CLIMATE CHANGE

SCIENTIFIC ASSESSMENT AND POLICY ANALYSIS

Final report

Agreement on technology?

Exploring the political feasibility of technology-oriented agreements and their compatibility with cap-and-trade approaches to address climate change

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Wetenschappelijke Assessment en Beleidsanalyse (WAB) Klimaatverandering

Het programma Wetenschappelijke Assessment en Beleidsanalyse Klimaatverandering in opdracht van het ministerie van VROM heeft tot doel:

- Het bijeenbrengen en evalueren van relevante wetenschappelijke informatie ten behoeve van beleidsontwikkeling en besluitvorming op het terrein van klimaatverandering;
- Het analyseren van voornemens en besluiten in het kader van de internationale klimaatonderhandelingen op hun consequenties.

De analyses en assessments beogen een gebalanceerde beoordeling te geven van de stand van de kennis ten behoeve van de onderbouwing van beleidsmatige keuzes. De activiteiten hebben een looptijd van enkele maanden tot maximaal ca. een jaar, afhankelijk van de complexiteit en de urgentie van de beleidsvraag. Per onderwerp wordt een assessment team samengesteld bestaande uit de beste Nederlandse en zonodig buitenlandse experts. Het gaat om incidenteel en additioneel gefinancierde werkzaamheden, te onderscheiden van de reguliere, structureel gefinancierde activiteiten van de deelnemers van het consortium op het gebied van klimaatonderzoek. Er dient steeds te worden uitgegaan van de actuele stand der wetenschap. Doelgroepen zijn de NMP-departementen, met VROM in een coördinerende rol, maar tevens maatschappelijke groeperingen die een belangrijke rol spelen bij de besluitvorming over en uitvoering van het klimaatbeleid. De verantwoordelijkheid voor de uitvoering berust bij een consortium bestaande uit MNP, KNMI, CCB Wageningen-UR, ECN, Vrije Universiteit/CCVUA, UM/ICIS en UU/Copernicus Instituut. Het MNP is hoofdaannemer en fungeert als voorzitter van de Stuurgroep.

Scientific Assessment and Policy Analysis (WAB) Climate Change

The Netherlands Programme on Scientific Assessment and Policy Analysis Climate Change (WAB) has the following objectives:

- Collection and evaluation of relevant scientific information for policy development and decision–making in the field of climate change;
- Analysis of resolutions and decisions in the framework of international climate negotiations and their implications.

WAB conducts analyses and assessments intended for a balanced evaluation of the state-of-the-art for underpinning policy choices. These analyses and assessment activities are carried out in periods of several months to a maximum of one year, depending on the complexity and the urgency of the policy issue. Assessment teams organised to handle the various topics consist of the best Dutch experts in their fields. Teams work on incidental and additionally financed activities, as opposed to the regular, structurally financed activities of the climate research consortium. The work should reflect the current state of science on the relevant topic.

The main commissioning bodies are the National Environmental Policy Plan departments, with the Ministry of Housing, Spatial Planning and the Environment assuming a coordinating role. Work is also commissioned by organisations in society playing an important role in the decision-making process concerned with and the implementation of the climate policy. A consortium consisting of the Netherlands Environmental Assessment Agency (MNP), the Royal Dutch Meteorological Institute, the Climate Change and Biosphere Research Centre (CCB) of Wageningen University and Research Centre (WUR), the Energy research Centre of the Netherlands (ECN), the Netherlands Research Programme on Climate Change Centre at the VU University of Amsterdam (CCVUA), the International Centre for Integrative Studies of the University of Maastricht (UM/ICIS) and the Copernicus Institute at Utrecht University (UU) is responsible for the implementation. MNP, as the main contracting body, is chairing the Steering Committee.

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Preface

This report was commissioned by the Netherlands Programme on Scientific Assessment and Policy Analysis (WAB) Climate Change. This report has been written by the Energy research Centre of the Netherlands ECN, the Institute for Environmental Studies (IVM) at the VU University of Amsterdam, and the Science, Technology and Society department (NWS) at Utrecht University, as a deliverable in the WAB project "Compatibility of technology-oriented and cap-and-trade approaches for international post-2012 climate policy'". The work for the project is listed as ECN project number 7.7798. Contact person for the project with ECN is Ms. H.C. de Coninck (phone: +31-224-564316, e-mail: deconinck@ecn.nl). The authors acknowledge helpful comments from Harro van Asselt, Richard Baron, Merrilee Bonney, Michel den Elzen, Marc Londo, Bert Metz, Cedric Philibert, Jeroen Peters, Richard Tol, and Takahiro Ueno.

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Technologieovereenkomsten voor internationaal klimaatbeleid: Is een emissiehandels-systeem te rijmen met technologiebenaderingen?

Klimaatverandering staat al geruime tijd op de internationale onderhandelingsagenda. Vijftien jaar geleden, in 1992, werd in de UNFCCC, een raamwerkconventie, afgesproken dat gevaarlijke klimaatverandering moet worden voorkomen. Alhoewel een belangrijke stap, was het onduidelijk welke landen hoeveel actie zouden moeten ondernemen. Dat werd verder vastgelegd in 1997, in het Kyoto Protocol. In dat verdrag, dat onderdeel uitmaakt van de UNFCCC, staat dat industrielanden hun broeikasgasemissies moeten verminderen, daarvoor emissiehandel mogen gebruiken, en dat ontwikkelingslanden onder voorwaarden hun emissiereducties kunnen verhandelen. Alhoewel Kyoto in werking is getreden en het in de industrielanden die het hebben geratificeerd leidt tot emissiereducties, heeft de grootste bijdrager aan het klimaatprobleem, de Verenigde Staten, zijn steun ingetrokken, en blijkt het verdrag maar weinig uit te richten in termen van broodnodige structurele veranderingen in het energiesysteem.

