveau des mers d'au moins 15 mètres par rapport à leur niveau actuel.[14] Les scientifiques prévoient une augmentation des niveaux marins de l'ordre d'un mètre ou plus au cours du 21e siècle si rien n'est fait pour réduire les émissions de GES.[15] Une telle hausse se traduirait par 30 millions de nouveaux sans-abri au Bangladesh.[16] Évidemment, de tels impacts seraient extraordinairement coûteux pour les populations, l'environnement et l'économie.

Le Groupe d'experts intergouvernemental sur l'évolution du climat (GIEC), la principale organisation mondiale scientifique vouée aux changements climatiques, a démontré que pour ne pas dépasser le seuil des 2 ºC, les pays industrialisés devront réduire leurs émissions de GES d'ici 2020 de l'ordre de 25 % à 40 % par rapport à leurs niveaux de 1990, afin de faire leur juste part pour produire les réductions nécessaires des émissions mondiales.[17] Bien que l'ensemble des pays industrialisés puissent en principe atteindre une cible de réduction de 25 % à 40 % même si le Canada n'atteignait qu'une cible moins contraignante, le Canada a de très bonnes raisons d'établir sa propre cible à l'intérieur de cette plage. Notamment, une analyse des différentes formules utilisées pour calculer la juste part des pays à réduire leurs émissions indique que la cible de réduction établie par le Canada d'ici 2020, en pourcentage, doit être très près de la cible de réduction en pourcentage de l'ensemble des pays industrialisés, nonobstant l'année de référence retenue.[18,19]

Selon l'analyse du GIEC, tous les pays Parties au Protocole de Kyoto ont convenu, en 2007, que cette plage de réduction des émissions des pays industrialisés devait guider les négociations actuellement en cours d'un nouvel accord mondial de réduction des émissions de GES.[20] À la conférence climatique des Nations Unis qui se tient à Poznan, en Pologne, en décembre 2008, les pays devront faire le prochain pas et commencer à évaluer des cibles spécifiques à l'intérieur de la plage de 25 % à 40 %, afin de donner le coup d'envoi à des négociations de la contribution des pays vers l'atteinte de la cible internationale. Il s'agit d'une étape cruciale vers la conclusion d'un nouveau traité mondial sur la réduction des émissions de GES pour l'après-2012, traité que les pays se sont entendus à finaliser à la conférence climatique des Nations Unies qui se tiendra à Copenhague en décembre 2009.[21]

Globalement, étant donné l'urgence démontrée par les plus récentes découvertes climatiques et le besoin que le Canada fasse sa juste part dans la lutte contre le réchauffement de la planète, l'Institut Pembina et la Fondation David Suzuki croient que le Canada doit réduire ses émissions de GES d'au moins 25 % par rapport à leurs niveaux de 1990, et ce, d'ici 2020. Comme discuté dans les sections précédentes, le Canada peut au besoin atteindre cette cible en complémentant ses mesures intérieures par des investissements de réduction des émissions dans les pays moins riches.

Notes

[1] Le gouvernement du Canada exprime sa cible d'ici 2020 sous la forme d'une réduction de 20 % par rapport aux niveaux des émissions de 2006 (voir Environnement Canada. 2008. *Prendre le virage vert : Cadre réglementaire sur les émissions industrielles de gaz à effet de serre*. Ottawa : gouvernement du Canada. iii). Cette cible peut être reformulée par rapport aux niveaux d'émissions de 1990 à partir des données d'émissions du *Rapport d'inventaire national* d'Environnement Canada.
[2] MKJA. 2008. *Preliminary Report — Exploration of a policy package to reduce Canadian greenhouse gas emissions 25% from 1990 levels by 2020, December 3, 2008.* Vancouver, C.-B.
[3] D'équivalent CO_2.
[4] Le sommaire peut être consulté en ligne à l'adresse http://www.hm-treasury.gov.uk/stern_review_executive_summary.htm.
[5] Par exemple, l'Institut Pembina et la Fondation David Suzuki soutiennent des crédits de pays en développement de certification Gold Standard. Voir http://www.cdmgoldstandard.org/.
[6] Clare Demerse et Matthew Bramley. 2008. *Choosing Greenhouse Gas Emission Reduction Policies in Canada.* Drayton Valley, AB : Fondation Pembina. Voir aussi en ligne à l'adresse http://climate.pembina.org/pub/1720.
[7] Ibidem.
[8] Dans le modèle, les règlements indiqués sont entrés en vigueur en 2011, mais ce n'est que parce que le modèle utilise des périodes d'investissement fixes de cinq ans.
[9] Dans le rapport de MKJA, la politique de tarification des émissions porte l'appellation « carbon charge ».
[10] Dans le rapport de MKJA, on parle de l'achat de permis d'émission internationaux.
[11] Voir Service canadien des forêts. 2007. *La forêt canadienne est-elle un puits ou une source de carbone?* Ottawa, ON : Ressources naturelles Canada. Voir aussi en ligne à l'adresse http://warehouse.pfc.forestry.ca/HQ/27502.pdf.
[12] Disponible en ligne à l'adresse http://www.climate.unsw.edu.au/bali/.
[13] James Hansen *et al*. 2007. « Climate change and trace gases » dans *Phil. Trans. R. Soc. A 365:1925*. Voir aussi en ligne à l'adresse http://pubs.giss.nasa.gov/docs/2007/2007_Hansen_etal_2.pdf.
[14] Eystein Jansen *et al*. 2007. « Paleoclimate » dans S. Solomon *et al*., éd. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, R.-U. et New York, NY : Cambridge University Press. p. 440–442. Voir aussi en ligne à l'adresse http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter6.pdf.
[15] Voir, par exemple, Stefan Rahmstorf. 2007. « A Semi-Empirical Approach to Projecting Future Sea-Level Rise, » dans *Science 315:368*. Voir aussi en ligne à l'adresse http://www.pik-potsdam.de/~stefan/Publications/Nature/rahmstorf_science_2007.pdf.
[16] Reuters. Le 3 novembre 2008. « U.N. chief urges climate change help despite slowdown » (http://www.enn.com/climate/article/38556, consulté le 26 novembre 2008).
[17] Sujata Gupta *et al*. 2207. « Policies, Instruments and Co-operative Arrangements » dans B. Metz *et al*., éd. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the*

Intergovernmental Panel on Climate Change. Cambridge, R.-U. et New York, NY : Cambridge University Press. p. 776. Voir aussi en ligne à l'adresse http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter13.pdf. L'analyse du GIEC s'appliquait à la stabilisation de la concentration de GES dans l'atmosphère à 450 parties par million de CO_2e. Cela correspond à une probabilité d'environ 50 % de limiter le réchauffement moyen de la planète à 2 ºC par rapport au niveau préindustriel. Voir Bill Hare et Malte Meinshausen. 2006. « How Much Warming Are We Committed to and How Much Can Be Avoided? » dans *Climatic Change 75, n^{os} 1-2* p. 111. Voir aussi en ligne à l'adresse http://www.springerlink.com/content/g5861615714m7381/fulltext.pdf.

[18] Niklas Höhne et Sara Moltmann. 2007. *Canada's emission reduction requirements under international climate policy approaches after 2012* (rapport pour la Table ronde nationale sur l'environnement et l'économie). Cologne, Allemagne : ECOFYS. L'année de référence acceptée internationalement pour les cibles de réduction des émissions de GES est 1990, puisque le premier rapport d'évaluation du GIEC a alerté les gouvernements du monde aux dangers des changements climatiques cette année-là. La CNUCC a été adoptée peu après, soit en 1992.

[19] De plus, la science indique qu'une réduction de 25 % à 40 % des émissions, accompagnée d'une contribution équitable aux réductions par les pays en développement, correspond à une probabilité de seulement environ 50 % de contenir le réchauffement à moins de 2 ºC (voir la note 17). C'est pourquoi Climate Action Network International a incité les pays industrialisés à viser le seuil supérieur de la plage, c.-à-d. plus près d'une réduction de 40 %.

[20] Secrétariat de la CCNUCC. *Report of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol on its resumed fourth session, held in Bali from 3 to 15 December 2007* (FCCC/KP/AWG/2007/5). p. 5. Voir aussi en ligne à l'adresse http://unfccc.int/files/meetings/cop_13/application/pdf/awg_work_p.pdf.

[21] Pour de plus amples renseignements sur la conférence de Poznan et le décompte vers Copenhague, voir Clare Demerse et Matthew Bramley. 2008. *UN Climate Negotiations in Poznan, Poland.* Drayton Valley, AB : Institut Pembina. Voir aussi en ligne à l'adresse http://climate.pembina.org/pub/1732.

PRELIMINARY REPORT

Exploration of a policy package to reduce Canadian greenhouse gas emissions 25% below 1990 levels by 2020

December 3rd, 2008

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Executive Summary

We reviewed the feasibility and cost of a 25% reduction in greenhouse gas (GHG) emissions below 1990 levels by 2020 (i.e., an absolute emissions target of 444 Mt) for the David Suzuki Foundation and the Pembina Institute. This analysis, completed using the CIMS hybrid technology simulation model and the DGEEM dynamic computable general equilibrium model, found the target is achievable, but only with a policy package of a stringency higher than that commonly discussed to date in Canada. Specifically, it includes:

- A carbon dioxide or equivalent (CO_2e) emissions charge, implemented as a full auction cap and trade or carbon tax on all combustion and almost all fixed process emissions equivalent to $50/tonne CO_2e in 2010 rising to $200/tonne CO_2e in 2020. If needed, non-fossil fuel sectors are refunded a sufficient amount of the carbon charge to maintain output at their 2008 level.
- A verifiably additive offset system to capture agricultural emissions reductions.
- A comprehensive suite of complementary regulations to address market failures, including:
    - Venting and flaring in the oil and gas sector is confined solely to safety purposes, with a carbon charge imposed for all registered safety emissions.
    - All new commercial buildings are built to LEED Gold standard or higher and residential buildings are required to be 50% more efficient than current standard practises. Both are also restrained from directly using fossil fuels in BC, Manitoba and Québec, including natural gas. All other options are allowed.
    - All new vehicles sold meet the California GHG emissions standards, with a gradually tightening standard due to become virtually zero by 2040.
    - As of 2011, white good appliance energy efficiency standards are raised to the most efficient commercially available versions of late 2008.
    - Almost all landfills are required to be covered, and the landfill gas flared or used to produce electricity and heat as the economics warrant.
    - A land use policy to encourage higher density urban form.

We also included a requirement to capture and store (CCS) all formation CO_2 from new natural gas processors, process CO_2 from new hydrogen production facilities, and all combustion CO_2 from all new coal fired electricity plants, oil sands facilities, and upgraders starting in 2011. This regulation, while not associated with a clear market failure, is meant to drive technological innovation and reduce costs associated with CCS use.

The carbon charge and most of the complementary polices are as strong as considered feasible. We tested their effect under two scenarios: one where the OECD countries impose policy as stringent as Canada ("OECD acts together"), and one where Canada goes further than its OECD trading partners ("Canada goes further"). To make up the difference between the target and domestic emissions reductions, purchases of international emissions permits are necessary in both scenarios. In the "OECD acts together" case purchases rising to 49.1 Mt per year in 2020 are necessary, while in the "Canada goes further" case 34.5 Mt of purchases are required.

Some key changes were made to nuclear generation costing in this analysis. Based on French government audits and literature, a 1.3¢/kwh waste and decommissioning charge was added to nuclear generation, as was a 4.0 ¢/kwh liability insurance charge. Nonetheless, the modeling scenario with these costing adjustments predicted the construction of new nuclear generation, a policy outcome with which the David Suzuki Foundation and the Pembina Institute disagree for various reasons, so nuclear generation was limited to existing capacity.

The policy package reduces long term GDP growth up to 3% below its business as usual path in the 2020s, i.e., GDP grows 19.3% instead of 22.1% from 2011 to 2020, and 43.4% instead of 47.4% from 2011 to 2030. Physical output in most sectors is relatively unaffected by the policy package, defined as a drop of less than 10% from business as usual 2020 output. The exceptions are the fossil fuel industries, freight transportation, and the cement and lime production sectors if fixed process emissions are included. Gross output, defined as the dollar value of sales, is significantly affected only in the fossil fuel sectors. The size of the labour force is relatively unchanged, but average salaries rise 11.4% from 2011 through 2020 instead of 18.1% in the business as usual case.

Nitric and adipic acid, solvents, consumption of halocarbons and forestry land-use change were not included in this analysis.

Introduction

In this report M.K. Jaccard and Associates Inc. (MKJA), at the request of the David Suzuki Foundation and the Pembina Institute, used two models of the Canadian energy economy — the CIMS hybrid technology simulation model and the DGEEM dynamic computable general equilibrium model — to explore the feasibility and cost of a 25% reduction in Canada's greenhouse gas (GHG) emissions from 1990 levels by 2020 (i.e., an emissions target of 444 Mt). This is a reduction schedule deeper and faster than most analyzed in the past, especially for Canada, and therefore is as much an exploration of the potential to achieve this kind of reduction as a detailed analysis of its costs and the necessary stringency of policy. This policy was explored under two contrasting global carbon policy scenarios; one where the OECD maintains the same level of carbon price as Canada, and one where Canada's policy is significantly more stringent. The developing countries are assumed to have non-existent or considerably reduced carbon emissions restrictions.

CIMS was used to explore the necessary emissions reductions and the sectoral technology, capital investment, energy, efficiency, and fuel switching implications, while DGEEM was used to explore the system-wide economic impacts, such as changes in GDP, employment, wages, and trade. Once a sufficient carbon price schedule combined with complementary regulations was found in CIMS to achieve the reduction target, DGEEM was run with the policy package to analyze the macroeconomic implications.

This report begins with descriptions of the CIMS and DGEEM models, followed by a description of the policy package and the scenario assumptions that were made. Finally, it concludes with results of the analysis. Appendices further describe CIMS and DGEEM. The last appendix describes the assumptions used to construct the reference case.

Method

Modeling Framework: CIMS

The CIMS model was originally designed as a predecessor to the NEMS model of the US Energy Information Administration, and has been subsequently developed for Canada by MKJA and the Energy and Materials Research Group at Simon Fraser University. It simulates the technological evolution of the energy-using capital stock in the Canadian economy (such as buildings, vehicles, and equipment) and the resulting effect on output, investment, labour and fuel costs, energy use, GHG and CAC emissions, and some material flows. The stock of energy-using capital is tracked in terms of energy service provided (m^2 of lighting or space heating) or units of physical product (metric tons of market pulp or steel). New capital stocks are acquired as a result of time-dependent retirement of existing stocks and growth in stock demand. Market shares of technologies competing to meet new stock demands are determined by standard financial factors as well as behavioral parameters from empirical research on consumer and business consumption and investment preferences. CIMS has three modules — energy supply, energy demand, and macro-economy — that can be simulated as an integrated model or individually. A model simulation comprises the following basic steps:

1. A base-case macroeconomic forecast initiates model runs. The macroeconomic forecast is at a sectoral or sub-sectoral level (e.g., it estimates the growth in total passenger travel demand or in airline passenger travel demand). The forecast adopted for this study is described in the reference case appendix.
2. In each time period, some portion of the existing capital stock is retired according to stock lifespan data. Retirement is time-dependent, but sectoral decline can also trigger retirement of some stocks before the end of their natural lifespan. The output of the remaining capital stocks is subtracted from the forecast energy service or product demand to determine the demand for new stocks in each time period.
3. Prospective technologies compete for new capital stock requirements based on financial considerations (capital cost, operating cost), technological considerations (fuel consumption, lifespan), and consumer preferences (perception of risk, status, comfort), as revealed by behavioral-preference research. The model allows both firms and individuals to project future energy and carbon prices with imperfect foresight when choosing between new technologies (somewhere between total myopia and perfect foresight about the future). Market shares are a probabilistic consequence of these various attributes.
4. A competition also occurs to determine whether technologies will be retrofitted or prematurely retired. This is based on the same type of considerations as the competition for new technologies.
5. The model iterates between the macro-economy, energy supply and energy demand modules in each time period until equilibrium is attained, meaning that energy prices, energy demand and product demand are no longer adjusting to changes in each other. Once the final stocks are determined, the model sums energy use, changes in costs, emissions, capital stocks and other relevant outputs.

The key market-share competition in CIMS can be modified by various features depending on evidence about factors that influence technology choices. Technologies can be included or excluded at different time periods. Minimum and maximum market shares can be set. The financial costs of new technologies can decline as a function of market penetration, reflecting economies of learning and economies of scale. Intangible factors in consumer preferences for new technologies can change to reflect growing familiarity and lower risks as a function of market penetration. Output levels of technologies can be linked to reflect complementarities.