In 2012 eindigt het Kyoto Protocol. De wetenschappelijke discussie over een nieuw internationaal klimaatverdrag dat het Kyoto Protocol moet opvolgen is al jarenlang in volle gang, maar een voor de hand liggende oplossing is niet gevonden, en de onderhandelingen gaan vooralsnog moeizaam. Het is mogelijk dat een vervolg op Kyoto weer volledig op een emissiehandelssysteem gebaseerd wordt, aangezien dat niet voor alle partijen acceptabel is gebleken. Er wordt gekeken naar andere vormen van klimaatregimes, waaronder afspraken over het realiseren van technologische verbeteringen die leiden tot broeikasgasreductie, die in aanvulling op een emissiehandelsverdrag ook het innovatie-marktfalen van emissiemarkten zouden kunnen corrigeren.

Dit rapport bespreekt enkele mogelijke voorbeelden van dergelijke technologieovereenkomsten, aan de hand van hun emissiereducties, de kosten en de politieke haalbaarheid. Vervolgens wordt bekeken hoe technologieovereenkomsten de werking van een emissiehandelssysteem zou beïnvloeden als beide naast elkaar zouden bestaan in de internationale context.

Mogelijke technologieovereenkomsten
Het schema hieronder vat de technologieovereenkomsten die zijn ontworpen samen. Het geeft aan dat iedere technologie of sector een andere benadering kan kiezen, en waarschijnlijk vereist. De ene overeenkomst schrijft echt technologie voor (zoals CO_2 afvang en opslag (CCS) of cement), terwijl andere overeenkomsten zich meer op emissiestandaarden (auto's) of brandstoffen (bioethanol) richten. Technologieovereenkomsten kunnen dus allerlei vormen aannemen, al naar gelang het aantal deelnemers, sectorkenmerken en de doelstelling.

Het beoordelingscriterium ‘milieueffectiviteit’ van de overeenkomsten omvat of de afspraak tot grote of beperkte broeikasgasreducties leidt. Dat hangt vaak af van de omvang van de sector en de bijdrage die de sector levert aan de mondiale broeikasgasemissies, maar ook van de ambitie in het hypothetische verdrag. Daarnaast is het in sommige gevallen onzeker dat het verdrag ook daadwerkelijk tot die reductie leidt – in dat geval kan de emissiereductie "niet gegarandeerd" worden. Dit is bijvoorbeeld het geval als de overeenkomst alleen in het verlagen van barrières voorziet, en geen concrete doelstellingen heeft.

Net als bij het milieueffect hangen de kosten ook af van hoe ingrijpend het verdrag is. De hoogste kosten zijn waarschijnlijk te vinden in het CCS-verdrag, dat grote emissiereductie tot gevolg heeft. Ook de prikkels die noodzakelijk lijken te zijn om het auto-verdrag haalbaar te maken kunnen voor de regering hoge kosten met zich meebrengen. De kosten zin waarschijnlijk lager voor overeenkomsten in efficiency en industriële toepassingen.

Uiteraard beïnvloeden hoge kosten de politieke haalbaarheid van het verdrag negatief, maar het is niet de enige factor. Andere overwegingen zijn het aantal deelnemers, institutionele en juridische barrières, en de sociale gevolgen van het verdrag.

Technologie overeenkomst	*Beschrijving*	*Emissiereductie*	*Kosten*	*Politieke haalbaarheid*
Ammonia	In China, India en de EU wordt bestaande capaciteit verbeterd en wordt nieuwe capaciteit met beste beschikbare technologie gebouwd. De EU ondersteunt technologieoverdracht gedurende eerste 5 jaar.	Beperkt maar zeker	Laag	Hoog
Bioethanol van suikerriet	Afrikaanse landen leveren bioethanol afkomstig van suikerriet aan de EU, die de investering financiert. Brazilië levert technologie en praktische ervaring.	Groot en zeker	Medium	Hoog, al moet rekening worden gehouden met sociale gevolgen van grootschalige landbouw in Afrika.
Auto's	Auto-industrie spreekt emissiedoel voor nieuwe persoonsauto's af. De landen waarin de industrie is gevestigd (VS, Japan, EU, India, Zuid-Korea, China) maken dit mogelijk via prikkels voor efficiency en low-carbon brandstof.	Groot en zeker	Hoog	Hoog door klein aantal deelnemers, laag als de voorschrijvende afspraak weerstand oproept.
Cement	Deelname van China, EU, India, Japan, en de VS in technologieafspraak voor state-of-the-art ovens, gebruik van low-clinker cement en CO_2-opslag op de lange termijn. Ook afspraken over technologieoverdracht.	Groot en zeker	Laag	Hoog door lage kosten; laag door het grote aantal installaties.
CO_2 afvang en opslag (CCS)	VS, EU, Rusland, China en India komen overeen om 50% of 100% van alle nieuwe elektriciteitscentrales met CCS uit te rusten. Ook een technologieoverdrachtfonds voor implementatie in ontwikkelingslanden.	Groot en zeker	Hoog	Laag door hoge kosten, mogelijk medium omdat de technologie als haalbaar en positief wordt ervaren, en hoog omdat de optie erg compatibel is met bestaande belangen in fossiele brandstoffen infrastructuur.
Kernenergie	VS/India deal: De VS levert kernenergietechnologie in ruil voor bepaalde veiligheidsbeloften.[1]	Mogelijk groot maar niet gegarandeerd	Laag	Hoog als er overeenstemming is; laag als problemen met het Non-Proliferation Treaty worden meegewogen.

Uit de grote verschillen tussen technologieovereenkomsten kunnen we concluderen dat dergelijke verdragen veel flexibiliteit bieden voor wat betreft het ontwerp van de overeenkomst. Dit betekent dat het verdrag mogelijk relatief eenvoudig aan de eisen van de technologie en de regionale of locale omstandigheden kan worden aangepast. Alle voorbeelden van mogelijke technologieovereenkomsten leiden tot emissiereducties, waarvan sommige erg substantieel - al zullen de kosten in dat geval een barrière vormen. De politieke haalbaarheid is moeilijk te voorspellen, en hangt sterk af van de details van het ontwerp van de overeenkomst.

1 De precieze inhoud van het verdrag is niet publiek.

Hoe kunnen technologieovereenkomsten en emissiehandel naast elkaar bestaan?
In dit rapport onderscheiden we vier manieren waarop internationale verdragen naast elkaar kunnen bestaan:

- "Separate": er zijn geen institutionele links tussen de verdragen; ze opereren onder verschillende internationale regimes met verschillende bureaucratieën. Voorbeeld: het Kyoto Protocol en het Asia-Pacific Partnership.
- "Linked": De verdragen opereren onder verschillende internationale regimes met verschillende bureaucratieën, maar er zijn beperkte mogelijkheden tot het linken van de twee overeenkomsten. Voorbeeld: het CDM en het EU Emissiehandelssysteem (EU ETS).
- "Integrated": De verdragen opereren onder verschillende internationale regimes met verschillende bureaucratieën, maar er zijn onbeperkte mogelijkheden tot het linken van de twee overeenkomsten. Voorbeeld: het CDM en het EU ETS als er geen beperkingen op het verhandelen van CDM credits in het EU ETS zouden zijn.
- "Joined": De verdragen opereren onder hetzelfde overkoepelende regime, en werken met dezelfde regels. Er is ook volledige vrijheid van uitwisseling van doelstellingen tussen de overeenkomsten. Voorbeeld: CDM onder het Kyoto Protocol.

We verkennen de vraag hoe de technologieovereenkomsten het beste zouden kunnen worden gelinkt met een emissiehandelsverdrag. Hiervoor nemen we twee van de technologieovereenkomsten (CCS en bioethanol) en kijken we in detail naar de interacties tussen die overeenkomsten met drie varianten van emissiehandel. De emissiehandelvarianten zijn: 1) "Kyoto Continued" onder dezelfde omstandigheden (en deelnemende landen) als het Kyoto Protocol tot nu toe; 2) een multi-stage benadering met naast de twee klassen van landen in Kyoto, de toevoeging van een derde categorie met mildere doelen. Die doelen kunnen zijn a) een CO_2-intensiteitsdoelstelling; en b) een zogenaamde "no-lose" doelstelling die landen toestaat een overschot aan emissierechten te verkopen, maar geen consequenties heeft in het geval dat de doelstelling niet wordt gehaald. We nemen aan dat de doelstelling voor grote ontwikkelingslanden in de multi-stage varianten de Verenigde Staten overhaalt om een absolute doelstelling te accepteren.

Helpen technologieovereenkomsten bij de totstandkoming van een internationaal emissiehandelsverdrag?
Om te bepalen of technologieovereenkomsten de totstandkoming van een emissiehandelsverdrag kunnen vergemakkelijken is een kwalitatieve speltheoretische analyse uitgevoerd. De analyse heeft als uitgangspunt dat de free-ridereffecten die inherent zijn aan het leveren van publieke goederen in een emissiehandelsverdrag gedeeltelijk kunnen worden gecompenseerd door de voordelen die deelname aan een technologieovereenkomst bieden. Of dit het geval is hangt af van de relatieve voorkeuren van de deelnemers aan het oorspronkelijke emissiehandelsverdrag, en van de winstgevendheid van de technologieovereenkomst.

In het geval van de bioethanol-overeenkomst is de conclusie dat de emissiehandels- en technologieovereenkomsten wellicht beter niet kunnen worden gelinkt. De reden is dat het noodzakelijk is dat alle spelers (EU, Afrika en Brazilië) aan de bioethanol-overeenkomst meedoen, anders werkt de overeenkomst niet. Een mogelijk dreigement van de EU om bijvoorbeeld Brazilie uit het voor dat land winstgevende bioethanol-verdrag te weren als het niet meedoet aan een multi-stage-verdrag is dus niet geloofwaardig.

Het is wat ingewikkelder voor de CCS-overeenkomst, die hoge kosten heeft en ingewikkelde belangenpatronen voor verschillende landen oplevert. De winstgevendheid, stabiliteit en geloofwaardigheid van de coalitie is daardoor moeilijk te analyseren, en hangt af van de winstgevendheid van de CCS-overeenkomst vergeleken met de kosten van het emissiehandelsverdrag. Met name voor de VS zijn de voordelen van het linken van de beide overeenkomsten onduidelijk.

Wat zijn de institutionele gevolgen?
Het naast elkaar bestaan van internationale verdragen met overlappende doelstellingen is in de literatuur uitgebreid besproken, en levert de conclusie op dat het de positie van zwakkere landen zou kunnen ondermijnen, en de consistentie, transparantie en effectiviteit kan verminderen.

Zouden technologieovereenkomsten in combinatie met een emissiehandelssysteem ook dit effect hebben, of kunnen ze elkaar misschien versterken?

Een technologieovereenkomst introduceert onvermijdelijk een technologievoorkeur in de opties voor broeikasgasreductie die zouden worden gerealiseerd in een (technologieneutraal) emissiehandelssysteem – in het geval van de bioethanol- en CCS-verdragen wordt er meer CCS en bioethanol gebruikt dan zonder het technologieverdrag. Enerzijds leidt deze "voortrekkerij" van bepaalde technologieën tot verminderde kosteneffectiviteit, maar anderzijds corrigeert het technologieverdrag een marktfalen van emissiehandel.

In tegenstelling tot de uitkomsten van de speltheoretische analyse levert het linken van de technologieovereenkomst winst op in termen van betere transparantie en consistentie tussen het emissiehandelsverdrag en de technologieovereenkomst. Beide verdragen als volledig "separate" behandelen leidt onvermijdelijk tot dubbeltellingen en beïnvloedt de milieuwaarde van de verdragen waarschijnlijk negatief. Dit kan worden verbeterd als de verdragen sterk zouden worden gelinkt, maar ook dit levert problemen op. Met name de kwestie wat de gemeenschappelijke eenheid zou moeten zijn waarin de resultaten van de verschillende verdragen moeten worden uitgedrukt is een netelige: het ligt voor de hand om tonnen gereduceerde CO_2-uitstoot te nemen, maar dat is niet altijd eenvoudig uit te rekenen voor technologieovereenkomsten, en laat mogelijk ruimte voor interpretatie. Dit probleem treedt vooral op in het geval van het bioethanol-verdrag, dat over gebruik van brandstof gaat en niet over directe emissiereductie.