Personal mobility provides an example of CIMS' operation. The future demand for personal mobility is forecast for a simulation of 30 or more years and provided to the energy demand module. After the first five years, existing stocks of personal vehicles are retired because of age. The difference between forecast demand for personal mobility and the remaining vehicle stocks to provide it determines the need for new stocks. Competition among alternative vehicle types (high and low efficiency gasoline, natural gas, biofuel, electric, gasoline-electric hybrid, and eventually hydrogen fuel-cell) and even among alternative mobility modes (single occupancy vehicle, high occupancy vehicle, public transit, cycling and walking) determines technology market shares. The results from personal mobility and all other energy services determine the demand for fuels. Simulation of the energy supply module, in a similar manner, determines new energy prices, which are sent back to the energy demand module. The new prices may cause significant changes in the technology competitions. The models iterate until quantity and price changes are minimal, and then pass this information to the macro-economic module. A change from energy supply and demand in the cost of providing personal mobility may change the demand for personal mobility. This information will be passed back to the energy demand module, replacing the initial forecast for personal mobility demand. Only when the model has achieved minimal changes in quantities and prices does it stop iterating, and move on to the next five-year time period.

The model was recently recalibrated to reflect EC's *National Inventory Report - Greenhouse Gas Sources and Sinks in Canada 1990-2006* as well as EC's online *Criteria Air Contaminant Emissions Summaries: 1990-2015.* We also updated the values from Natural Resources Canada's (NRCan) *Canada's Energy Outlook 2006 (CEO 2006)*, which provides the foundation of CIMS' physical output forecast to 2020, to reflect recently released output, energy and emissions data for 2005 from Natural Resources Canada's *Comprehensive Energy Use Database* and Statistics Canada's *Report on Energy Supply and Demand*. Details of the reference case are provided in an appendix. More on CIMS is also provided in an appendix.

CIMS Limitations and Uncertainties

Like all models, CIMS is a representation of the real world, not a perfect copy. Even though CIMS is very detailed compared to other models used for similar purposes, its broad scope (it represents almost all GHG emissions and energy consumption throughout the economy) requires many simplifying assumptions. The main uncertainties and limitations in the model are:

- **Technological detail and dynamics:** CIMS contains a considerable level of technological detail in each of its sectoral sub-models. This detail enables CIMS to show accelerated market penetration of alternative technologies in response to an energy, climate change or criteria air contaminant policy and to ensure that reference and policy scenarios are grounded in technological and economic reality, including realistic capital stock life and turnover. While care has been taken in representing the engineering and economic parameters of the many technologies in CIMS, including costs, uncertainty exists as to the appropriate cost and operating parameters of specific current and future technologies.

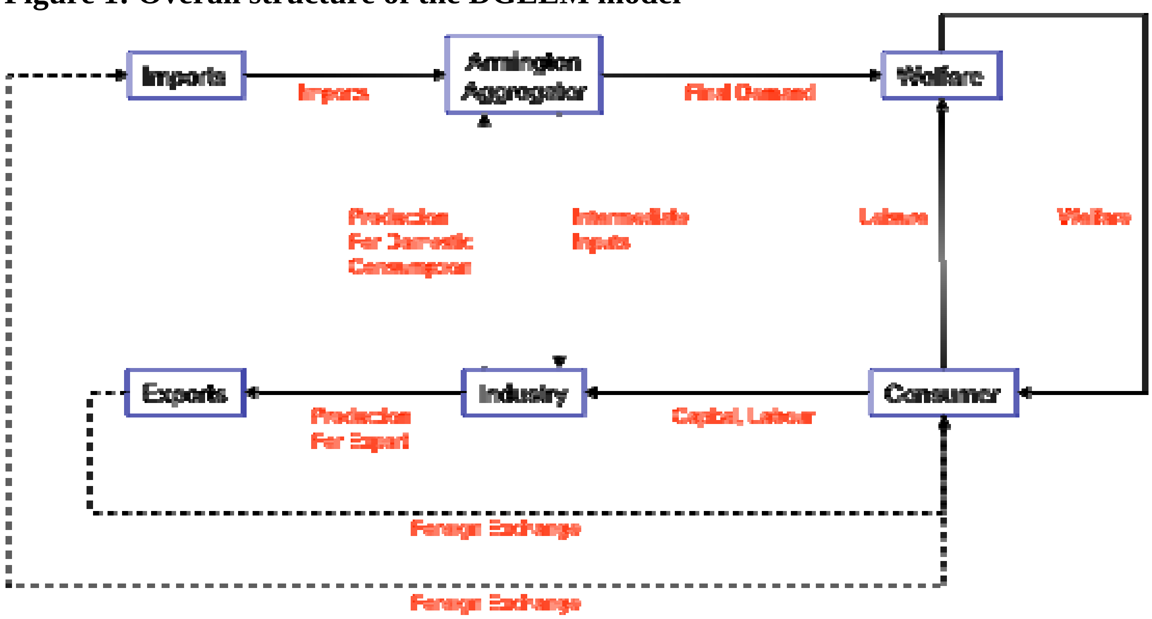
  While CIMS contains a representation of dynamic technological change that depicts how the costs of new technologies can be reduced through economies of scale and production experience based on historical experience, there is no guarantee that these relationships will hold in the future. In addition, CIMS only contains technological options that are known today (including those that are not yet commercialized). By definition, CIMS does not contain a depiction of new technologies that have not yet been invented and as a result, CIMS could miss technological substitution options in later years of the forecast. There are, however, only 12 years to 2020 — 12 years for brand new technologies not currently in CIMS to be invented, prototyped, commercialized and to enter the capital stock. Capital is mostly fairly longed-lived in buildings and industry, and there is simply not enough time for radical change to occur, other than by shutting industrial sectors down. This uncertainty becomes larger over time, but is of more concern after 2025-2030, which limits the concern for this analysis.

- **Behavioural realism:** The technology choice algorithm of CIMS takes into account implicit discount rates revealed by real-world technology acquisition behavior, intangible costs that reflect consumer and business preferences, and heterogeneity in the marketplace. Incorporating behavioral realism is critical in order to predict realistic consumer and firm response to policies; incorporating these preferences at a detailed level into a model that is technologically explicit is challenging. In addition to the sheer volume of the data requirements, the non-financial preferences of consumers and firms are difficult to estimate, and can change over time. The complexities associated with estimating behavioral parameters, combined with the fact that information cannot be collected for all the technology competitions in CIMS, result in a high degree of uncertainty associated with these parameters overall. The potential for preference change is also a key uncertainty.
- **External inputs:** CIMS requires external forecasts of macroeconomic activity in each sub-sector: population growth forecasts and starting fuel price forecasts on which to base the analysis. These forecasts are uncertain and could affect the results of the simulations. In addition, since no individual forecast is available to provide all key inputs over the period of interest in this analysis, we have adopted inputs from several different sources. We have used respected sources that are cited in the reference case appendix, and attempt to ensure consistency between various sources, but it is likely that the various inputs we use are not perfectly consistent with one another.
- **Equilibrium feedbacks:** Unlike most computable general equilibrium models (which do not generally contain technological detail), the current version of CIMS, while it does include direct responses of firms and consumers to increased input and final goods prices, does not equilibrate government budgets nor the markets for employment and investment. Also, its representation of the economy's inputs and outputs is skewed toward energy supply, energy intensive industries, and key energy end-uses in the residential, commercial/institutional, and transportation sectors. As a result, it is likely to underestimate the full structural response of the economy to energy and climate change policies. For this reason, using the pricing results from CIMS, we use the DGEEM model of the Canadian economy to estimate the effect of the specified emissions reduction target.

Modeling Framework: DGEEM

DGEEM is a multi-sector, open-economy computable general equilibrium model of the Canadian economy. In the model, a representative consumer is the owner of the primary factors (labour and capital). The consumer rents these factors to producers, who combine them with intermediate inputs to create commodities. These commodities can be sold to other producers (as intermediate inputs), to final consumers, or sold to the rest of the world as exports. Commodities can also be imported from the rest of the world. DGEEM is a small open-economy model – Canada is assumed to be a price taker for internationally traded goods. The key economic flows in DGEEM are captured schematically in Figure 1.

Figure 1: Overall structure of the DGEEM model



DGEEM assumes that all markets clear – prices adjust until supply equals demand. All markets are assumed to be perfectly competitive, such that producers never make excess profits and that supply equals demand. Likewise, factors of production are completely employed, so that there is no involuntary unemployment and no non-productive capital.

Previous versions of DGEEM have used a static framework. In a static framework, the accumulation and depreciation of capital is not modeled explicitly, so the model cannot capture the implications of changes in policy on investment and capital accumulation. Instead, investment capital is modeled as a fixed stock whose overall level does not change in response to changes in economic or environmental policy.

The version of DGEEM used for this project adopts a dynamic framework. In a dynamic framework, consumers are assumed to maximize utility over multiple time periods by choosing an appropriate rate of investment and consumption in each time period. In this approach, investment is directly influenced by changes in policy. Changes in investment cause changes in the level of capital stock that can be employed by firms, which influences overall economic growth and other variables.

Like most computable general equilibrium models, DGEEM imposes the restriction of constant returns to scale on producers to make the model more tractable.[1] Likewise, it imposes the assumption that consumer preferences are homothetic.[2]

The data underlying the model is derived primarily from the Statistics Canada System of National Accounts. We use the S-Level Input, Output, and Final Demand tables to populate the model, and aggregate these to focus on sectors of primary interest.[3] Energy consumption is disaggregated using data from the CIMS model and from the Natural Resources Canada publication *Canada's Energy Outlook: The Reference Case to 2006*.

DGEEM is implemented in GAMS, using the MPS/GE substructure.

An appendix with more information is provided for DGEEM.

DGEEM limitations and uncertainties, and how they interact with CIMS

Like CIMS, DGEEM is a representation of the real world, not a perfect copy. DGEEM is designed to capture the economy as a whole, and especially to integrate consumer demand, labour and capital supply, and the markets for all key inputs and outputs. This comes at the cost of simplifying assumptions. The main uncertainties and limitations in the model are:

- **Depiction of technological and technology dynamics:** Like most CGE models DGEEM makes use of production functions to depict technology and production, which assume a smooth substitution between all inputs at a given rate, depicted as an elasticity. In certain industries, such as services, there does seem to be a relatively smooth substation frontier between capital, labour, energy and materials. In other industries, such as electricity production or the iron and steel industry, this is not the case since fundamentally different technologies can produce the final end product. This phenomenon is not confined to industry; natural gas furnaces or electric resistance heaters can both be used to heat buildings, but have completely different capital and operating cost, energy use, and emissions profiles. It is for these reasons that bottom-up models initially conceived, including the one that evolved into CIMS.
- **Calibration of the social accounting matrix:** Like all calibrated as opposed to estimated CGE models, DGEEM must be calibrated to a given year's input and output of primary factors, goods and services.[4] This creates a base structure from which the model adjusts to policy shocks. If the chosen year is unrepresentative,

[1] Constant returns to scale implies that if all inputs to a firm are doubled, then all outputs are likewise doubled.

[2] Homothetic preferences imply that as consumer income doubles, demand for all goods and services doubles.

[3] The benchmark year for the model is 2000. Data for the year 2000 are based on a three year average of data from 1999, 2000, and 2001 in order to reduce the dependence of the model on statistical quirks from a single year.

[4] Calibrated CGE models operate from a single input output matrix from a given year, where all inputs and outputs are balanced. Estimated CGE models operate from parameters estimated from historical time series.

or economic or technology structure is changing quickly, the outputs of the model may be biased.

- **Forecasts of population, labour-force participation and labour productivity.**

How CIMS and DGEEM relate to each other and the analysis

In sum, DGEEM and CIMS are two different ways of modeling the Canadian energy economy, each with strengths and weaknesses. In this analysis we have treated CIMS as the lead model for emissions responses, capital investment, and fuel and technology choices, and DGEEM as the lead model for macroeconomic responses. DGEEM's production function structure has been calibrated to CIMS' emissions pricing response to ensure the macroeconomic consistency, but we provide CIMS' results for all energy, emissions, and changes in sector output, unit cost, and expenditures on capital, energy and labour. In turn, we have provided DGEEM's responses for changes in GDP, employment and trade.

Modeling the Target

The purpose of this project was to investigate the feasibility and cost of reducing GHG emissions by 25% from 1990 levels by 2020. Given the depth of the emissions target, we have assumed a full auction cap and trade or carbon tax of the necessary stringency to hit the target in 2020, starting with a price of $50/tonne in 2010 with complementary regulations as listed after Table 1. The GHG price path, which also assumes a steady rise to $300/t by 2030, is shown in Table 1.

Table 1: Projected emissions prices ($/tonne CO_2e $2005) for covered emissions

2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
50	65	80	95	110	125	140	155	170	185	200
2021	***2022***	***2023***	***2024***	***2025***	***2026***	***2027***	***2028***	***2029***	***2030***	***2031->***
210	220	230	240	250	260	270	280	290	300	300

The complementary regulations, based on market failures, were as follows:

- Venting and flaring in the oil and gas sector are confined solely to safety purposes, with a carbon charge imposed for all safety orientated emissions.
- To simulate urban sprawl containment, the urban footprint of single-family homes was constrained to its forecast 2010 level, and all new housing growth is redirected to higher density housing. This policy is a proxy for a more sophisticated land use planning policy to reduce GHG emissions through reduced transportation and buildings emissions.
- All new commercial buildings are built to LEED Gold standard or higher, and are restrained from directly using fossil fuels, including natural gas, in BC, Manitoba and Québec. All other options, including heat pumps, ground source heat pumps, and electric resistance heating are allowed.
- All new residential housing is built to an energy efficiency standard 50% higher than today's norm for new housing, and are restrained from directly using fossil

fuels, including natural gas, in BC, Manitoba and Québec. All other options, including heat pumps, ground source heat pumps, and electric resistance heating are allowed.

- All new vehicles sold meet the California GHG emissions standards, with expectation of a gradually tightening standard due to become virtually zero beyond the horizon of this analysis.
- As of 2011, white good appliance energy efficiency standards are raised to the most efficient commercially available versions of late 2008.
- Almost all landfills are required to be covered, and the captured landfill gas emissions flared to reduce the CO_2 forcing potential or used to produce some combination of electricity and heat as the economics warrant.

We also included a requirement to capture and store (CCS) all formation CO_2 from new natural gas processors, and all combustion CO_2 from all new coal fired electricity plants, oil sands facilities, and upgraders starting in 2011. This regulation, while not associated with a clear market failure is meant to drive technological innovation and reduce costs associated with CCS use.

To prevent undue economic dislocation, a rule was also followed for the non-fossil fuel sectors whereby sufficient carbon revenue was returned to a sector to at least maintain production at 2008 levels, i.e., to maintain employment and investment already in place. Two sectors - metal smelting and industrial minerals - required this support in the "Canada goes further" scenario.

We have assumed the same package of carbon pricing and complementary regulations under two opposing "bookend" scenarios: one where Canada's OECD trading partners maintain a carbon policy as strict as Canada's ("OECD acts together"), and one where "Canada goes further" and Canada's carbon pricing policy is significantly more stringent than that of its trading partners. Because of the uncertainty surrounding future OECD and developing world climate policy, these two contrasting scenarios should be thought of as learning tools and not strict predictions of future events – they provide our best estimate of the bounds of the effect of carbon competitiveness effects. As will be seen, these effects are potentially significant for a couple of sectors, but not for the economy as a whole.

Emissions reductions from the policy package were not quite large enough in either scenario to hit the target in 2020, even given the carbon price path and the regulations. The price and regulations are considered as strong as they may realistically be, so a further 49.1 Mt of international permit purchases are made in 2020 in the "OECD acts together" case, an amount sufficient to hit the target once added to the domestic reductions; the detailed permit purchase schedule from 2010 through 2020 is provided in the results section. In the "Canada goes further" case, 34.5 Mt of permits were required in 2020.

Scenario Assumptions

In order to determine the GHG abatement opportunities in the Canadian economy over time, we use the concept of a reference scenario and a policy scenario. The reference scenario shows how the Canadian economy might evolve in the absence of specific new policies to reduce GHG emissions, while the policy scenario shows how the economy might evolve under the policy package. The difference between the two scenarios is due to the effect of the policy. When doing this type of analysis, many assumptions need to be made. Some key overall conditions include:

- *In the "OECD acts together" scenario we have assumed that Canada's OECD trading partners impose GHG policy at least as stringent as Canada's.* This assumption has important impacts on how the policy affects Canada's trade in industrial goods, and is realized in CIMS' macroeconomic module. CIMS simulates international trade by using Armington substitution elasticities to proxy the demand for traded goods. These elasticities were calculated for use in the Finance Canada CASGEM model, and we use them to operate as price elasticities in CIMS.[5][6] These elasticities represent how the domestic and foreign demand for Canadian products might change in response to changes in the cost of domestic production, and are a composite of domestic and foreign demand for Canadian traded goods, i.e., if the elasticity is -1, and price goes up 1%, demands fall 1%. The Armington formulation is a composite of the propensity of customers of Canadian goods to substitute foreign equivalents and the end-use demand for a given good. If Canada's major trading partners have similar climate policies, their costs of production would presumably change in a similar magnitude to Canada, reducing the propensity of customers of Canadian goods to substitute foreign equivalents because the relative prices remain the same (i.e., they go up in all regions). It does not, however, reduce the propensity for them to substitute low carbon equivalents (i.e., to replace high carbon cement with lower carbon building materials); because the price of carbon intense goods has gone up in all regions, demand falls in all regions subject to its own price elasticity. We use our best judgement to reduce the Armington elasticities to remove the effect of the first component, and preserve the end-use demand effect. *In the second "Canada goes further" scenario we have assumed that while the OECD and the US in particular could impose carbon pricing, Canada imposes sufficiently stronger carbon pricing (approximately 50-100% greater) that it can be considered to be "acting alone",* and the Armington elasticities were adjusted accordingly.