Voor wat betreft een combinatie van het CCS-verdrag en de no-lose multi-stage benadering zou de vraag of het technologieverdrag in het "business as usual" scenario moet worden opgenomen moeten worden beantwoord. Als het CCS-verdrag zou worden meegenomen in de baseline, voorkomt dat dubbeltellingen, maar het zou de aantrekkelijkheid van de verdragen voor landen als China en India verminderen.

Conclusie
Dit rapport heeft de compatibiliteit van internationale technologieovereenkomsten en een emissiehandelssysteem door middel van speltheoretische en institutionele analyses verkend. Is het al niet eenvoudig om eenduidige antwoorden te geven over de politieke haalbaarheid van afzonderlijke verdragen, de uitwerking van een combinatie van verdragen is nog complexer. Een robuuste voorspelling kan dan ook niet worden gemaakt, al kan wel worden geconcludeerd dat het waarschijnlijk is dat technologieovereenkomsten een bijdrage aan de haalbaarheid van een klimaatregime zouden kunnen leveren. Meer kennis van kosten en opbrengsten, en inzicht in strategische overwegingen en voorkeuren van afzonderlijke landen zijn echter noodzakelijk voor het maken van betere voorspellingen. Ook zouden de details van de technologieovereenkomsten verder uitgewerkt moeten worden, en zou er in meer detail moeten worden gekeken naar oplossingen voor de problemen rondom fragmentatie en dubbeltellingen van de verdragen.

Een andere onzekerheid die in deze studie niet aan bod is gekomen is de rol van de private sector. Alhoewel landen aan de onderhandelingstafel zitten, zijn de technologieën die door technologieverdragen worden gestimuleerd vaak in handen van bedrijven. De dynamiek daarvan, alsmede vragen rondom bescherming van intellectueel eigendom, zouden verder kunnen worden onderzocht.

Ondanks de onzekerheden concludeert dit rapport dat technologieovereenkomsten zouden kunnen helpen om de huidige impasse in de klimaatonderhandelingen te doorbreken. De voordelen van technologieovereenkomsten zijn vooral te vinden in de grotere prikkels om mee te doen en in de voorspelbaarheid van kosten, terwijl het resultaat in termen van emissiereductie substantieel kan zijn en het bovendien het gebrek aan innovatie in emissiemarkten kan corrigeren. Nadelen zijn de verminderde kosteneffectiviteit, en dat het naast elkaar bestaan van meerdere overeenkomsten, ook als ze sterk geïntegreerd zijn, kan leiden tot verminderde transparantie en dubbeltellingen van emissiereducties. Om de laatste reden lijkt het raadzaam de technologieovereenkomsten en het emissiehandelssysteem onder één internationaal klimaatregime onder te brengen, en de UNFCCC is daarvoor de meest voor de hand liggende kandidaat. Mocht het niet lukken om beide verdragen in een overkoepelend regime onder te brengen, dan moeten er sterke maatregelen worden getroffen om de milieueffectiviteit van beide verdragen te garanderen.

Executive Summary

Background and objectives
Climate change has been on the international policy agenda since the United Nations Framework Convention on Climate Change (UNFCCC) was agreed in 1992. Recent authoritative reports have further emphasised the seriousness and urgency of the problem, but have also indicated that climate change can be mitigated if adequate action is taken in the short and medium term. The Kyoto Protocol was the UNFCCC's answer to the call for measures and has been effective in establishing an international carbon market and reducing emissions in some countries and regions. Its format, a cap-and-trade regime, is in theory economically most efficient, but has been unsuccessful in achieving participation of all relevant countries – notably of the United States. Progress on an improved follow-up of the Kyoto Protocol has been slow so far, and alternatives that have been started parallel to the Kyoto Protocol, notably the US-led Asia-Pacific Partnership on Clean Development and Climate, are unlikely to be environmentally effective.

The deadlock in the negotiations on an international cap-and-trade based climate regime has renewed interest in other types of agreements, inspired by the thought that it may be worthwhile to sacrifice some of global cost effectiveness in exchange of political support and compliance with an agreement. One of the options for a different form of international agreements to address climate change is a group of agreements aimed at advancing greenhouse gas reducing technologies: technology-oriented agreements (TOAs). The question, however, is whether technology- or sector-oriented types of agreements can be designed in such a way that they can lead to real and measurable reductions in emissions. Existing technology agreements are known to have advanced research and development (by providing a "technology push"), but examples of such agreements solving environmental problems (for which a "technology pull" is also needed) are sparse.

In addition to this environmental effectiveness, as it is unlikely that the climate regime would be fully founded on agreements related to technology, as a cap-and-trade regime is expected to proliferate within the European Union or within a wider, Kyoto-minded, coalition. Therefore TOAs would have to operate alongside other agreements.. Another issue that then requires further exploration is whether TOAs would negatively or positively interact with cap-and-trade regimes, if they would be pursued by different or the same countries at the same time.

We hope to shed some light on these questions in this work. Reflecting what we identify as the main generic questions around TOAs, the objectives of this study are:
- To design concrete hypothetical TOAs and evaluate their environmental effectiveness, costs, and political feasibility.
- To explore how such TOAs could be embedded in the international climate regime.
- To assess the consequences for the attractiveness of an international climate regime as a result of including TOAs alongside a cap-and-trade agreement.
- To evaluate what the institutional interactions between cap-and-trade and technology-oriented agreements would be under different scenarios of co-existence.

To meet the objectives, in Part I of this report, we identify a number of potential technologies and, in cooperation with technological experts, design a hypothetical TOA for them. By assuming technology realisation targets in the design of the TOA for different participating countries, we determine environmental effectiveness and costs. We also apply a political feasibility framework to all TOAs. In Part II, using a qualitative game-theoretical analysis, it is then explored whether such TOAs would positively or negatively impact the coming about of a climate regime, including cap-and-trade. Subsequently, an institutional analysis identifies any interactions in the cases that the TOA and a cap-and-trade agreement are separate, linked or fully joined in one regime.

Can TOAs be environmentally effective, cheap and politically feasible?
The environmental effectiveness (i.e. the emissions reduction the agreement is to achieve) depends on the type of agreement. If the agreement is certain to lead to emission reductions (be-

cause inherent in the agreement), the environmental effectiveness is described as ‘guaranteed’. However, if the agreement only aims to take away political or legal barriers to deployment of the technology, the environmental effectiveness cannot be guaranteed. The emission scope of the agreement is also assessed here; as the ammonia agreement only covers a small amount of greenhouse gas emissions, its effect is small, whereas the scope of a CO_2 capture and storage (CCS) agreement is much larger, and its effect is large.

Among other things, such as burden sharing, cost burden is dependent on the scope of the emission reductions, given that emission reductions beyond low or negative mitigation costs lead to higher costs. Sometimes, such as in the case of bioethanol, the costs depend on domestic policies (biofuels obligation in EU) or on oil and gas commodity prices. Cost effectiveness is not comparatively assessed in this report, but TOAs are almost certainly less cost-effective cap-and-trade agreements. However, the likelihood that emissions reductions are complied with in areas where they are relatively cheap are estimated to be higher in the case that a TOA is agreed on them.

The outcome of the political feasibility assessment is summarised in the scheme below, where in most cases it is a diffuse balance between positive and negative aspects.

Technology-oriented agreement	*Contents*	*Environmental effectiveness*	*Cost burden*	*Political feasibility*
Ammonia	In China, India and EU, existing capacity is revamped and new capacity is built according to BAT standards only. Technology transfer funded by EU during first 5 years	Small but guaranteed	Small	High
Sugarcane-based bioethanol	Sub-Saharan African countries agree to supply sugar-cane-based bioethanol to the EU, which finances the initial investment. Brazil provides technology and practical experience	Large and guaranteed	Medium	High, although concerns on social/equity constraints should be taken into account
Cars	Car manufacturing industries agree on an emission target for new person cars. Their countries of origin (US, Japan, EU, India, South Korea, China) enable this by agreeing efficiency and low-carbon fuel incentives.	Large and guaranteed	Large	High because of small number of actors; low as technology forcing agreement meet resistance
Cement	Participation of China, EU, India, Japan, US in technology mandates for state-of-the-art kilns, low-clinker cement use and CCS in the longer term. Also technology transfer provisions.	Large and guaranteed	Small	High because of low cost burden; low for large number of actors
CO_2 capture and storage	US, EU, Russia, China and India agree on 50% or 100% of all new power plants to be equipped with CCS, and on a technology transfer fund to enable implementation in non-Annex I countries.	Large and guaranteed	Large	Low because of cost burden, may be medium because of positive technology perception and high for good compatibility with vested interests in fossil-fuel

				sector
Nuclear energy	US/India deal: US supplies nuclear energy technology to India in return for safeguards[2]	Potentially large but not guaranteed	Small	High as agreement is in place; low if NPT problems are considered

The scheme above shows a striking variability in TOAs. TOAs are not a straightjacket for a climate regime: they offer flexibility to align the incentive structure with both the technology or sector that is targeted and the countries that participate. In conclusion, a number of TOAs could be explored and might be politically feasible as well as environmentally effective. Costs can be high, and can pose barriers to implementation. In addition, and depending upon the specific design, various TOAs would have social and legal consequences that need to be addressed.

How could TOAs be embedded in the international climate regime?
The current state of negotiations leaves much scope for speculation on how an international climate regime that comprises of different components might be built up. As a starting point, this study assumes that part of the world's countries will sign up to a cap-and-trade agreement, such as a follow-up of the Kyoto Protocol of a more differentiated multi-stage agreement, and another part will take part in a TOA. The countries under a cap-and-trade regime and a TOA may overlap, even fully for some TOAs.

The question then arises how the TOAs and cap-and-trade agreement co-exist. It is thinkable that both types of agreements are developed in complete separation without any official links. It is also possible, however, that the UNFCCC forms an umbrella for different agreements that are fully integrated. We distinguish four scenarios, essentially levels of integration, of co-existing TOAs and cap-and-trade regimes:

- Separate: the TOA and the cap-and-trade agreement co-exist under different international agreements, have separate bureaucracies. No substantial interdependencies between the regimes exist. Example: the Kyoto Protocol and the Asia-Pacific Partnership.
- Linked: the TOA and cap-and-trade agreement co-exist under different international agreements and have separate bureaucracies. There are substantial interdependencies between the regimes, but the use of such exchanges between them is limited based on predetermined rules. Example: the ETS and the CDM: it is possible to use CERs in the ETS, but there is no full integration of the markets.
- Integrated: the TOA and cap-and-trade agreement co-exist under different international agreements and have separate bureaucracies. There are substantial interdependencies between the regimes, and the use of such exchanges between them is not limited. Example: the ETS and the CDM if there would be no limit on the use of CERs in the ETS.
- Joined: the TOA and cap-and-trade agreement co-exist under the same international agreements and operate under the same bureaucracy and set of rules. There is also full substantial interchangeability of targets between the TOA and the cap-and-trade agreement. E.g.: the CDM under the Kyoto Protocol.

In addition to the level of integration of the agreement types, the participation in the various agreements matters for the institutional overlap and the possibilities of linkage. The different outcomes in the case that the TOA is applied only in countries where also a cap-and-trade agreement is implemented, and the case where there is very limited geographical overlap between the two agreement types are both discussed. In the first case, it is assessed whether the benefits from the TOA would make agreement to a cap-and-trade more attractive through a qualitative game-theoretic exercise. The second case does not evaluate such interdependency in the coming about of the climate regimes, but assumes that a TOA and a cap-and-trade agreement are in place, and discusses the institutional consequences for the different levels of integration. For both cases, we evaluate two TOAs: the sugarcane-based bioethanol and the CCS-TOAs.

The cap-and-trade agreements that are evaluated are a follow-up of the Kyoto Protocol, named "Kyoto-continued", with the same set of rules and the same participation, and a "multi-stage" agreement with quantitative emission targets for Annex-I countries, an ‘intermediate stage’ for

2 Detailed contents of the treaty is confidential

emerging economies and no targets but CDM for least-developed countries. For multi-stage, we assume that the US ratifies because its condition of targets for emerging economies is fulfilled.