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[5] The Armington elasticities in CIMS are from Wirjanto, T. (1999)."Estimation of Import and Export Elasticities: A report prepared for the Economic and Fiscal Policy Branch at the Department of Finance." Department of Economics, University of Waterloo

[6] For details of CIMS' macroeconomic mechanics see Bataille, C., M. Jaccard, J. Nyboer and N. Rivers. (2006). "Towards General Equilibrium in a Technology-Rich Model with Empirically Estimated Behavioral Parameters." In *Hybrid Modeling: New Answers to Old Challenges, Special Issue of the Energy Journal*, 27:93-112.

- *We have assumed the carbon pricing and complementary regulations are at least as stringent following 2020 as they are in 2020.* Firms and consumers in CIMS make investment and consumption decisions with limited foresight of future emissions prices. The carbon price is assumed to rise to $300/tonne CO_2e by 2030. As a result, consumers factor this in to some degree in decisions made prior to 2021.
- *NRCan's "Canada's Energy Outlook 2006" was considered to be the starting point for output and energy data* because of its comprehensiveness and status as Canada's national energy use forecast. *EC's GHG Inventory was considered the starting points for all emissions intensity data* because of its comprehensiveness and status as Canada's national emissions forecast, as are EC's emissions coefficients for fuel combustion. When NRCan's energy use is calculated by EC's emissions coefficients, the results do not always match, but we have attempted to reconcile them as best as possible. The differences are most significant in the upstream oil and gas sector, specifically the combustion coefficients associated with upstream and transmission oil and gas fugitives. All forecast values have been updated for the most recent official historical data.
- *We have allowed domestic and export demand for crude oil to fluctuate in response to the cost of producing it.* While there are substantial economic rents associated with crude oil when prices are high (>$50/barrel), in the long run its output is sensitive to the cost of producing oil and long run expectations of demand and prices. In our analysis we have assumed minimal rents; as domestic demand rises and falls, and as export demand rises and falls, we assume changes in the cost of production translate into changes in price, with appropriate responses in demand. *We have also allowed natural gas production to fluctuate based on its cost of production, and how this affects the price and demand.* There is substantial uncertainty what will happen to Canadian gas production in a carbon limited North America. Domestic consumption of natural gas drops significantly under both scenarios, but if the United States imposes any sort of carbon restrictions, as we have assumed, it will need to make significant efforts to decarbonize its electricity system. This will likely involve a substantial switch from coal to natural gas generation, which will likely require some combination of more LNG imports, shale gas production, and Mexican and Canadian gas imports. Given there are pressures to both increase and reduce gas production in a carbon limited world, we experimented with both fixed and flexible NG production, and finally chose flexible production for harmonization with the macroeconomic analysis.
- *The emissions charge policy simulated here is based on a cap and trade with full auction, or a carbon tax, with any revenue attained from the emissions charge recycled to households and labour taxes.* The revenue recycling worked as follows:
    (1) Permit/tax revenues are collected by government.

(2) Sufficient revenues were returned to non-fossil fuel production sectors to maintain 2005 BAU output (i.e., 50% of carbon revenues were returned to industrial minerals and metal smelting in the "Canada goes further" scenario).
(3) Government uses these revenues, along with all other tax receipts, to finance purchases of public goods (health care, defence, education, roads, etc.). The quantity of provision of public goods remains the same in the policy and BAU cases (even though the price of provision may change in response to a policy).
(4) Government transfers enough of the total tax revenues back to households to maintain transfers between government and households at the same level in BAU and under the policy package.
(5) If there is still money left over, it is used to lower the labour tax rate, until the government budget is balanced. Labour income taxes are lowered, not transfer mechanisms like Employment Insurance and Canada Pension Plan.

- Agricultural emissions reductions, which rise to 7.3 Mt in 2020, are assumed to be strictly additional and verifiable with adequate government enforcement to ensure additionality and verifiability. The agricultural emissions model in CIMS was designed to incorporate only those emissions reductions that are highly likely to be additional, verifiable and resistant to free-ridership, and its estimate of emissions reductions is used for this analysis. Further, it is assumed government purchases these emissions reductions, not industry, with the appropriate monetary flows.

Results

We provide first emissions reductions, key emission reduction actions, changes in physical output, and capital, labour and energy costs from CIMS. We then provide the changes in GDP, wages, employment, and trade from DGEEM.

CIMS – Sector, emissions, investment and energy impacts

Table 2 provides the annual reductions in emissions by sector and for the whole economy under the influence of the policy package.

Table 2: Annual reduction of all GHG emissions (Mt CO_2e) from BAU to Policy

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	7.1	7.2	18.9	18.9	28.5	28.5
Commercial	3.1	3.1	12.0	12.0	22.5	22.5
Personal Trans.	3.6	3.6	11.9	11.9	28.3	28.3
Freight Trans.	12.8	12.9	36.7	37.0	60.4	61.2
Chemical Products	0.1	0.3	2.6	3.3	4.3	5.0
Industrial Minerals	0.6	1.2	3.1	4.4	6.4	7.5
Iron and Steel	0.2	0.2	0.6	1.2	0.8	2.0
Metal Smelting	0.1	0.3	0.4	0.6	0.7	1.0
Mineral Mining	0.2	0.3	0.6	1.2	1.0	1.9
Paper Manufacturing	0.1	0.2	0.2	0.4	0.2	0.4
Other Manufacturing	2.1	2.2	4.4	4.6	7.1	7.4
Agriculture	0.8	0.8	4.6	4.6	7.2	7.3
Waste	1.6	1.6	24.9	24.9	25.7	25.7
Electricity	6.8	7.0	24.1	24.9	38.3	39.3
Petroleum Refining	1.4	1.4	5.4	5.5	10.3	10.3
Petroleum Crude Extr.	6.3	6.7	56.0	59.0	94.9	99.1
Natural Gas Extraction	3.5	3.5	18.5	20.9	21.5	25.1
Coal Mining	0.1	0.1	0.3	0.4	0.5	0.5
Ethanol	0.0	0.0	-0.3	-0.3	-0.4	-0.4
Biodiesel	0.0	0.0	-1.3	-1.2	-2.4	-2.4
Total	**50.5**	**52.5**	**223.7**	**234.2**	**355.8**	**370.3**

Emissions reductions were 14.5 Mt greater in the “Canada goes further” scenario in 2020, a small (3.9%) portion of the overall reduction of 370.3 Mt. The differences between the two scenarios, mainly increased reduction in output, were significant only for a few sectors: industrial minerals, chemical products, metal smelting and natural gas and petroleum crude extraction. Only two sectors, metal smelting and industrial minerals, qualified for carbon revenue returns to keep output at its 2008 level; each was returned 50% of its carbon charges after the sectors made their investment decisions.

The biggest reductions come from petroleum crude extraction (94.9 to 99.1 Mt in 2020 depending on the scenario), freight transportation (60.4 to 61.2 Mt), electricity (38.3 to 39.2 Mt), personal transportation (28.3 Mt), residential and commercial buildings (28.5 to 22.5 Mt), natural gas extraction (21.5 to 25.1 Mt) and the landfill waste sector (25.7 Mt). These reductions are due to capital investment in energy and GHG efficiency measures (e.g., CCS), fuel switching, and output reductions in a couple of key sectors. The overall reductions are 34.5 to 49.1 Mt short of the target in 2020, and it is assumed this is made up through international permit purchases – the cost and foreign exchange requirements associated with this are included in the DGEEM macroeconomic analysis.

Table 3 provides the annual reductions expressed as percentages compared to the reference case (i.e., BAU 2020 is compared to Policy 2020). Again, there are very small differences between the scenarios. The very large percentage increases in biodiesel and ethanol are due to the very low starting values.

Table 3: Annual % reduction of all GHG emissions (Mt CO_2e) from BAU to Policy

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	18%	19%	49%	49%	72%	72%
Commercial	9%	9%	32%	32%	55%	55%
Personal Trans.	3%	3%	11%	11%	24%	24%
Freight Trans.	13%	13%	33%	33%	47%	48%
Chemical Products	1%	2%	21%	27%	35%	40%
Industrial Minerals	4%	7%	17%	24%	33%	38%
Iron and Steel	1%	2%	5%	9%	5%	14%
Metal Smelting	1%	3%	4%	7%	9%	12%
Mineral Mining	4%	6%	12%	23%	18%	37%
Paper Manufacturing	1%	3%	3%	7%	6%	11%
Other Manufacturing	10%	11%	19%	20%	27%	28%
Agriculture	2%	2%	10%	10%	15%	15%
Waste	6%	6%	84%	84%	84%	84%
Electricity	6%	6%	21%	22%	35%	36%
Petroleum Refining	7%	7%	25%	25%	42%	43%
Petroleum Crude Ext.	7%	7%	41%	44%	58%	61%
Natural Gas Ext.	5%	6%	29%	33%	39%	45%
Coal Mining	4%	4%	14%	16%	19%	22%
Ethanol	-247%	-248%	-2323%	-2342%	-2088%	-2102%
Biodiesel	-62%	-60%	-1024%	-1010%	-1560%	-1529%
Total	**7%**	**7%**	**28%**	**29%**	**42%**	**44%**

Table 4 provides the emissions reductions by sector and region for the "OECD acts together" scenario, and Table 5 describes them for the "Canada goes further" scenario. Most reductions occur in Alberta (168.5 Mt / 45%) and Ontario (81.9 Mt / 22%), with 25% (93.2 Mt) of all reduction occurring in the Alberta Petroleum Crude sector.

Emissions reductions are greatest in the petroleum crude sector (27%), freight transportation (17%) and electricity (11%).

Table 4: Emissions reductions in 2020 by sector and region (Mt CO_2e) from BAU to Policy "OECD acts together"

	BC	AB	SK	MB	ON	PQ	ATL	∑	%
Residential	2.1	5.6	0.8	0.6	15.3	3.0	1.1	28.5	8%
Commercial	2.1	3.6	0.9	0.7	11.3	2.3	1.6	22.5	6%
Personal Trans.	4.0	3.0	0.8	0.8	10.6	7.0	2.0	28.2	8%
Freight Trans.	10.2	10.7	2.3	1.3	20.6	9.7	5.6	60.4	17%
Chemicals	0.1	3.5	0.0	0.0	0.4	0.3	0.0	4.3	1%
Ind. Minerals	0.7	0.8	0.0	0.0	3.9	0.9	0.0	6.3	2%
Iron and Steel	0.0	0.0	0.0	0.0	0.7	0.0	0.1	0.8	0%
Metal Smelting	0.1	0.0	0.0	0.0	0.1	0.5	0.0	0.7	0%
Mineral Mining	0.1	0.0	0.4	0.0	0.1	0.2	0.1	0.9	0%
Paper Mnftg	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0%
Other Mnftg	2.0	0.7	0.0	0.2	2.4	1.5	0.3	7.1	2%
Agriculture	0.3	1.5	1.1	1.5	1.6	1.0	0.3	7.3	2%
Waste	4.8	2.6	0.9	0.9	7.1	7.1	2.4	25.8	7%
Electricity	0.3	26.1	8.5	-1.3	1.4	0.6	2.8	38.4	11%
Pet. Refining	1.3	1.9	0.3	0.0	4.2	1.6	1.0	10.3	3%
Pet. Crude Ext.	0.4	90.3	4.0	0.0	0.0	0.0	0.1	94.8	27%
NG Ext.	6.9	11.5	1.5	0.1	0.6	0.0	0.8	21.4	6%
Coal Mining	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.5	0%
Ethanol	-0.1	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.3	0%
Biodiesel	-0.2	-0.5	-0.2	0.0	-0.9	-0.3	-0.3	-2.4	-1%
Total	**35.4**	**161.5**	**21.4**	**4.8**	**79.3**	**35.41**	**17.9**	**355.7**	**100%**
%	10%	45%	6%	1%	22%	10%	5%	100%	

Table 5: Emissions reductions in 2020 by sector and region (Mt CO_2e) from BAU to Policy "Canada goes further"

	BC	AB	SK	MB	ON	PQ	ATL	∑	%
Residential	2.1	5.6	0.8	0.6	15.3	3.0	1.1	28.5	8%
Commercial	2.1	3.6	0.9	0.7	11.3	2.3	1.6	22.5	6%
Personal Trans.	4.1	3.0	0.8	0.8	10.6	7.0	2.0	28.3	8%
Freight Trans.	10.5	10.7	2.4	1.3	20.9	9.8	5.7	61.3	17%
Chemicals	0.1	4.1	0.0	0.0	0.5	0.3	0.0	5.0	1%
Ind. Minerals	1.0	1.0	0.0	0.0	4.1	1.2	0.2	7.5	2%
Iron and Steel	0.0	0.0	0.0	0.0	2.0	0.0	0.0	2.0	1%
Metal Smelting	0.1	0.0	0.0	0.1	0.1	0.7	0.1	1.1	0%
Mineral Mining	0.1	0.0	1.3	0.0	0.1	0.2	0.2	1.9	1%
Paper Mnftg	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.3	0%
Other Mnftg	2.1	0.8	0.0	0.2	2.5	1.5	0.3	7.4	2%
Agriculture	0.3	1.5	1.1	1.5	1.6	1.0	0.3	7.3	2%
Waste	4.8	2.6	0.9	0.9	7.1	7.1	2.4	25.8	7%
Electricity	0.3	26.8	8.7	-1.3	1.5	0.6	2.8	39.4	11%
Pet. Refining	1.3	1.9	0.3	0.0	4.2	1.6	1.0	10.3	3%
Pet. Crude Ext.	0.4	93.2	5.3	0.0	0.0	0.0	0.1	99.0	27%
NG Ext.	7.3	13.9	1.8	0.1	1.0	0.1	0.9	25.1	7%
Coal Mining	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.6	0%
Ethanol	-0.1	0.0	0.0	0.0	-0.1	-0.1	0.0	-0.3	0%
Biodiesel	-0.2	-0.5	-0.2	0.0	-0.9	-0.2	-0.3	-2.3	-1%
Total	**36.6**	**168.5**	**24.2**	**4.9**	**81.9**	**36.2**	**18.4**	**370.7**	**100%**
%	10%	45%	7%	1%	22%	10%	5%	100%	

Table 6 and Figure 2 describe the actions taken to reduce GHGs out to 2020 in the "OECD acts together" scenario, assuming the policy package remains at the same stringency out to 2030 (i.e., complementary regulations plus \$300/tonne CO_2e). Figure 3 and Table 7 provide the same for when "Canada goes further". In the short to medium run out to 2020, the most important actions are:

- Carbon capture and storage (105 Mt in 2020 in "OECD acts together" and 94 Mt in "Canada goes further"). In early years this is primarily from relatively pure CO_2 sources, such as formation CO_2 from natural gas processing and CO_2 from steam reformation of methane to produce hydrogen.
- Energy efficiency (62 Mt in 2020 in "OECD acts together" and 63 Mt in "Canada goes further"), primarily in the personal and freight transportation sectors.
- Other GHG control (55 Mt in 2020 in "OECD acts together" and 60 Mt in "Canada goes further"), which includes control of fugitives in upstream oil and gas, and capping, flaring and cogeneration of landfill gas
- International permit purchases (49 Mt in 2020 in "OECD acts together" and 35 Mt in "Canada goes further")
- Switching to electricity in all sectors, including buildings (48 Mt in 2020 in "OECD acts together" and 47 Mt in "Canada goes further")

- Switching to renewables in electricity production (43 Mt in 2020 in "OECD acts together" and 42 Mt in "Canada goes further"). This is largely hydro and wind.
- Output reductions (24 Mt in 2020 in "OECD acts together" and 48 Mt in "Canada goes further"), mostly reduced output in the entire fossil fuel industry.