Would TOAs make climate agreements more attractive?
By applying qualitative game-theoretic analysis, we have examined whether the overall attractiveness of a climate regime will increase as a result of technology issue linkage through a TOA. Generally there are three conditions for successful issue linkage: the coalitions should be profitable for all involved, stable, and the implicit threat of the linkage, that a country is excluded form the TOA if it doesn't sign up to the cap-and-trade agreement, should be credible. Climate change agreements provide public goods; a TOA provides a club good. Climate change coalitions (based on cap-and-trade) are typically not stable because of free-rider incentives inherent in public goods, but TOAs, providing a club good, can be profitable and stable. Linking the negotiations about club and public goods could enhance the profitability and stability of the linked coalition in comparison to the separate public good coalition, but it would reduce the profitability and stability of the club good coalition.

Whether linking is a worthwhile (and credible) strategy depends on the relative preferences(in terms of profitability) of the original members of the climate change coalition over both approaches to address the climate change problem. By detailing these preferences for the specific countries and TOAs we investigate, we can draw conclusions on whether the TOA and cap-and-trade approaches could or should be 'linked' in one overarching agreement. The analysis confirms one important conclusion from the literature on issue linkage in climate policy: issue linkage can increase cooperation on emission reduction, but will decrease cooperation on technology development and diffusion.

In the case study of the bioethanol-TOA we concluded that issue linkage could confront the EU with a real dilemma. In fact, if the EU would have strong preferences for both a cap-and-trade agreement and a TOA on bioethanol, it would be probably wise not to link them, but to pursue them separately on their own merits, as the threat of excluding a country like Brazil, required for the bioethanol-TOA, might not be credible. A 'separate' scenario would be the most effective outcome.

The case of the CCS-TOA is more complex. Different groups of countries have different incentive structures and so the profitability, stability and credibility of a linked agreement become difficult to analyse. Much depends on assumptions related to the extent of profitability of the TOA for the various countries involved, relative to the cost of the cap-and-trade agreement. We tentatively concluded that linkage of cap-and-trade and TOA for India and China are 'natural' (without cap-and-trade no TOA), but that the linkage would be problematic (or at least ambiguous) for the US.

What are the institutional consequences of including TOAs in the overall climate regime?
The institutional impacts of co-existence of TOAs and a cap-and-trade agreement are discussed in the context of the ongoing debate on fragmentation of international law. An institutional analysis is performed, which shows the consequences of various modes of co-existence based on the effectiveness and functioning of the institutions. The debate focuses on the question whether a complex collection of different treaties for the same purpose threatens consistency and accountability of the participants in the different agreements, which could lead to undermining of the overall objective of the regime complex.

For the bioethanol-TOA, the interaction with any of the cap-and-trade agreements first and foremost consists of the TOA introducing a 'technology bias' in the cap-and-trade agreement, as the TOA probably leads to more bioethanol use than would otherwise be the case. In theory this reduces the cost-effectiveness of the cap-and-trade agreement, but in practice this is not necessarily the case as the TOA is designed to correct market failures that would not fully be corrected in the cap-and-trade agreement. Accountability and consistency problems can be limited more easily when the agreements are more intimately linked; so for the joined-case, the problems are likely to be less than for the separate case. However, it is not entirely clear what the metric for comparing achievements in both agreements might be, and this could pose problems even in a joined case. Provided issues around double-dipping and other interactions are either dealt with or accepted, the danger of the TOA undermining the cap-and-trade agreements is regarded to be limited as all parties in the TOA are also parties to the cap-and-trade agreement.

The CCS-TOA, similar to the bioethanol case, would create a technology bias in the countries with a target in all cap-and-trade variants; so for the EU and Russia in the "Kyoto-continued" variant, and for all countries involved in the multi-stage variants, including India and China. In the case of the multi-stage post-2012 cap-and-trade variant, the obligations of the TOA would allow China and India to achieve their targets more easily and sell more carbon credits to the countries with an absolute target, if those credits are regarded as additional under the rules that will then prevail. The linked and joined scenarios, where the CCS-TOA is linked to the Kyoto-continued agreement, would have methodological challenges for the US, which is assumed here to participate in the TOA but not in Kyoto-continued, as a baseline would have to be constructed. This situation leaves much room for manoeuvring, potentially leading to the undermining of the effectiveness of the Kyoto-continued agreement or the TOA.

For the multi-stage no-lose target scenario, for China and India, a decision would have to be made to count the TOA outcome as part of the no-lose baseline or not. If it would be taken into account, double-dipping would be prevented, but the TOA might become unattractive to China and India. If the CCS-TOA is not taken into account in the baseline, the reductions as a consequence of the TOA would be double-counted as CDM in the Kyoto-continued agreement, or as easy ways to reach the targets in the multi-stage variants. In general, there is substantial interaction but the interaction is limited and can be prevented by agreeing on clear and transparent rules. However, complex negotiations will have to be conducted if the CCS-TOA is pursued in a linked or joined way with a cap-and-trade agreement.

Conclusion
Neither our application of game-theory nor the institutional analysis allow us to make firm predictions of behaviour of countries and regions with respect to TOAs in combination with post-2012 cap-and-trade variants. For such predictions, we would need more information on costs and pay-off functions, we would need a deeper understanding of the strategic incentives of some of the countries regarding the different options, and we would have to dive deeper into the details of the various TOAs. Moreover, a better understanding of the institutional challenges and constraints regarding the compatibility question would be required. An additional challenge is understanding the role of the private sector. Technologies are often not owned by states (although states often represent the interests of their private sectors), leading to a different dynamic, including complicated IPR issues, than would be the case if states would be the proprietor of the technology.

Although an ultimate answer to the question whether TOAs combined with a cap-and-trade regime can provide a way out of the logjam in the climate negotiations cannot be given, our analysis does give us a clue that TOAs can help. In the case that the design of the TOA introduces a beneficial reciprocity in the cap-and-trade regime, the combination of both types of agreements can lead to a better environmental outcome than a cap-and-trade treaty only, through wider participation and a dual emission target and technology diffusion target, notwithstanding the less cost-effective outcome.