Table 6: Actions taken to reduce emissions "OECD acts together", Mt CO_2e

	2005	2010	2015	2020
Baseline emissions	711*	738	797	849
Policy Emissions	711	688	574	493
Emissions reductions				
Carbon Capture And Storage	0	1	59	105
Energy Efficiency	0	21	42	62
Other GHG Control (waste and oil &gas fugitives)	0	8	47	55
Fuel Switching to Electricity	0	9	26	48
Fuel Switching to Renewables	0	5	21	43
Output Reduction	0	4	18	24
CCS Energy Efficiency Penalty	0	0	6	12
Fuel Switching to Other Fuels	0	0	5	8
Fuel Switching to Nuclear	0	0	0	0
International Permit purchases	0	5	27	49
Target = Baseline - policy emissions – reduction actions - permit purchases				444

*Note: Does not match EC GHG inventory because it includes BAU carbon sequestration in agriculture. Land use change in forestry is not included, and neither are nitric and adipic acid production, solvents or HFCs.

Figure 2: Emission reduction actions “OECD acts together”

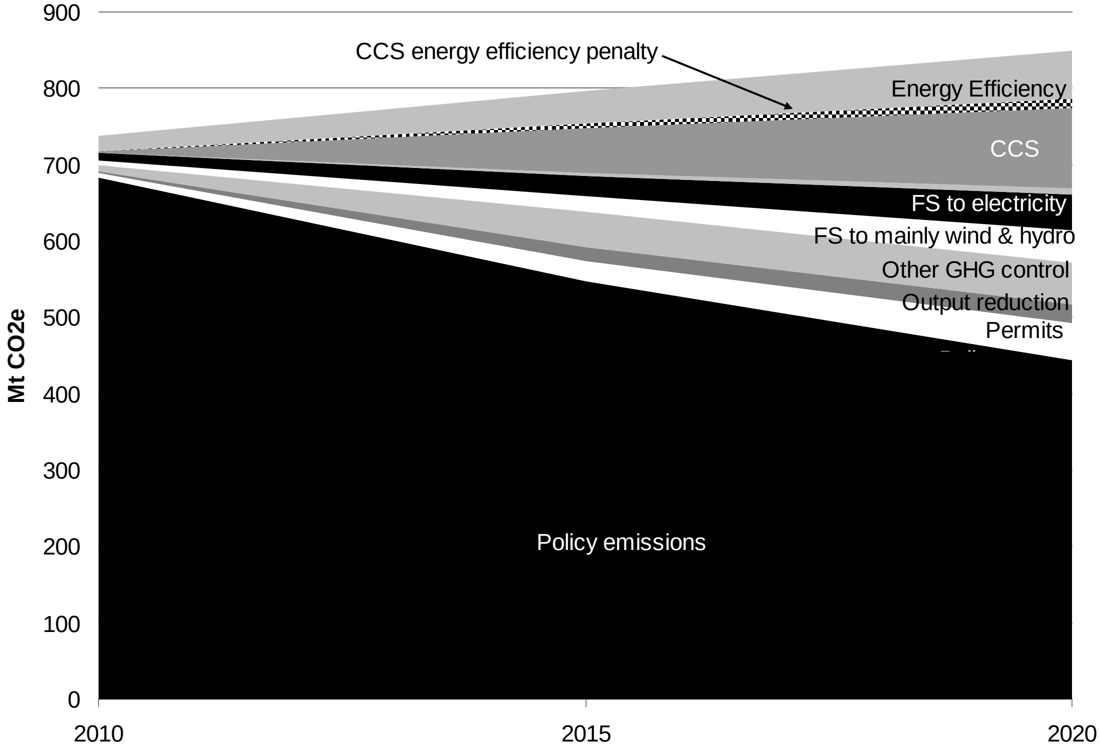
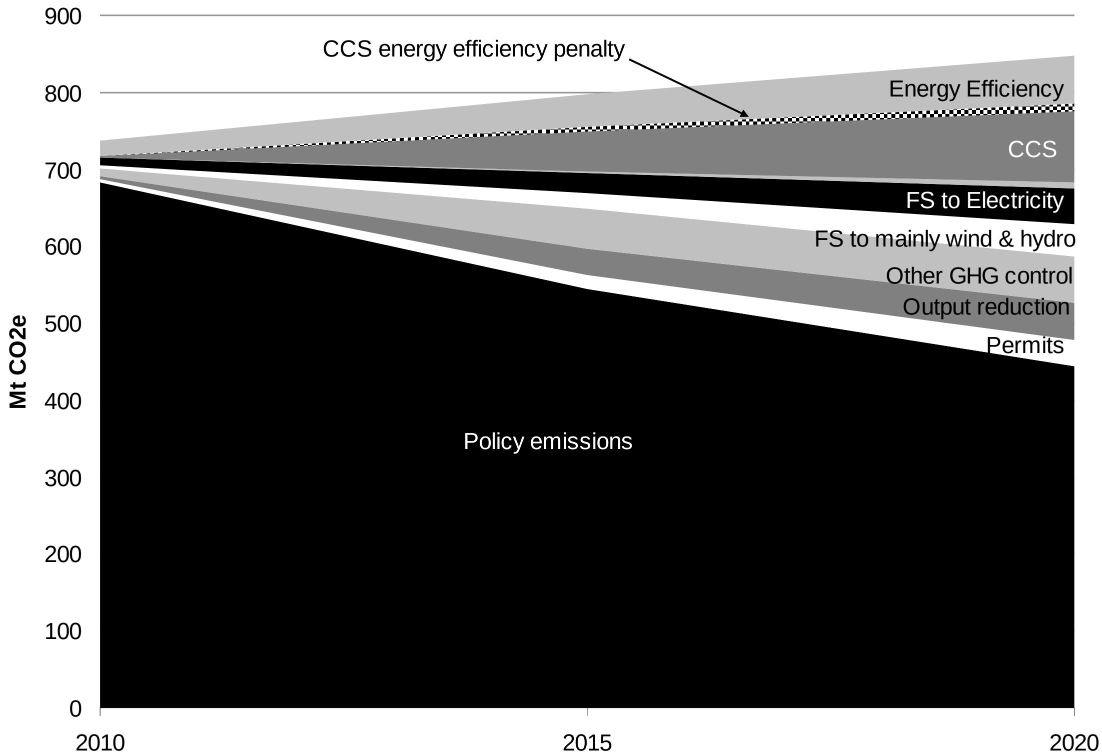


Table 7: Actions taken to reduce emissions "Canada goes further"

	2005	2010	2015	2020
Baseline emissions	711*	738	797	849
Policy Emissions	710	686	563	479
Emissions reductions				
Carbon Capture And Storage	0	1	52	94
Energy Efficiency	0	21	42	63
Other GHG Control (waste and oil &gas fugitives)	0	9	50	60
Output Reduction	5	5	34	48
Fuel Switching to Electricity	0	10	26	47
Fuel Switching to Renewables	0	5	20	42
CCS Energy Efficiency Penalty	0	0	5	10
Fuel Switching to Other Fuels	-4	0	4	7
Fuel Switching to Nuclear	0	0	0	0
International Permit purchases	0	3	19	35
Target = Baseline - policy emissions – reduction actions - permit purchases				444

*Note: Does not match EC GHG inventory because it includes BAU carbon sequestration in agriculture

Figure 3: Emission reduction actions "Canada goes further" , Mt CO_2e



The necessary capital investment, operations, and fuel switching changes in each sector engender changes in capital, energy, labour and emissions costs. Output impacts, which are included in these values, will be discussed later. Table 8 through to Table 11 document, by sector:

- the changes in capital expenditure for energy using and producing capital stock;
- changes in labour related to energy using and producing capital stock;
- changes in energy costs; and
- payments for emissions (which are transfers within the economy).

Table 8: Increase in annual capital costs ($2005 millions) from BAU to policy case

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	196	204	1,132	1,151	122	118
Commercial	-1,413	-1,399	-524	-473	566	560
Personal Trans.	-2,107	-2,106	-7,827	-7,825	-6,084	-6,084
Freight Trans.	-1,939	-1,981	-4,547	-4,682	-3,480	-3,892
Chemical Products	-23	-82	53	-112	59	-91
Industrial Minerals	-18	-66	-12	-88	168	21
Iron and Steel	0	-12	-50	-152	-36	-140
Metal Smelting	-22	-70	-59	-119	-30	-60
Mineral Mining	-25	-93	-181	-576	-99	-384
Paper Manufacturing	-124	-472	-104	-438	-14	-147
Other Manufacturing	-22	-52	-7	-36	1	-20
Agriculture	-13	-13	-83	-83	-43	-43
Waste	11	11	204	204	51	50
Electricity	7,353	6,951	10,658	9,279	12,081	11,268
Petroleum Refining	-115	-116	-64	-74	-209	-213
Petroleum Crude Ext.	72	-1	3,436	628	2,821	1,626
Natural Gas Ext.	-594	-643	-885	-1,460	-781	-1,169
Coal Mining	-87	-89	-50	-81	-43	-61
Ethanol	1	1	41	41	330	332
Biodiesel	25	24	880	867	1,194	1,147
Total	**1,158**	**-3**	**2,008**	**-4,028**	**6,570**	**2,817**

The capital investment patterns differ significantly between the two scenarios. In general, more capital is required in the "OECD acts together" case than the "Canada goes further" case. Output falls less, and therefore more capital is required to decarbonise electricity generation equipment, buildings, industrial machinery, rolling stock, etc.

Differences between the sectors are evident, with the largest impacts on the transport and electricity sectors. Just under $10 billion less capital is invested and spent annually in the transport sector in 2020, mainly because more efficient vehicles tend to be smaller. There is also significant mode shifting in both personal and freight transportation, both of which reduce capital expenditure. There may be disagreement as to whether these reductions should be directly construed as benefits as consumers and firms are induced to use different vehicles and modes than they would have chosen in the reference case, implying a reduction in welfare and profits. It is beyond the scope of this analysis to fully analyze the costs and benefits of mode switching and the use of smaller, more efficient vehicles, as it would require discussion of the welfare impacts of urban form and its amenability to transit, impacts on local air quality, and host of other issues.

Another sector with significant changes in capital investment is the electricity sector whose requirements for capital have risen by $11-$12 billion annually by 2020. This is due to across-the-board fuel switching to electricity, further impelled by regulations prohibiting direct use of fossil fuels for space and water heating for all new buildings in commercial and residential in BC, Manitoba, and Québec. Electricity production is one of the lowest cost areas to achieve low and zero GHG energy production, and its use goes up markedly across the economy.

Table 9 describes the changes in labour or equivalent time expenditures (e.g., in transportation) directly associated with energy using capital in the economy. A wider picture of the impacts on labour will be provided in the DGEEM macroeconomic section following the CIMS results. The labour results roughly match the impact of the capital results.

Table 9: Increase in annual operating & maintenance costs ($2005 million) from BAU to policy case

	2010		2015		2020	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	-4	-4	-20	-20	-33	-33
Commercial	-3	-3	-16	-16	-28	-28
Personal Trans.	-980	-980	-3,041	-3,041	-4,849	-4,849
Freight Trans.	-2,503	-2,511	-5,595	-5,640	-8,128	-8,260
Chemical Products	-4	-16	4	-51	13	-70
Industrial Minerals	-1	-8	12	-6	29	-3
Iron and Steel	-10	-24	-79	-217	-117	-374
Metal Smelting	-7	-23	-32	-62	-52	-89
Mineral Mining	-5	-17	-40	-138	-60	-208
Paper Manufacturing	-40	-122	-57	-227	-62	-258
Other Manufacturing	-3	-9	-3	-15	-2	-18
Agriculture	33	33	116	116	158	158
Waste	5	5	103	102	125	125
Electricity	763	721	1,745	1,566	2,857	2,597
Petroleum Refining	-124	-125	-277	-283	-495	-505
Petroleum Crude Ext.	-227	-286	-775	-2,569	-1,025	-3,601
Natural Gas Ext.	-230	-244	-766	-1,267	-1,288	-2,087
Coal Mining	-22	-22	-33	-41	-44	-56
Ethanol	5	5	61	62	544	543
Biodiesel	52	51	1,921	1,892	4,351	4,228
Total	**-3,305**	**-3,580**	**-6,774**	**-9,855**	**-8,106**	**-12,787**

Table 10 describes the changes in annual energy expenditures by sector. There are significant differences between the sectors. Both scenarios have considerable savings in early years, but these continue only in the tighter "Canada goes further" scenario where $6.0 to $7.0 billion is saved annually. The residential and commercial sectors spend more due to the enforced switch away from direct fossil fuel use in Québec, BC and

Manitoba. Considerable amounts are saved in the transport sector due to efficiency and mode shifting.

Table 10: Increase in annual fuel costs ($2005 million) from BAU to policy case

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	165	120	2,802	2,684	4,473	4,397
Commercial	-142	-178	1,407	1,294	1,732	1,644
Personal Trans.	-1,601	-1,602	-3,702	-3,705	-5,645	-5,650
Freight Trans.	-4,672	-4,709	-6,323	-6,483	-5,724	-6,263
Chemical Products	25	-22	296	-10	379	-118
Industrial Minerals	25	5	52	-2	35	-51
Iron and Steel	-31	-39	-48	-94	-66	-172
Metal Smelting	100	61	188	98	205	95
Mineral Mining	22	-21	206	-54	252	-165
Paper Manufacturing	-6	-112	234	-27	226	-42
Other Manufacturing	47	-11	487	348	576	395
Agriculture	30	27	383	375	659	656
Waste	-7	-7	-203	-202	-325	-325
Electricity	-121	-152	-470	-691	-744	-1,109
Petroleum Refining	-103	-106	-183	-210	-384	-421
Petroleum Crude Ext.	46	-7	1,651	302	2,984	1,028
Natural Gas Ext.	-240	-271	-269	-733	-620	-1,215
Coal Mining	-14	-15	38	26	58	41
Ethanol	4	4	28	28	61	60
Biodiesel	13	12	481	471	1,057	1,018
Total	**-6,463**	**-7,023**	**-2,945**	**-6,584**	**-811**	**-6,197**

Table 11 shows the direct average annual payments made for emissions by all sectors. These revenues are recycled as described earlier. The amounts involved are considerable, rising from $30.4 billion in the "OECD acts together" case and $30.5 billion in the "Canada goes further" case in 2010, to $89.5-86.6 billion in 2020. Half of the sector specific revenue is returned in the cases of the industrial minerals and metals smelting sectors in the "Canada goes further" scenario.

Table 11: Average annual emissions charge costs that are recycled as reduced labour taxes ($2005 million)

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	1,573	1,572	2,504	2,503	2,229	2,228
Commercial	1,620	1,620	3,225	3,226	3,643	3,643
Personal Trans.	5,016	5,016	12,126	12,125	17,878	17,879
Freight Trans.	4,133	4,128	9,514	9,475	13,652	13,495
Chemical Products	580	572	1,202	1,110	1,613	1,474
Industrial Minerals	793	763	1,870	1,715	2,632	2,429
Iron and Steel	713	710	1,665	1,589	2,664	2,410
Metal Smelting	527	520	1,141	1,114	1,562	1,510
Mineral Mining	254	250	585	509	866	671
Paper Manufacturing	295	292	595	571	723	687
Other Manufacturing	926	920	2,358	2,332	3,842	3,790
Electricity	5,600	5,587	11,073	10,973	14,044	13,829
Petroleum Refining	943	942	2,073	2,069	2,801	2,787
Petroleum Crude Ext.	4,427	4,410	9,903	9,531	13,488	12,643
Natural Gas Ext.	3,013	3,009	5,535	5,226	6,851	6,123
Coal Mining	106	105	255	250	416	401
Ethanol	1	1	36	37	78	78
Biodiesel	6	6	172	170	512	502
Total	**30,525**	**30,422**	**65,831**	**64,524**	**89,494**	**86,581**

Table 12 describes the impact of the increased production costs on physical output in each sector (note this is physical output, not gross output in dollar terms). The most heavily impacted sectors are industrial minerals (-8 to 19%, limited by revenue recycling sufficient to maintain estimated 2008 production), petroleum refining (-30 to 31%), petroleum crude extraction (-9 to -20%), and natural gas extraction (-21 to -30%). Electricity production rises 18-20% by 2020 to accommodate fuel switching. These results do not include any form of border tax adjustment to value imports according to their GHG content; these would alleviate the impacts, but also increase emissions.

Table 12: Projected annual % reduction in physical output from the business as usual case to the policy case

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	-2%	-2%	-4%	-4%	-4%	-4%
Commercial	-1%	-1%	-6%	-6%	-8%	-8%
Personal Trans.	0%	0%	-2%	-2%	-2%	-2%
Freight Trans.	-6%	-6%	-9%	-10%	-11%	-12%
Chemical Products	0%	-1%	-2%	-5%	-2%	-7%
Industrial Minerals	-2%	-6%	-6%	-14%	-8%	-19%
Iron and Steel	0%	-1%	-2%	-5%	-2%	-9%
Metal Smelting	-1%	-2%	-2%	-6%	-3%	-8%
Mineral Mining	0%	0%	-1%	-3%	-2%	-5%
Paper Manufacturing	-1%	-5%	-2%	-8%	-3%	-9%
Other Manufacturing	0%	-1%	-1%	-2%	-1%	-2%
Electricity	6%	6%	13%	11%	20%	18%
Petroleum Refining	-7%	-7%	-18%	-18%	-30%	-31%
Petroleum Crude Ext.	-2%	-3%	-7%	-16%	-9%	-20%
Natural Gas Ext.	-3%	-4%	-12%	-18%	-21%	-30%
Coal Mining	-10%	-10%	-14%	-17%	-17%	-21%
Ethanol	252%	253%	1900%	1910%	11910%	11881%
Biodiesel	77%	75%	1631%	1606%	2834%	2754%
Total	-2%	-2%	-4%	-4%	-4%	-4%

To provide perspective, **Table 13** provides the change in physical output from 2005 to 2020 in the policy cases. Except for the refining and natural gas sectors, which fall 18% and 28% respectively, and the metal smelting and industrial minerals sectors, which receive rebates of 50% of their carbon charge costs in the "Canada goes further" scenario, no sector actually reduces output from 2005 levels in 2020.[7]

In an environment where all of North America is reducing emissions, there is some uncertainty that Canada's natural gas output will fall. The price of NG, based on its relatively low GHG intensity and utility for making electricity, could stay high enough to maintain Canadian production. We will further explore the impacts on this sector in the next version of this analysis.

Table 13: Projected increase in physical output from 2005 to 2020 in the policy case

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	5%	5%	9%	10%	16%	16%
Commercial	10%	10%	16%	17%	29%	29%
Personal Trans.	20%	20%	34%	34%	50%	50%
Freight Trans.	11%	11%	19%	19%	29%	27%
Chemical Products	6%	5%	11%	7%	17%	11%
Industrial Minerals	6%	2%	12%	3%	18%	4%
Iron and Steel	4%	3%	8%	4%	13%	5%
Metal Smelting	5%	3%	3%	0%	4%	0%
Mineral Mining	6%	6%	9%	6%	10%	6%
Paper Manufacturing	0%	-3%	3%	-3%	7%	0%
Other Manufacturing	13%	12%	27%	25%	42%	40%
Electricity	13%	12%	26%	24%	42%	39%
Petroleum Refining	-4%	-4%	-10%	-10%	-18%	-18%
Petroleum Crude Ext.	28%	27%	54%	39%	71%	50%
Natural Gas Ext.	0%	0%	-1%	-7%	-18%	-28%
Coal Mining	-4%	-5%	1%	-3%	7%	1%
Ethanol	1765%	1771%	17326%	17415%	151663%	151304%
Biodiesel	360%	356%	7748%	7637%	17220%	16748%
Total	5%	5%	9%	10%	16%	16%

One of the key emissions reduction actions is decarbonization of electricity, and fuel switching to electricity from other fuels, requiring more electricity be made. Figure 4 provides the BAU and policy electricity generation mix for "OECD acts together", and Figure 5 for "Canada goes further".

There were some key changes in the electricity sector for this analysis compared to previous analyses done with CIMS.

[7] One exception is the pulp and paper sector, which reduce output below 2005 levels in 2010 through 2015. We will explore carbon revenue returns to this sector in the next version of this study.

- It is the stated policy of the David Suzuki Foundation that no new nuclear capacity be built in Canada. Given this, we explored a restriction on nuclear generation based on full societal cost measure that would include waste, decommissioning and liability insurance. New nuclear energy was required to pay a 1.3 ¢/kwh waste and decommissioning charge, based on recent French legal decisions regarding the cost of waste disposal and decommissioning of France's existing fleet, as well as a 4.0 ¢/kwh liability insurance charge to capture the implicit government insurance subsidy on nuclear power.[8] These charges did not make nuclear sufficiently expensive to prevent new capacity from being purchased in the policy case, so total nuclear capacity was limited to existing 2005 capacity. Nuclear generation is 5 TWh greater under policy than BAU, but this is because the fleet is retired less quickly than it would have been in BAU. BAU included the waste, decommissioning and insurance charges as well; on the premise that politicians and regulatory bodies are aware of these costs.
- CCS costs were raised significantly to reflect recent estimate of costs (i.e., post combustion CCS has been raised from prices starting at \$50/tonne CO_2e to \$75-\$100+ /tonne CO_2e).
- Reflecting recent experience with wind power in other jurisdictions (e.g., Spain, Portugal, Germany and Denmark), we reduced near term constraints on wind to a maximum of 15% of generation by 2020. The policy drove the share of wind to 13.3% of total generation in 2020.

In the "OECD acts together" scenario (Figure 4) total generation increases 140 TWh compared to BAU, while in the "Canada goes further" scenario (Figure 5) total generation rises 124 TWh. Of the increase in 2020 production of 140 to 124 TWh, small and large hydro took 69 to 62 TWh, wind and other renewables 76 to 70 TWh, nuclear 5 TWh, and coal and NG with CCS 32 to 30 TWh. Coal and NG without CCS lost 43-42 TWh of generation share.

[8] The waste and decommissioning charge is from « Le démantèlement des installations nucléaires et la gestion des déchets radioactifs », Rapport Public Particulier, Cour des Comptes, Janvier 2005. The insurance charge is from Heyes, A. and C. Heyes, "An empirical analysis of the Nuclear Liability Act (1970) in Canada" *Resource and Energy Economics* 2000, 22(1):91-101.

Figure 4: Electricity production and mix "OECD acts together"

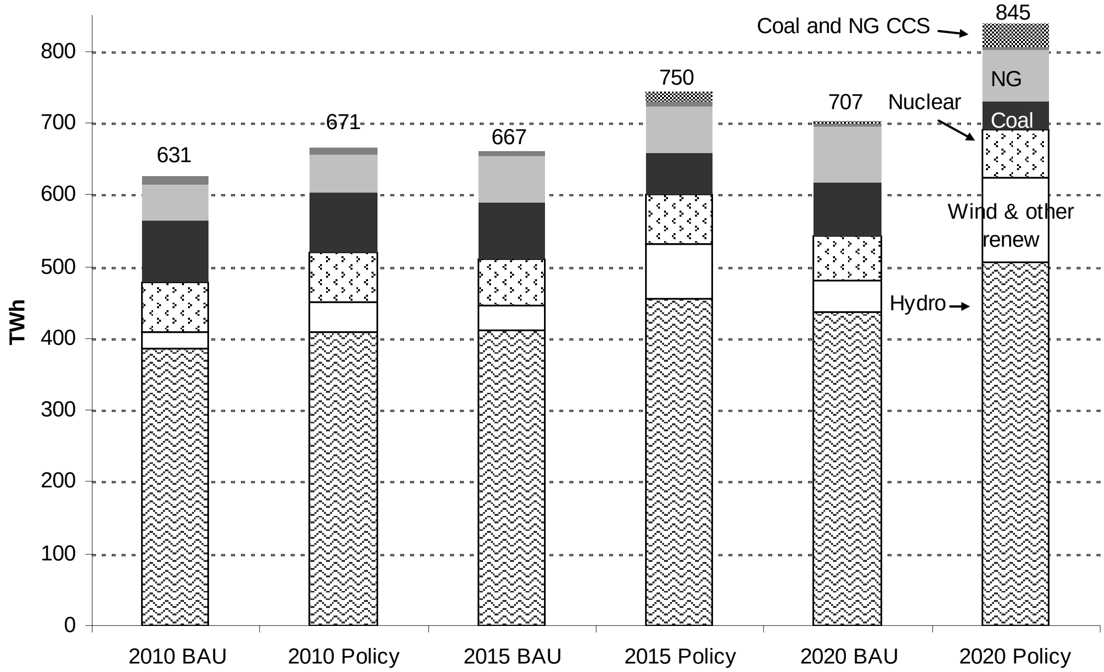


Figure 5: Electricity production and mix "Canada goes further"

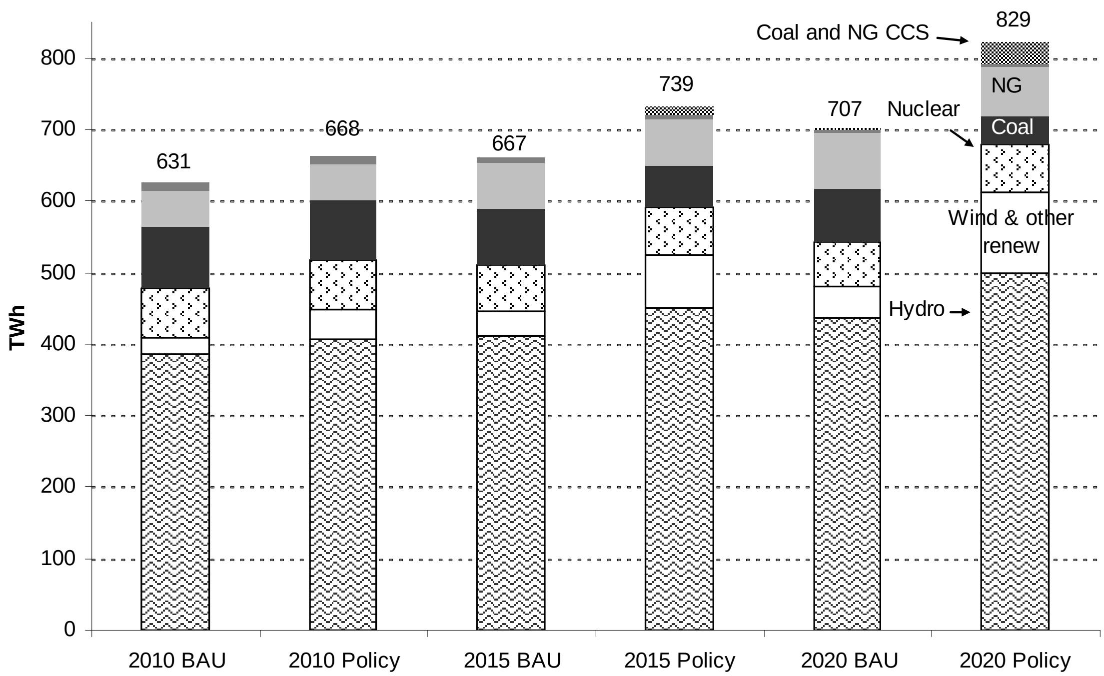


Table 14 summarizes the net financial effects that come out of CIMS. It adds the changes in annual capital, energy, and labour costs. Emissions costs are not included as they are transfers to the rest of the economy.

Table 14: Annual net financial costs by sector ("+" = costs, "-" = gains, $2005 millions (Sum of annual capital, labour related to energy use, and energy costs)

	2010		*2015*		*2020*	
	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further	OECD trading partners act together	Canada goes further
Residential	357	321	3,914	3,816	4,562	4,483
Commercial	-1,559	-1,579	866	806	2,270	2,176
Personal Trans.	-4,687	-4,688	-14,570	-14,571	-16,578	-16,582
Freight Trans.	-9,114	-9,202	-16,465	-16,805	-17,332	-18,415
Chemical Products	-2	-120	353	-174	451	-279
Industrial Minerals	5	-69	51	-96	231	-33
Iron and Steel	-40	-75	-177	-464	-220	-687
Metal Smelting	71	-32	97	-83	123	-55
Mineral Mining	-8	-132	-15	-768	93	-757
Paper Manufacturing	-171	-706	73	-693	150	-447
Other Manufacturing	21	-72	476	297	575	357
Agriculture	49	47	415	408	773	770
Waste	9	9	104	104	-150	-150
Electricity	7,995	7,519	11,933	10,154	14,194	12,756
Petroleum Refining	-341	-347	-525	-566	-1,088	-1,138
Petroleum Crude Ext.	-109	-294	4,312	-1,638	4,779	-946
Natural Gas Ext.	-1,064	-1,158	-1,920	-3,460	-2,689	-4,472
Coal Mining	-123	-126	-46	-96	-29	-76
Ethanol	9	10	130	131	934	935
Biodiesel	90	88	3,282	3,230	6,601	6,393
Total	**-8,610**	**-10,605**	**-7,711**	**-20,467**	**-2,348**	**-16,167**

Table 15 interpolates the financial impacts of "OECD acts together" between 2010, 2015 and 2020, and adds net foreign permit purchases. Table 16 shows the assumed schedule of foreign permit purchases, which rise in price from $25/tonne in 2010 to $100/tonne in 2020. Total payments are $22.1 billion by 2020; the annual payment in 2020 is $.9 billion. Domestic emissions costs are not included as they are transfers to the rest of the economy. The summed impacts over time in the "OECD acts together" scenario, *which are not discounted*, are a net *reduction* in expenditure on capital, labour and energy of $49.3 billion. If the transportation impacts are removed, the summed impacts are a net *increase* in expenditure of $249.0 billion. In the "Canada goes further" scenario (Table 17) the total including transportation is a reduction in expenditure of $167.1 billion, while excluding transportation the net increase in financial costs is $136.4 billion. These values do not necessarily represent net benefits to society; these are usually calculated as changes in consumer surplus or welfare.

Table 15: Annual net financial costs by sector ("+" = costs, "-" = gains, $2005 billions (Sum of annual capital, labour related to energy use, and energy costs) ("OECD acts together")

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑
Residential	0.4	1.1	1.8	2.5	3.2	3.9	4.0	4.2	4.3	4.4	4.6	34.3
Commercial	-1.6	-1.1	-0.6	-0.1	0.4	0.9	1.1	1.4	1.7	2.0	2.3	6.5
Trans. Personal	-4.7	-6.7	-8.6	-10.6	-12.6	-14.6	-15.0	-15.4	-15.8	-16.2	-16.6	-136.6
Trans. Freight	-9.1	-10.6	-12.1	-13.5	-15.0	-16.5	-16.6	-16.8	-17.0	-17.2	-17.3	-161.7
Chem. Products	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.5	3.1
Ind. Minerals	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	1.0
Iron and Steel	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-1.7
Metal Smelting	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.1
Mineral Mining	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Paper Man.	-0.2	-0.1	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Other Man.	0.0	0.1	0.2	0.3	0.4	0.5	0.5	0.5	0.5	0.6	0.6	4.2
Agriculture	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	0.8	4.5
Waste	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	-0.1	-0.1	0.1
Electricity	8.0	8.8	9.6	10.4	11.1	11.9	12.4	12.8	13.3	13.7	14.2	126.2
Pet. Refining	-0.3	-0.4	-0.4	-0.5	-0.5	-0.5	-0.6	-0.8	-0.9	-1.0	-1.1	-6.9
Crude Oil Ext.	-0.1	0.8	1.7	2.5	3.4	4.3	4.4	4.5	4.6	4.7	4.8	35.6
NG Ext.	-1.1	-1.2	-1.4	-1.6	-1.7	-1.9	-2.1	-2.2	-2.4	-2.5	-2.7	-20.9
Coal Mining	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.7
Ethanol	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.5	0.6	0.8	0.9	3.5
Biodiesel	0.1	0.7	1.4	2.0	2.6	3.3	3.9	4.6	5.3	5.9	6.6	36.5
International Permit Payments	0.1	0.3	0.5	0.8	1.2	1.7	2.2	2.8	3.4	4.1	4.9	22.1
Total	**-8.5**	**-8.1**	**-7.7**	**-7.2**	**-6.7**	**-6.0**	**-4.5**	**-2.8**	**-1.1**	**0.7**	**2.6**	**-49.3**

Table 16: Schedule of international permit payments ($2005 millions).