This potentially positive result should be weighted, however, against the possibility of regime fragmentation and the threat that might entail to consistency and accountability of the international institutions. In the context of regime fragmentation which is sometimes referred to as a threat to consistency and accountability of international institutions, linked TOAs and cap-and-trade agreements would generate methodological challenges. It is possible that they can still be accounted for in one metric and their rules can be made convertible and compatible, but such a situations is likely to pose challenges.

Preferably, a cap-and-trade regime and the various TOAs should come about under one umbrella regime, in order to allow for early detection of inconsistencies. The UNFCCC would be the most likely candidate for this, and it is recommended that this organisation allows for multiple treaties that do not require full global participation in order to streamline negotiations on TOAs. Should it not be possible to bring all treaties under one regime such as the UNFCCC, then accountability and consistency with the cap-and-trade regime should be a spearhead in the construction and the design of the TOAs. Although there are clear benefits to trying such responsible linking, it would be challenging to bring such consistency into a more complex regime.

Part I: Political feasibility of potential technology-oriented agreements

1. Introduction

Recent developments in international climate change science have confirmed that urgent action is necessary if the ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC), of avoiding dangerous climate change, is still to be achieved. Climate change has been on the international policy agenda since the UNFCCC was agreed in 1992. The Kyoto Protocol was the UNFCCC's answer to the call for measures and has been effective in establishing an international carbon market and reducing emissions in some countries and regions. The Kyoto Protocol, however, has not achieved long-term commitment of all relevant countries; notably the United States' rejection of the Protocol is regarded as detrimental to its environmental outcome. A follow-up of the Kyoto Protocol is currently under discussion, but progress has been slow so far.

In theory, the economically most efficient form of a global agreement is a global cap-and-trade agreement. However, the political feasibility of such an agreement has proven to be low, as the Kyoto Protocol, the first version of a global cap-and-trade-like regime, has not been ratified by the world's largest emitter, the United States. In addition to the free-riding incentives which the United States follows, so far, it has been very difficult to agree on a follow-up agreement that gives meaningful and fair incentives to emerging economies such as China and India.

Although recent signs stem optimistic, particularly the G8 Declaration (2007) where the US has agreed to engage in negotiations on a post-2012 agreement, it remains highly uncertain whether an effective global climate regime fully founded on another cap-and-trade type of agreement is politically feasible. In addition, it has been suggested that a new agreement would have to be more effective in promoting technology development and diffusion.

These are the reasons why alternatives for and complements to cap-and-trade agreements are considered. Many potential post-2012 institutional designs have been evaluated, and all have advantages and disadvantages (see, e.g., Aldy et al., 2003). Alternatives parallel to the Kyoto Protocol, notably the US-led Asia-Pacific Partnership on Clean Development and Climate (APP), are unlikely to be environmentally effective (Asselt, 2007), but acknowledge the relevance of technology in finding a solution for climate change, and indicate a general interest for technology-oriented agreements. Although technology-push agreements, such as the APP, are by design unlikely to reduce greenhouse gas emissions, technology- or sector-oriented type of agreement may be designed as technology-pull agreements in such a way that they lead to real and measurable reductions in emissions (Bodansky, 2007; Coninck et al., 2007a), they have not been studied in detail as of yet.

This report is the first part of a research project that explores the compatibility of a cap-and-trade regime with a different form of international agreements to address climate change: technology-oriented agreements (TOAs). The objective of this report is dual: 1) to *explore what the political feasibility and environmental effectiveness of TOAs are,* and 2) *what the institutional consequences for the international climate regime complex may be, if TOAs and cap-and-trade approaches co-exist.* The report thus first identifies a number of hypothetical TOAs, and assess their environmental effectiveness, costs, and political feasibility. The second part of the project will select two of the hypothetical TOAs, and will analyse their compatibility with a number of cap-and-trade variants.

TOAs are defined as those international agreements that are aimed at advancing research, development, demonstration, and/or deployment of technologies. With respect to TOAs to address global climate change, these technologies would be aimed specifically at reducing GHG emissions. A general review of such agreements, including an examination of their potential relevance for climate change, was already conducted (Coninck et al., 2007). Four types of TOAs are distinguished:

1. Knowledge sharing and coordination;
2. Research, development and demonstration (RD&D);
3. Technology transfer; and
4. Technology deployment mandates, standards, and incentives.

The dominance of economic instruments in current thinking round climate policymaking have kept TOAs from playing a role in the discussions and studies on international agreements in the context of climate change. The current deadlock in the climate negotiations has however renewed interest in other types of agreements. This is inspired by the thought that it may be worthwhile to sacrifice some of global cost effectiveness in exchange of political support and compliance with an agreement (Barrett, 2003). In addition, initiatives by the United States, supported by a number of emerging economies, such as the Asia-Pacific Partnership, have indicated that the interest in technology as a solution-targeted approach (rather than emissions as a problem-targeted approach) is rising. Many scholars, however, have raised concerns about environmental effectiveness and costs of such technology-oriented initiatives (see e.g. Höhne, 2005). Besides political feasibility, we explore the emissions reductions and costs of our hypothetical TOAs.

The discussion of supplements or alternatives to the Kyoto Protocol in this report should not be seen as a critique to the Kyoto Protocol, or to the UNFCCC as such. Rather, the authors feel that it is worth exploring other options in the potential case that the important post-2012 follow-up of Kyoto will not gain sufficient support among the global players. The agreements described in this part may provide a different or additional way to achieve the much-needed emission reductions. Moreover, TOAs may co-exist with a cap-and-trade regime.