		OECD acts together		Canada goes further	
	Price ($/tonne CO_2e)	Mt	Payments	Mt	Payments
2010	25	4.5	$ 112	3.1	$ 78
2011	32.5	8.9	$ 290	6.3	$ 204
2012	40	13.4	$ 536	9.4	$ 376
2013	47.5	17.9	$ 848	12.5	$ 596
2014	55	22.3	$ 1,228	15.7	$ 863
2015	62.5	26.8	$ 1,674	18.8	$ 1,176
2016	70	31.2	$ 2,187	22.0	$ 1,537
2017	77.5	35.7	$ 2,767	25.1	$ 1,945
2018	85	40.2	$ 3,415	28.2	$ 2,399
2019	92.5	44.6	$ 4,129	31.4	$ 2,901
2020	100	49.1	$ 4,910	34.5	$ 3,450
Total			$ 22,095		$ 15,525

Table 17: Annual net financial cost (“+” = costs, “-“ = gains, $2005 billion). Sum of annual capital, labour related to energy use, & energy costs (“Canada goes further”)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑
Residential	0.3	1.0	1.7	2.4	3.1	3.8	3.9	4.1	4.2	4.3	4.5	33.5
Commercial	-1.6	-1.1	-0.6	-0.1	0.3	0.8	1.1	1.4	1.6	1.9	2.2	5.8
Trans. Personal	-4.7	-6.7	-8.6	-10.6	-12.6	-14.6	-15.0	-15.4	-15.8	-16.2	-16.6	-136.7
Trans. Freight	-9.2	-10.7	-12.2	-13.8	-15.3	-16.8	-17.1	-17.4	-17.8	-18.1	-18.4	-166.9
Chem. Products	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-2.1
Ind. Minerals	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	-0.8
Iron and Steel	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.5	-0.6	-0.6	-0.6	-0.7	-4.6
Metal Smelting	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.7
Mineral Mining	-0.1	-0.3	-0.4	-0.5	-0.6	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-6.5
Paper Man.	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.6	-0.6	-0.5	-0.5	-0.4	-6.9
Other Man.	-0.1	0.0	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.4	2.3
Agriculture	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.6	0.7	0.8	4.5
Waste	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	-0.1	-0.1	0.1
Electricity	7.5	8.0	8.6	9.1	9.6	10.2	10.7	11.2	11.7	12.2	12.8	111.6
Pet. Refining	-0.3	-0.4	-0.4	-0.5	-0.5	-0.6	-0.7	-0.8	-0.9	-1.0	-1.1	-7.3
Crude Oil Ext.	-0.3	-0.6	-0.8	-1.1	-1.4	-1.6	-1.5	-1.4	-1.2	-1.1	-0.9	-11.9
NG Ext.	-1.2	-1.6	-2.1	-2.5	-3.0	-3.5	-3.7	-3.9	-4.1	-4.3	-4.5	-34.2
Coal Mining	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-1.1
Ethanol	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.5	0.6	0.8	0.9	3.5
Biodiesel	0.1	0.7	1.3	2.0	2.6	3.2	3.9	4.5	5.1	5.8	6.4	35.6
International Permit Payments	0.1	0.2	0.4	0.6	0.9	1.2	1.5	1.9	2.4	2.9	3.5	15.5
Total	**-10.5**	**-12.4**	**-14.2**	**-15.9**	**-17.6**	**-19.3**	**-18.1**	**-16.8**	**-15.5**	**-14.1**	**-12.7**	**-167.1**

DGEEM - Macroeconomic impacts

The policies used in CIMS to meet the -25% from 1990 levels by 2020 were also analyzed in DGEEM to understand possible macroeconomic implications. Due to the technical complexity of the complementary regulations simulated in CIMS, it was not possible to directly model them in DGEEM. However, most of the regulations are designed to mimic the carbon price in sectors and situations where there is likely to be a carbon market failure. The one exception is the CCS regulation; this is unlikely to bias the results, however, as many fewer facilities are built in the crude oil and NG sectors.[9] Table 18 provides some selected macroeconomic impacts of the two scenarios.

Table 18: Selected macroeconomic impacts in real dollars

	BAU 2011 to 2020 growth	OECD acts together Policy 2011 to 2020 growth	Canada goes further Policy 2011 to 2020 growth
Gross domestic product	+22.03%	+19.27%	+19.21%
Consumption	+24.25%	+19.97%	+19.84%
Average salary (2020, $2003 CAD) 2010 =$43,831	$51,753	$48,839	$49,044
Labour force size	+6.36%	+6.15%	+6.35%
Returns to labour (wage rate * labour force)	+9.68%	+4.08%	+4.83%
Imports	+20.18%	+18.62%	+18.55%
Exports	+19.67%	+20.23%	+20.54%

The model suggests that in the “OECD acts together” scenario GDP will grow 19.3% instead of 22.0% in the BAU over 2011-2020. Imports grow slightly less (18.6 vs. 20.2%), and exports slightly more (20.2 vs. 19.7%), partly to help pay for international permits. The “OECD acts together” and “Canada goes further” scenarios are largely similar from a macroeconomic perspective, with the latter experiencing slightly higher GDP losses and consumption reductions.

The 2010 BAU average salary is $43,831 ($2003), and 18.452 million people are working. In the BAU scenario 1.188 million jobs are created from 2011 to 2020, and the 2020 average salary is $51,753. In the “OECD acts together” scenario 1.164 million jobs are created, and the average 2020 salary is $48,839. As a result, the labour force grows 6.2% instead of 6.4%. In the “Canada goes further“ scenario, 1.179 million jobs are created, and the average salary is $49,044.

Table 19 provides changes in gross output and employment by sector in 2020 for the “OECD acts together” scenario. Overall employment increases 19% instead of 26%

[9] Our modelling shows a drop in NG production and consumption, largely because of fuel switching in the electricity production, commercial and residential buildings sectors, as well as lower exports due to increased production costs. These results have some uncertainty in them in regards to US demand for Canadian natural gas. Conventional natural gas reserves in Canada are being depleted faster than they are being replaced, but a significant amount of shale and tight gas is available, at production cost of $4+/GJ. If North American retail natural gas prices rise and stay in the $7/GJ range in the policy case, Canada is likely to produce significant amounts of shale and tight gas. Shale gas tends to have significant amounts of formation CO_2 in it, and CCS will be required to capture and store this CO_2 if any significant emissions reductions targets are to be met.

between 2011 and 2020 as a result of the policy package. Fossil fuel industries bear most of the reduction. The reader should note that the labour columns are in total expenditure, not people employed as in Table 18.

Table 19: Changes in gross output and employment by sector in 2020 "OECD acts together", expressed as % change in total expenditures

	BAU 2011 to '20 increase in gross output ($)	Policy 2011 to '20 increase in gross output ($)	BAU 2011 to '20 increase in labour expenditures ($)	Policy 2011 to '20 increase in labour expenditures ($)
Agriculture	21%	22%	27%	24%
Pet. Crude Extraction	18%	-11%	25%	-15%
Natural Gas Extraction	11%	-16%	19%	-25%
Coal Mining	2%	-35%	7%	-36%
Other Mining	18%	13%	23%	14%
Electricity	41%	51%	-1%	-7%
Construction Industry	18%	17%	21%	17%
Other Manufacturing	21%	24%	26%	25%
Pulp and Paper	21%	22%	27%	23%
Petroleum Refining	13%	4%	20%	2%
Chemicals	21%	22%	28%	21%
Industrial Mineral	18%	19%	23%	20%
Iron and Steel	20%	22%	25%	21%
Warehousing	23%	18%	26%	19%
Freight Transport	21%	20%	27%	19%
Services	22%	17%	27%	19%
Government	23%	19%	26%	19%
Total	21%	18%	26%	19%

Labour expenditure in electricity drops significantly in BAU and Policy in the model simulations. Coal and natural gas electricity generation employ significantly more people per unit of generation than hydroelectricity. In both BAU and policy coal production is significantly reduced, and hydroelectricity increases. In the policy case coal and NG production are significantly reduced, while hydroelectricity gains yet more market share of a larger generation base. The per unit generation labour requirements of nuclear, wind and other renewables are also less than that of coal and natural gas, but to a lesser degree than hydro.

Figure 6 shows the forecasted over time impacts of the policy package on gross domestic product. 0.0% represents the BAU growth path. While overall GDP continues to increase, the policy package increasingly slows the economy out to 2027, and then the growth path starts to return to potential. These are contrasted against overall GDP in Figure 7. GDP is $36 billion less than BAU in 2020.

Figure 6: Annual impact of policy package on gross domestic product "OECD acts together" compared to BAU growth path

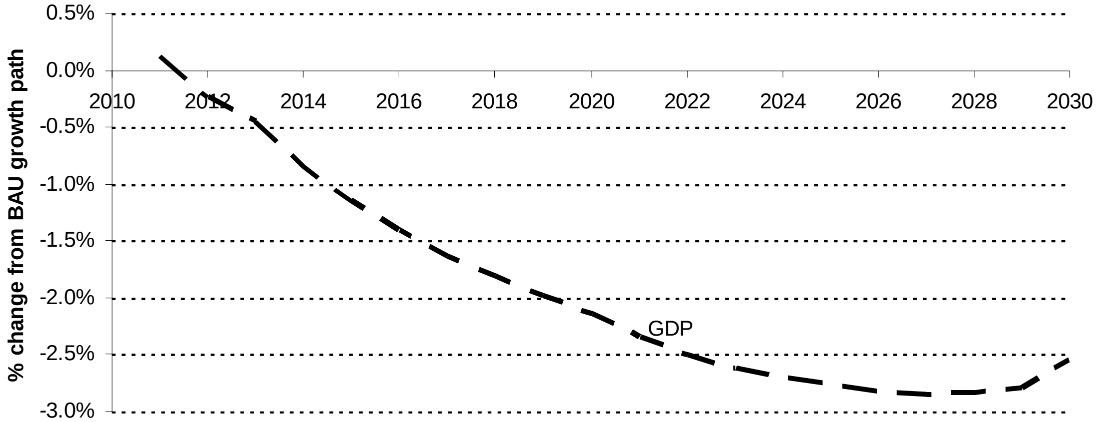
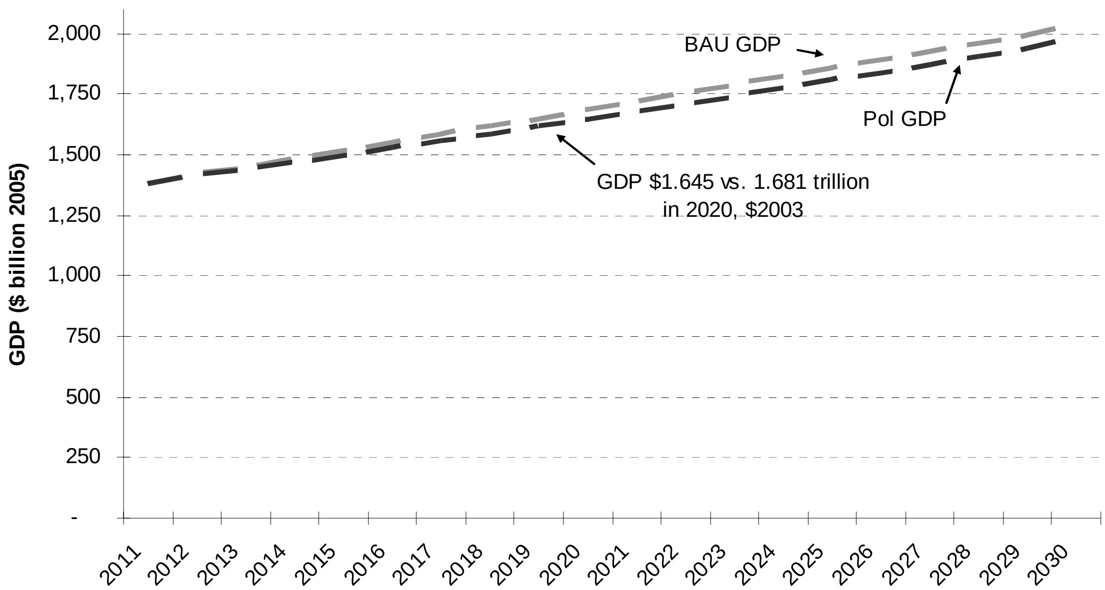


Figure 7: Absolute GDP under BAU and Policy, "OECD acts together"



Appendix – CIMS

CIMS has a detailed representation of technologies that produce goods and services throughout the economy and attempts to simulate capital stock turnover and choice between these technologies realistically. It also includes a representation of equilibrium feedbacks, such that supply and demand for energy intensive goods and services adjusts to reflect policy.

CIMS simulations reflect the energy, economic and physical output, GHG emissions, and CAC emissions from its sub-models as shown in Table 20. CIMS does not include adipic and nitric acid, solvents or hydrofluorocarbon (HFC) emissions. CIMS covers nearly all CAC emissions in Canada except those from open sources (e.g., forest fires, soils, and dust from roads).

Table 20: Sector Sub-models in CIMS

Sector	BC	Alberta	Sask.	Manitoba	Ontario	Quebec	Atlantic
Residential	■	■	■	■	■	■	■
Commercial/Institutional	■	■	■	■	■	■	■
Personal Transportation	■	■	■	■	■	■	■
Freight Transportation	■	■	■	■	■	■	■
Industry							
Chemical Products	■	■			■	■	
Industrial Minerals	■	■			■	■	■
Iron and Steel					■	■	
Non-Ferrous Metal Smelting*	■			■	■	■	■
Metals and Mineral Mining	■		■	■	■	■	■
Other Manufacturing	■	■	■	■	■	■	■
Pulp and Paper	■	■			■	■	■
Energy Supply							
Coal Mining	■	■	■				■
Electricity Generation	■	■	■	■	■	■	■
Natural Gas Extraction	■	■	■	■	■	■	■
Petroleum Crude Extraction	■	■	■		■		■
Petroleum Refining	■	■	■		■	■	■
Agriculture & Waste	■	■	■	■	■	■	■

* Metal smelting includes Aluminium.

Model structure and simulation of capital stock turnover

As a technology vintage model, CIMS tracks the evolution of capital stocks over time through retirements, retrofits, and new purchases, in which consumers and businesses make sequential acquisitions with limited foresight about the future. This is particularly important for understanding the implications of alternative time paths for emissions reductions. The model calculates energy costs (and emissions) for each energy service in the economy, such as heated commercial floor space or person kilometres travelled. In each time period, capital stocks are retired according to an age-dependent function (although retrofit of un-retired stocks is possible if warranted by changing economic conditions), and demand for new stocks grows or declines depending on the initial exogenous forecast of economic output, and then the subsequent interplay of energy supply-demand with the macroeconomic module. A model simulation iterates between energy supply-demand and the macroeconomic module until energy price changes fall below a threshold value, and repeats this convergence procedure in each subsequent five-year period of a complete run.

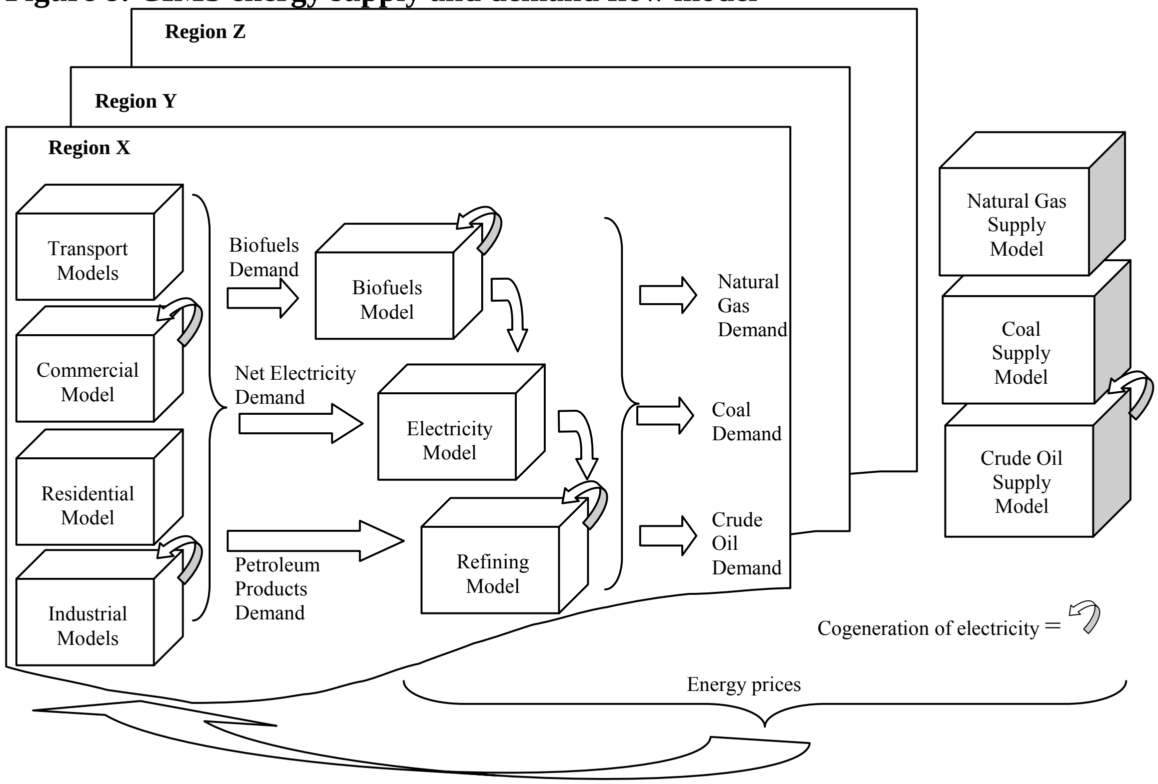
CIMS simulates the competition of technologies at each energy service node in the economy based on a comparison of their life cycle cost (LCC) and some technology-specific controls, such as a maximum market share limit in the cases where a technology is constrained by physical, technical or regulatory means from capturing all of a market. Instead of basing its simulation of technology choices only on financial costs and social discount rates, CIMS applies a definition of LCC that differs from that of bottom-up analysis by including intangible costs that reflect consumer and business preferences and the implicit discount rates revealed by real-world technology acquisition behaviour.

Equilibrium feedbacks in CIMS

CIMS is an integrated, energy-economy equilibrium model that simulates the interaction of energy supply-demand and the macroeconomic performance of key sectors of the economy, including trade effects. Unlike most computable general equilibrium models the current version of CIMS does not equilibrate government budgets and the markets for employment and investment. Also, its representation of the economy's inputs and outputs is skewed toward energy supply, energy intensive industries, and key energy end-uses in the residential, commercial/institutional and transportation sectors.

CIMS estimates the effect of a policy by comparing a business-as-usual forecast to one where the policy is added to the simulation. The model solves for the policy effect in two phases in each run period. In the first phase, an energy policy (e.g., ranging from a national emissions price to a technology specific constraint or subsidy, or some combination thereof) is first applied to the final goods and services production side of the economy, where goods and services producers and consumers choose capital stocks based on CIMS' technological choice functions. Based on this initial run, the model then calculates the demand for electricity, refined petroleum products and primary energy commodities, and calculates their cost of production. If the price of any of these commodities has changed by a threshold amount from the business-as-usual case, then supply and demand are considered to be out of equilibrium, and the model is re-run based on prices calculated from the new costs of production. The model will re-run until a new equilibrium set of energy prices and demands is reached. Figure 8 provides a schematic of this process. For this project, while the quantities produced of all energy commodities were set endogenously using demand and supply balancing, endogenous pricing was used only for electricity and refined petroleum products; natural gas, crude oil and coal prices remained at exogenously forecast levels (described later in this section), since Canada is assumed to be a price-taker for these fuels.

Figure 8: CIMS energy supply and demand flow model



In the second phase, once a new set of energy prices and demands under policy has been found, the model measures how the cost of producing traded goods and services has changed given the new energy prices and other effects of the policy. For internationally traded goods, such as lumber and passenger vehicles, CIMS adjusts demand using price elasticities that provide a long-run demand response that blends domestic and international demand for these goods (the "Armington" specification).[10] Freight transportation is driven by changes in the combined value added of the industrial sectors, while personal transportation is adjusted using a personal kilometres-travelled elasticity (-0.02). Residential and commercial floor space is adjusted by a sequential substitution of home energy consumption vs. other goods (0.5), consumption vs. savings (1.29) and goods vs. leisure (0.82). If demand for any good or service has shifted more than a threshold amount, supply and demand are considered to be out of balance and the model re-runs using these new demands. The model continues re-running until both energy and goods and services supply and demand come into balance, and repeats this balancing procedure in each subsequent five-year period of a complete run.

Empirical basis of parameter values

Technical and market literature provide the conventional bottom-up data on the costs and energy efficiency of new technologies. Because there are few detailed surveys of the annual energy consumption of the individual capital stocks tracked by the model

[10] CIMS' Armington elasticities are econometrically estimated from 1960-1990 data. If price changes fall outside of these historic ranges, the elasticities offer less certainty.

(especially smaller units), these must be estimated from surveys at different levels of technological detail and by calibrating the model's simulated energy consumption to real-world aggregate data for a base year.

Fuel-based GHGs emissions are calculated directly from CIMS' estimates of fuel consumption and the GHG coefficient of the fuel type. Process-based GHGs emissions are estimated based on technological performance or chemical stoichiometric proportions. CIMS tracks the emissions of all types of GHGs, and reports these emissions in terms of carbon dioxide equivalents.[11]

Both process-based and fuel-based CAC emissions are estimated in CIMS. Emissions factors come from the US Environmental Protection Agency's FIRE 6.23 and AP-42 databases, the MOBIL 6 database, calculations based on Canada's National Pollutant Release Inventory, emissions data from Transport Canada, and the California Air Resources Board.

Behavioral parameters are estimated through a combination of literature review, judgment, supplemented with the use of discrete choice surveys for estimating models whose parameters can be transposed into behavioral parameters in CIMS.

Simulating endogenous technological change with CIMS

CIMS includes two functions for simulating endogenous change in individual technologies' characteristics in response to policy: a declining capital cost function and a declining intangible cost function. The declining capital cost function links a technology's financial cost in future periods to its cumulative production, reflecting economies-of-learning and scale (e.g., the observed decline in the cost of wind turbines as their global cumulative production has risen). The declining capital cost function is composed of two additive components: one that captures Canadian cumulative production and one that captures global cumulative production. The declining intangible cost function links the intangible costs of a technology in a given period with its market share in the previous period, reflecting improved availability of information and decreased perceptions of risk as new technologies become increasingly integrated into the wider economy (e.g., the "champion effect" in markets for new technologies); if a popular and well respected community member adopts a new technology, the rest of the community becomes more likely to adopt the technology.

Please see the following list of publications for further information on CIMS:

Bataille, C., M. Jaccard, J. Nyboer and N. Rivers. (2006). "Towards General Equilibrium in a Technology-Rich Model with Empirically Estimated Behavioral Parameters." *Hybrid Modeling: New Answers to Old Challenges, Special Issue of the Energy Journal.*

Jaccard, M., J. Nyboer, C. Bataille, and B. Sadownik (2003). "Modeling the Cost of Climate Policy: Distinguishing Between Alternative Cost Definitions and Long run Cost Dynamics." *The Energy Journal* 24(1): 49-73.

Rivers, N. and M. Jaccard. (2005) "Combining Top-Down and Bottom-Up Approaches to Energy-Economy Modeling Using Discrete Choice Methods." *The Energy Journal* 26(1): 83-106.

[11] CIMS uses the 2001 100-year global warming potential estimates from Intergovernmental Panel on Climate Change, 2001, "Climate Change 2001: The Scientific Basis", Cambridge University Press, UK.

Appendix - DGEEM

The model is a single-region Ramsey-type dynamic putty-clay general equilibrium model of the Canadian economy. It is calibrated to the input, output, and final demand tables produced by Statistics Canada. Data for these tables is based on an average of 1999-2001 data, and updated to a 2010 reference year according to sectoral and overall growth rate forecasts produced by Natural Resources Canada (2006), using the so-called RAS algorithm (Robinson, Cattaneo, and El-Said, 2001).

Household

The representative household maximizes intertemporal utility, where utility is given by a constant elasticity of intertemporal substitution function:

$$\max U = \sum_{t=1}^{T} \left(\frac{1}{1+\rho} \right)^{t} u(c_t) \tag{1}$$

where T is the time horizon of the model, ρ is the rate of pure time preference, c_t is consumption, and $u(c_t)$ is the instantaneous utility of consumption, given by:

$$u(c_t) = \frac{c_t^{1-\theta} - 1}{1-\theta} \tag{2}$$

Where $\sigma_t = 1/\theta$ is the elasticity of intertemporal substitution.

Instantaneous consumption is based on a nested constant elasticity of substitution function, in which consumption of leisure (l) and goods (g) are substitutes with constant elasticity of substitution, $\sigma_{cl} = 1 / (1 - \gamma_{cl})$, and where the time subscripts have been dropped for clarity of exposition:

$$c = \left(\alpha_{cl} l^{\gamma_{cl}} + (1-\alpha_{cl}) g^{\gamma_{cl}} \right)^{1/\gamma_{cl}} \tag{3}$$

Utility from consumption of individual goods, g, is a nested constant elasticity of substitution function in the consumption-leisure function:

$$g=\left(\begin{array}{l}\alpha_{ene}\left(\left(\alpha_{ht}\left(\left(\alpha_{eg}q_{ng}{}^{\gamma_{eg}}+(1-\alpha_{eg})q_{el}{}^{\gamma_{eg}}\right)^{1/\gamma_{eg}}\right)^{\gamma_{ht}}+(1-\alpha_{ht})q_t{}^{\gamma_{ht}}\right)^{1/\gamma_{ht}}\right)\\+(1-\alpha_{ene})\left(\left(\sum\alpha_{ne}q_{ne}{}^{\gamma_{ne}}\right)^{1/\gamma_{ne}}\right)^{\gamma_{ene}}\end{array}\right)^{1/\gamma_{ene}} \tag{4}$$

Where q_{ng} is household natural gas consumption, q_{el} is electricity consumption, q_t is petroleum product consumption, q_{ne} is non-energy product consumption, and each γ is related to an elasticity of substitution σ by $\gamma = 1 - 1/\sigma$, where σ_{eg} is the elasticity of substitution between natural gas and electricity, σ_{ht} is the elasticity of substitution between the electricity-gas aggregate and petroleum products, σ_{ne} is the elasticity of substitution between non-energy products, and σ_{ene} is the elasticity of substitution between the energy aggregate and the non-energy aggregate. The α parameters in the above equations are all determined through calibration with the benchmark data set.

The consumer maximizes intertemporal utility subject to an intertemporal budget balance:

$$\sum_{t=1}^{T}\sum p_{gt}g_t(1+tc_{gt})=\sum_{t=1}^{T}\left(\frac{(L_t-l_t)w_t}{1+td_{lt}}\right)+TRN_t+\frac{K_0r_0}{1+td_{k0}}-\frac{K_{T+1}r_{T+1}}{1+td_{kT+1}} \tag{5}$$

Where p_{gt} is the price of good g in period t, tc_{gt} is the ad valorem tax on final consumption of good g in period t, TRN_t represents lump sum transfers from government to households in period t, L_t is the exogenous labour endowment, l_t is the endogenous leisure demand, w_t is the gross wage rate, td_{lt} is the direct tax on labour income, td_{kt} is the direct tax on capital income, r_t is the rental rate on capital, and K_t is the capital stock. The final two terms on the right hand side represent the value of the initial capital stock and the post-terminal capital stock, respectively.

Production

Production of goods in each sector j in each time period is given by a constant returns to scale constant elasticity of substitution function, where an energy-value added aggregate is combined with intermediate material inputs to produce output (time subscripts have again been dropped for clarity of exposition):

$$Y_j=\left(\alpha_{s,j}eva_j{}^{\gamma_{s,j}}+(1-\alpha_{s,j})in_j{}^{\gamma_{s,j}}\right)^{1/\gamma_{s,j}} \tag{6}$$

Energy products are subsequently nested to represent differing ease of substitutability between alternative energy types:

$$eva_j = \left(\alpha_{eva,j} va_j^{\gamma_{eva,j}} + (1-\alpha_{eva}) en_j^{\gamma_{eva,j}}\right)^{1/\gamma_{eva,j}} \tag{7}$$

$$en_j = \left(\alpha_{ef,j} f_j^{\gamma_{ef,j}} + (1-\alpha_{ef,j}) el_j^{\gamma_{ef,j}}\right)^{1/\gamma_{ef,j}} \tag{8}$$

$$f_j = \left(\alpha_{cgl,j} gl_j^{\gamma_{cgl,j}} + (1-\alpha_{cgl,j}) co_j^{\gamma_{cgl,j}}\right)^{1/\gamma_{cgl,j}} \tag{9}$$

$$gl_j = \left(\alpha_{gl,j} ng_j^{\gamma_{gl,j}} + (1-\alpha_{gl,j}) rpp_j^{\gamma_{gl,j}}\right)^{1/\gamma_{gl,j}} \tag{10}$$

Capital and labour form a value-added aggregate, and intermediate material inputs form an intermediate aggregate:

$$va_j = \left(\alpha_{kl,j} k_j^{\gamma_{kl,j}} + (1-\alpha_{kl,j}) l_j^{\gamma_{kl,j}}\right)^{1/\gamma_{kl,j}} \tag{11}$$

$$in_j = \left(\sum \alpha_{in,j} i_j^{\gamma_{in,j}}\right)^{1/\gamma_{in,j}} \tag{12}$$

Producers maximize profits, and profits for each sector are zero in each time period in equilibrium (time subscripts are suppressed):

$$\pi_j = p_j Y_j - rK_j(1+tf_k) - wl_j(1+tf_l) - \sum p_{in} in_j \tag{13}$$

Where p_j is the price of output, tf_f is the net input tax rate on factors of production, p_{in} is the price of inputs, and in_j is the quantity of inputs. The α terms in the above equations represent calibrated distribution parameters, and the γ parameters are exogenously specified parameters that relate to substitution elasticities via the relationship $\gamma = 1 - 1/\sigma$. Substitution elasticities are as follows: σ_s = elasticity of substitution between energy/value added aggregate and intermediate input aggregate; σ_{eva} = elasticity of substitution between energy and value added, σ_{ef} = elasticity of substitution between electricity and fuels, σ_{cgl} = elasticity of substitution between coal and other fuels, σ_{gl} = elasticity of substitution between natural gas and petroleum products, σ_{kl} = elasticity of substitution between capital and labour, σ_{in} = elasticity of substitution between intermediate inputs.

Government

One government agent represents all three levels of Canadian government. Government collects net tax revenue (less subsidies), including both direct and indirect taxes. Taxes included in the model are (1) a direct labour income tax and (2) a direct corporate income tax, (3) an indirect factor input tax/subsidy on producers, (4) a consumption tax on final consumption and investment, and (5) import tariffs. The rates of all indirect taxes and subsidies are calibrated to the input output data, while the rates for direct taxes are derived from separate data on direct income taxation. All taxes are assumed to remain constant throughout the simulation unless endogenously modified (as described in the text). When a carbon price is applied, government is considered the owner of emission permits (or the collector of tax receipts, in the case of a carbon tax).

Government expenditures finance provision of an aggregate public good (health, education, etc.). In all simulations, provision of the aggregate public good remains constant at reference case levels. Remaining government budget is transferred to households in lump sum unless otherwise specified. Government is subject to an intertemporal budget constraint such that all net tax revenue is balanced by expenditures and transfers.

Trade

To allow for cross-hauling, the model uses an Armington formulation for international trade in which domestically and internationally produced goods are treated as imperfect substitutes. In particular, each domestic consumption good *i* is a constant elasticity of substitution aggregate of domestic and foreign goods:

$$g_i = \left(\alpha_{hf,i} h_i^{\gamma_{hf,i}} + (1-\alpha_{hf,i}) f_i^{\gamma_{hf,i}}\right)^{1/\gamma_{hf,i}} \tag{14}$$

Where h_i and f_i are the quantities of domestic and foreign good, respectively, and where $\sigma_{hf,i} = 1 / (1 - \gamma_{hf,i})$ is the Armington elasticity for commodity *i*. For exports, a similar constant elasticity of transformation is applied to each domestic production industry:

$$Y_j = \left(\alpha_{dx,i} d_i^{\gamma_{dx,i}} + (1-\alpha_{dx,i}) x^{\gamma_{dx,i}}\right)^{1/\gamma_{dx,i}} \tag{15}$$

Where d_i and x_i are the quantities of domestically produced good for domestic and export markets, respectively, and where $\sigma_{dx,i} = 1 / (1 - \gamma_{dx,i})$ is the Armington elasticity for commodity *i*.

Trade in commodities is mediated through the foreign exchange market, which allows Canadian currency to appreciate or depreciate relative to foreign currencies. In each period, the model requires balance in the foreign exchange market relative to the reference case scenario (in which there is a balance of trade surplus).

Dynamics

The model is a Ramsey-type growth model, in which consumers endogenously choose how much of total output to invest in a given period. The capital stock evolves subject to these investments:

$$K_{t+1} = K_t \cdot (1-\delta) + I_t \tag{16}$$

Where k_t is the total capital stock in time t, δ is the rate at which the capital stock depreciates, and I_t is the total investment in period t. Overall investment is an aggregate of investment goods (time subscripts are suppressed):

$$I = (\sum_g \alpha_{Ig} g^{\gamma_I})^{1/\gamma_I} \tag{17}$$

Where the elasticity of substitution between alternative investment goods is $\sigma_I = 1/(1-\gamma_I)$.

Investment is a 'zero-profit' activity:

$$r(1+\phi)I - \sum_i p_i g(1+ti_i) = 0 \tag{18}$$

Where ϕ is the interest rate, and ti_i is the tax on investment demand for good i.

Because the model has a finite horizon, a constraint is needed for final period investment. Following Lau et al. (2002), the following constraint is used:

$$\frac{I_T}{I_{T-1}} \geq \sum_J \frac{Y_{j,T}}{Y_{j,T-1}} \tag{19}$$

Parameters

Parameter	***Description***	***Value***
	Household utility function elasticities	
σ_t	Elasticity of intertemporal substitution	0.5
σ_{cl}	Elasticity of substitution between consumption and leisure	0.8
σ_{eg}	Elasticity of substitution between electricity and natural gas in residential consumption	0.65
σ_{ht}	Elasticity of substitution between gas-electricity aggregate and petroleum products	0.3
σ_{ne}	Elasticity of substitution between non-energy goods	0.25
σ_{ne}	Elasticity of substitution between non-energy aggregate and energy aggregate	0.15
	Production function elasticities	
$\sigma_{s,j}$	Elasticity of substitution between energy-value-added aggregate and material aggregate	0
$\sigma_{va,j}$	Elasticity of substitution between energy and value added aggregate	0.27 – 1.8
$\sigma_{ef,j}$	Elasticity of substitution between electricity and fuels	0.2 – 1.8
$\sigma_{cgl,j}$	Elasticity of substitution between coal and other fuels	0.3 – 0.8
$\sigma_{gl,j}$	Elasticity of substitution between natural gas and petroleum products	0.1 – 2.69
$\sigma_{kl,j}$	Elasticity of substitution between capital and labour	1.1
$\sigma_{in,j}$	Elasticity of substitution between intermediate non-energy material inputs	0.05 – 0.5
	Trade elasticities	
$\sigma_{hf,i}$	Elasticity of substitution between home and foreign goods (Armington elasticity)	0.9 – 3.5
$\sigma_{dx,i}$	Elasticity of transformation between domestic and export markets	0.9 – 3.5
	Dynamic parameters	
ϕ	Interest rate	0.039
δ	Depreciation rate	0.05

Appendix - The Reference Scenario

The reference scenario described in this report is based on several external inputs showing how the economy will evolve over the coming 12 years to 2020 (CIMS typically simulates out to 2050, but we have not reported 2021 onward for this project). Many key inputs underlying the reference scenario are highly uncertain, and if the economy evolves differently than as shown in this reference scenario, energy consumption and emissions will also differ from what we show here. Credible sources have been used to guide key inputs wherever possible, but no amount of research allows perfect foresight into the future of the economy. As a result, the scenario described here should be considered just one possible reference scenario. We consider it a reasonable "business as usual" forecast, based on historic trends and research into likely future technological and economic evolution, but the uncertainty remains large. We begin by highlighting our key assumptions, and follow by showing the results of our forecast.

Key economic drivers and assumptions

CIMS uses an external forecast for the economic or physical output of each economic sector to develop the business as usual forecast. For example, CIMS requires an external forecast for the number of residential households, another for the amount of cement produced in the province, and another for amount of natural gas produced as applicable. These forecasts can be internally adjusted when a policy is applied.

For all energy demand sectors, the external forecast through 2020 is based on the same data used by NRCan to develop the national energy outlook in 2006.[12]

Table 21: Canada economic and demographic forecast

	Units	*2005*	*2010*	*2015*	*2020*
Gross Domestic Product	*Billion 1997$* [a]	1,083.7	1,237.5	1,383.9	1,552.2
Population	*Millions*	32.2	33.5	34.7	35.8

Note: [a] Gross domestic product is presented in basic prices

While the residential, commercial and transportation sectors are not the direct subject of policy in this analysis, their demand for electricity, processed natural gas and refined petroleum products set the stage for many of the industrial sectors subject to the *Regulatory Framework*. The CIMS models for each of these sectors were updated with 2005 data to ensure their demand for energy end use commodities fits history, is reasonable, and adjusts in a credible fashion with population, economic growth and technology.

Physical output in each of the industrial sectors was also updated to reflect recently released 2005 statistics. Energy use for each sector was also checked against Statistics Canada's *Report on Energy Supply and Demand 2005*, as well as NRCan's *Comprehensive Energy Use Database*. 2005 emissions of GHGs and CACs were

[12] Natural Resources Canada, 2006, "Canada's Energy Outlook: The Reference Case 2006", Analysis and Modelling Division, Natural Resources Canada.

calibrated against the aforementioned energy use statistics and EC's draft *GHG Inventory for 2005*.[13]

Table 22 summarizes the reference case economic output forecast that is adopted for this forecast. As has been emphasized throughout, this forecast reflects historic and anticipated future trends, but is highly uncertain, particularly in the later years of the forecast.

Table 22: Reference case forecast of physical output[14]

	Units	2005	2010	2015	2020
Demand Sectors					
Residential	*thousands of households*	12,607	13,545	14,416	15,222
Commercial	*million m^2 of floorspace*	653.4	729.2	810.9	911.1
Transportation					
Passenger	*billion passenger-km*	617	742	839	944
Freight	*billion tonne-km*	865	966	1,083	1,198
Manufacturing Industry					
Chemical Products	*thousand tonnes* [a]	18,369	19,468	20,777	21,979
Industrial Minerals	*thousand tonnes* [b]	16,623	17,951	19,751	21,393
Pulp and Paper	*thousand tonnes* [c]	20,103	20,466	21,296	22,114
Iron and Steel	*thousand tonnes*	14,200	14,740	15,564	16,403
Metal Smelting	*thousand tonnes*	4,577	4,838	4,839	4,916
Mining	*thousand tonnes*	246,385	262,005	270,985	274,301
Other Manufacturing	*million $2005*	181,806	205,184	231,403	260,052
Waste	*million tonnes of waste in place*	670	696	722	747
Supply Sectors					
Crude Oil (CAP report)					
Conventional Light	*thousand barrels/day*	580	513	428	351
Conventional Heavy	*thousand barrels/day*	475	438	392	322
Synthetic	*thousand barrels/day*	495	878	1,539	2,075
Blended Bitumen	*thousand barrels/day*	436	880	1,246	1,437
Natural Gas (CIMS)	*billion cubic feet/day*	16.78	17.27	18.85	17.26
Coal Mining	*million tonnes*	67.5	72.3	80.2	88.2
Electricity Generation	*TWh*	545.3	576.8	610.0	646.8
Petroleum Refining	*million m^3*	99.8	101.6	107.8	115.8
Ethanol	*TJ*	30.51	163.06	268.14	388.85

[13] Environment Canada, "National Inventory Report: 1990-2005. Greenhouse Gas Sources and Sinks in Canada." November 2007.

[14] Notes: [a] chemical product output is the sum of chlor-alkali, sodium chlorate, hydrogen peroxide, ammonia, methanol, and petrochemical production
[b] industrial mineral output is the sum of cement, lime, glass, and brick production
[c] pulp and paper output is the sum of linerboard, newsprint, coated and uncoated paper, tissue and market pulp production
[d] natural gas production includes coal bed methane

Energy prices

CIMS also requires an external forecast for energy prices. As for sectoral output, fuel prices can change while a policy scenario is running if the policy induces changes in the cost of fuel production. Reference case prices for most fuels through 2020 are derived from the recent energy outlook published by NRCan (the industrial and electricity coal price forecasts were derived from forecasts by the U.S. Environmental Protection Agency), with some modification based on the latest NEB forecasts. Table 23 shows the fuel price forecast that was used to develop the reference case forecast in this report – the values differ slightly by province depending on supply costs and taxation; the values for Ontario are provided. Like the other forecasts that are used as inputs to CIMS, it should be recognized that the fuel price forecast adopted here is highly uncertain, particularly in the longer term. In addition, the fuel price forecasts that we have adopted are intended to reflect long-term trends only, and will not reflect short-term trends caused by temporary supply and demand imbalances.

Table 23: Ontario reference case price forecast for key energy commodities

	Units	*2005*	*2010*	*2015*	*2020*
Crude Oil (WTI)	*2003$ / barrel*	62.45	46.84	46.84	46.84
Natural Gas					
Industrial	*2005$ / GJ*	10.64	9.63	8.56	8.71
Residential	*2005$ / GJ*	13.85	12.62	11.43	11. 30
Commercial	*2005$ / GJ*	12.22	11.01	9.90	9.87
Electricity Generation	*2005$ / GJ*	10.03	9.00	8.63	8.89
Coal					
Market	*2005$ / GJ*	2.87	3.36	3.36	3.36
Electricity Generation	*2005$ / GJ*	2.57	3.00	3.00	3.00
Gasoline	*2005$ / GJ*	25.27	31.07	25.98	23.33
Diesel (Road)	*2005$ / GJ*	21.89	28.25	23.36	20.87
Electricity					
Industrial	*2005$ / GJ*	17.73	18.03	19.12	19.37
Residential	*2005$ / GJ*	24.04	24.72	25.48	27.39
Commercial	*2005$ / GJ*	20.74	21.41	23.15	25.41

Note: All prices in Canadian dollars.

Reference case energy and emissions outlook

Based on the key economic assumptions highlighted above, we used CIMS to develop an integrated reference case forecast for energy consumption and GHG and CAC emissions through 2020. The CIMS model captures virtually all energy consumption and production in the economy.

The reference case forecast for total energy consumption is shown in Table 24, while Tables 26 through 28 show natural gas, refined petroleum product, and electricity consumption, respectively. The residual energy consumption of other fuel types (total minus natural gas, refined petroleum products, and electricity) is not explicitly shown in this report.

Table 24: Reference case total energy consumption

	Units	2005	2010	2015	2020
Demand Sectors					
Residential	PJ	1,399.10	1,417.00	1,488.03	1,567.41
Commercial	PJ	1,126.56	1,197.71	1,293.12	1,412.71
Transportation	PJ	2,617.73	2,787.72	3,103.38	3,451.61
Manufacturing Industry	PJ	2,298.77	2,352.33	2,436.57	2,526.78
Waste	PJ	85.28	88.41	91.54	94.42
Agriculture	PJ	208.51	201.28	196.13	197.10
Supply Sectors					
Crude Oil	PJ	591.86	1,033.54	1,608.55	1,990.11
Natural Gas	PJ	704.72	691.84	686.28	607.01
Coal Mining	PJ	21.47	22.09	23.11	24.14
Utility Electricity Gen.	PJ	3,708.22	3,745.23	3,805.08	3,887.52
Petroleum Refining	PJ	337.68	352.27	385.50	427.50
Ethanol	PJ	0.03	0.14	0.24	0.34
Total	***PJ***	***13,100.36***	***13,890.51***	***15,118.89***	***16,189.12***

Note: Producer consumption of energy (e.g., consumption of hog fuel in the pulp and paper sector or refinery gas in the petroleum refining sector) is included in these totals. Energy consumption in the electricity generation sector includes consumption of water, wind, nuclear, and biomass using coefficients adopted from the International Energy Agency.[15]

Table 25: Reference case natural gas consumption

	Units	2005	2010	2015	2020
Demand Sectors					
Residential	PJ	632.97	644.99	704.85	736.83
Commercial	PJ	568.08	616.71	676.42	745.77
Transportation	PJ	13.23	7.57	3.29	2.31
Manufacturing Industry	PJ	745.25	762.11	796.19	820.30
Waste	PJ	0.00	0.00	0.00	0.00
Agriculture	PJ	26.86	26.57	26.31	26.01
Supply Sectors					
Crude Oil	PJ	282.12	543.72	824.05	955.79
Natural Gas	PJ	639.04	624.44	609.83	535.65
Coal Mining	PJ	2.51	2.63	2.89	3.16
Electricity Generation	PJ	354.75	416.44	495.83	582.85
Petroleum Refining	PJ	73.51	80.94	95.22	111.46
Ethanol	PJ	0.02	0.13	0.21	0.29
Total	***PJ***	3,338.37	3,726.36	4,235.42	4,520.91

[15] International Energy Agency, 2007, "Energy Balances of OECD Countries: 2004-2005". Renewable electricity generation is assumed to require 1 GJ of energy (e.g., wind, hydro) for each GJ of electricity generated. Nuclear electricity generation is assumed to require 1 GJ of energy for each GJ of thermal energy generated.

Table 26: Reference case refined petroleum product consumption

	Units	*2005*	*2010*	*2015*	*2020*
Demand Sectors					
Residential	*PJ*	105.29	65.93	31.62	18.42
Commercial	*PJ*	77.86	58.64	48.43	40.56
Transportation	*PJ*	2,601.21	2,772.18	3,088.24	3,434.88
Manufacturing Industry	*PJ*	157.19	146.60	149.71	161.00
Waste	*PJ*	0.00	0.00	0.00	0.00
Agriculture	*PJ*	144.74	137.59	132.50	133.54
Supply Sectors					
Crude Oil	*PJ*	76.74	74.01	74.57	88.27
Natural Gas	*PJ*	25.19	25.26	26.83	24.38
Coal Mining	*PJ*	6.10	6.16	6.83	7.72
Electricity Generation	*PJ*	130.39	105.32	80.90	56.99
Petroleum Refining	*PJ*	95.60	92.54	91.80	93.08
Ethanol	*PJ*	0.00	0.01	0.02	0.03
Total	***PJ***	3,420.45	3,484.62	3,732.10	4,059.72

Table 27: Reference case electricity consumption

	Units	*2005*	*2010*	*2015*	*2020*
Demand Sectors					
Residential	*PJ*	578.37	637.60	688.84	749.17
Commercial	*PJ*	480.61	522.35	568.27	626.38
Transportation	*PJ*	3.15	6.75	8.58	9.85
Manufacturing Industry	*PJ*	691.59	705.96	708.13	715.98
Waste	*PJ*	-0.27	-0.49	-0.68	-0.93
Agriculture	*PJ*	36.92	37.12	37.30	37.51
Supply Sectors					
Crude Oil	*PJ*	44.95	59.69	79.39	91.20
Natural Gas	*PJ*	40.50	42.14	49.62	46.98
Coal Mining	*PJ*	4.04	4.06	4.31	4.56
Electricity Generation	*PJ*	0.00	0.00	0.00	0.00
Petroleum Refining	*PJ*	16.90	15.00	14.64	14.83
Ethanol	*PJ*	0.00	0.00	0.00	0.01
Total	***PJ***	1,896.79	2,030.27	2,158.61	2,295.87

Based on total energy consumption as well as on process emissions in the industrial sector and supply sectors, we calculate the GHG emissions associated with the reference case forecast (Table 28). In the absence of new policies to control GHG emissions, emissions are expected to grow in all sectors of the Canadian economy. Especially strong growth is expected in the crude oil sector as a result of rapidly expanding output.

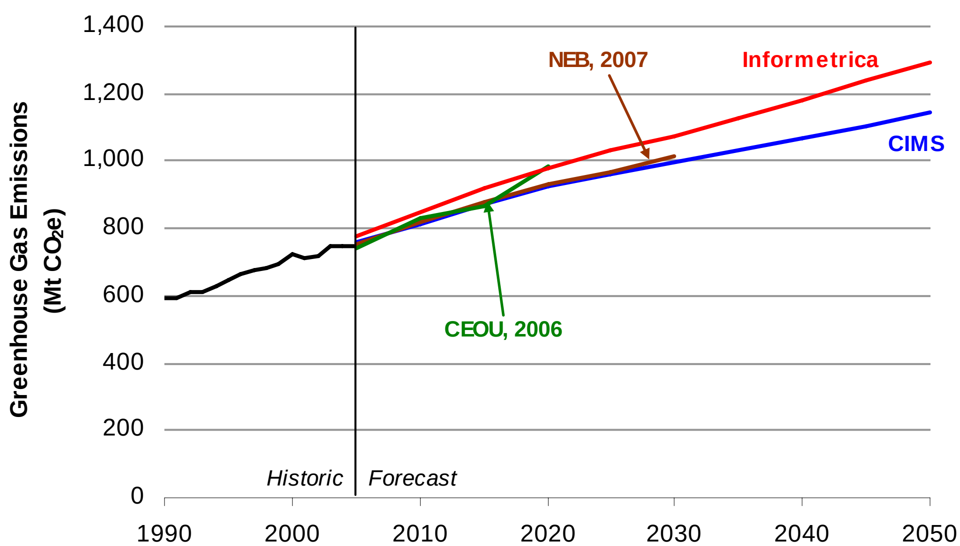
Table 28: Reference case GHG emissions

	Units	*2005*	*2010*	*2015*	*2020*
Demand Sectors					
Residential	*Mt of CO_2e*	41.18	38.60	38.97	39.61
Commercial	*Mt of CO_2e*	34.51	35.54	37.80	40.71
Transportation	*Mt of CO_2e*	187.43	199.37	221.66	246.34
Manufacturing Industry	*Mt of CO_2e*	83.94	85.16	87.21	89.99
Waste	*Mt of CO_2e*	27.48	28.51	29.54	30.52
Agriculture	*Mt of CO_2e*	58.81	51.73	46.99	48.21
Supply Sectors					
Crude Oil	*Mt of CO_2e*	65.53	94.86	135.20	162.36
Natural Gas	*Mt of CO_2e*	64.91	63.72	62.75	55.71
Coal Mining	*Mt of CO_2e*	2.22	2.20	2.37	2.55
Electricity Generation	*Mt of CO_2e*	126.26	118.77	112.71	108.48
Petroleum Refining	*Mt of CO_2e*	19.40	20.22	22.00	24.27
Ethanol	*Mt of CO_2e*	0.00	0.01	0.01	0.02
Total	***Mt of CO_2e***	711.70	738.76	797.32	848.92

Note: CIMS does not include nitric and adipic acid production, consumption of halocarbons, “other and undifferentiated production”, and solvents.

Figure 9 compares the total GHG emissions reported in this reference case to those in the NRCan reference case, a recent forecast by Informetrica Ltd. prepared for the federal government, and the recently released NEB 2007 forecast. All show Canada’s energy-related GHG emissions increasing over time from 734 Mt in 2005 to between 900 and 1000 Mt by 2020. Forecasting emissions for Canada is a highly uncertain process, especially given the rapidly changing forecasts for oil sands production.

Figure 9: Reference case GHG emissions (all adjusted to include nitric and adipic acid production, solvents, halocarbons, and “other & undifferentiated emissions”).



Note: Historic emissions in this chart are from Environment Canada’s 2005 Greenhouse Gas Inventory.