The method taken to examine the hypothetical TOAs is by a political constraints framework, which is developed in Section 2. With the possible exception of the nuclear energy case, which discusses an existing deal between the US and India, none of the TOAs actually exists in the form presented here. Section 3 goes on in describing the agreements proposed here, in terms of expected emissions reduction (i.e. environmental effectiveness) and costs. The agreements are not global but involve a group of relevant countries. They are in the fields of bioethanol from sugarcane, ammonia production, cement production, CO_2 capture and storage, carbon efficiency in cars, and nuclear energy. Each section that discusses the characteristics of the agreement, its environmental effectiveness and costs, also assesses the political feasibility according to the framework in Section 2. This part does not have a concluding section, but conclusions will be presented in Part III.

2. Political feasibility framework

While there are varying definitions of 'political feasibility' (of policy proposals) at its core it can be characterized as a policy proposal being palatable enough to a majority of parties so as to overcome enough resistance that would inhibit the policy's adoption and/or implementation. For example, if one were to ask what the political feasibility is of instituting a 100% tariff on all new cars imported into the Netherlands or the EU, what is meant is that, will such a proposal meet with enough approval by those in power to impose it as well as those who would be affected by it.

As the above description suggests, feasibility can be seen as overcoming some form of resistance, resistance itself implies the presence of certain constraints that would inhibit the approval of a policy proposal (May, 1986). Thus, if these constrains were to be enumerated and assessed, then one could have some understanding of the likelihood of a proposal gaining acceptance. Understanding the constraints a proposal might face is however, only a part of assessing feasibility. There exist also certain influencing factors that contextualize the policy proposal and help set the stage for creating a strategy to overcome the constraints. It is then the combined understanding of the influencing factors as well as the points of constraint that can form the basis of a feasibility assessment.[3]

Interestingly, not much attention has been given to the assessment of political feasibility as such in either public policy literature or political science writings. The concept has been phrased in different ways, e.g. in criteria analysis for international climate regimes (see e.g. Aldy et al., 2003). The lack of generic work on political feasibility is indeed surprising as public policy is heavily governed by its surrounding political climate and a framework for navigating a policy proposal through the political waters would be most useful. Be that as it may, this section attempts to construct a framework that could be useful in assessing the political feasibility of Technology-Oriented Agreements (TOAs) for climate change. It is loosely based upon the works of Majone (1989), May (1986), Meltsner (1972) and Webber (1986). Essentially, this section lists and briefly describes the most important factors and constraints to be considered, and presents them in the form of descriptive questions. This framework is not prescriptive nor is it a straightforward model but should be seen as a focusing aid to be applied to each of the six TOA case studies. In the end, by asking the questions set out here of each case study, one should gain a greater understanding of the likelihood that the TOA in question might gain acceptance.

2.1 Influencing factors

Influencing factors are factors that help contextualize the policy proposal within the 'political' arena by highlighting external elements that can have direct and indirect influence over the acceptability of the proposal. There are four key factors to be considered for a feasibility assessment: actors, resources, time frame & timing, and leverage points.

2.1.1 Actors

Actors (Meltsner, 1972) refer to the parties to whom you are making your policy proposal and whose acceptance you must win. The first step in any feasibility assessment is to outline the actors (i.e. the people) that will be involved in the negotiation and assess their motivations, beliefs and bargaining power in light of the proposed policy option.

<u>Actor's motivation</u> refers to the person or parties' desires, drives, goals or objectives. Every actor has some motivation for taking part in negotiations, in terms of TOAs perhaps the party wants new technologies to boost industrial production, perhaps they are generally interested in

3 While there is a direct relation between factors and constraints, this paper does not attempt to construct or detail those influencing links between the two, as it would unduly expand the scope of this short paper and is not entirely necessary for understanding the framework. It would however be an interesting exercise in the future on it own right.

reducing their GHG emissions, or perhaps they are interested in money to support their farmers. These are simplistic examples but whichever the case, if possible one should try to pinpoint as many motivations of the other party and see if they fall in line with the proposal. If not exactly, can the proposal be adjusted to square better with their motivations?

Actor's beliefs in this case refer to the attitudes and values held by an actor. In some sense this can be seen as the core of any political feasibility assessment as it is attitudes and values that make up one's politics. Any policy proposal must of course not run counter to the beliefs one holds, it would be useless to advocate a transfer of nuclear technology if the country or actors involved in the negotiations are fundamentally opposed to nuclear energy. Thus one should attempt to outline the attitudes and values of the actors involved and look at the policy proposal in light of those beliefs. A related and perhaps further step would be to target the policy proposal towards those actors (if the situation allows) whose beliefs are most in line with that of the proposal. This however may not always be the case and the proposal then, if possible, might be altered to fit as close as possible with the other parties beliefs.

Actor's bargaining power refers to the amount of political clout or power the actor has to accept or reject your policy proposal. The underlying point here is twofold. Firstly, it is to identify, out of the pool of actors, who has the most clout and secondly to make a judgment whether to engage that actor or if possible avoid that actor. For example, which ministry has more clout, the Ministry of Finance or Ministry of Environment? Would it be more advantageous to hold negotiations with the Finance Ministry if they are in a better position to see that your proposal gets accepted? While this is probably not a fundamental criterion like *actor's beliefs* it is an important one all the same and should be taken into consideration when possible.

2.1.2 Resources

Resources, materiel or otherwise, here refers to the relation of what parties have on offer in relation to each other. The concept is plainly straightforward and in general, subconsciously assessed by most people prior to any push for a policy proposal. Nevertheless, it is important to reiterate the concept, as it is an integral part of a feasibility assessment framework. In relation to pushing for TOAs, one should assess what actual resources one has to offer and if in fact that the other party wants these as well (this is related to Actors above and to the constraints detailed below). Moreover, one should consider unrelated resources that might act as 'deal sweeteners'. These are things that have no relation to the policy proposal at hand but are resources that the other party might be seeking and that if offered in combination with the proposal make it more likely to be adopted. Note that in some cases different resources will need to be identified for the different actors, depending on the number of actors involved in the negotiation.

2.1.3 Time frame and timing

Time frame and timing are important elements to any feasibility assessment and must be considered with care.

Time frame refers the length of time expected by the proponent of the proposal to be used in the *adoption* and *implementation* of the proposal. In other words, how much time is needed to convince others that the proposal should be accepted? In general: the more time there is, the better the chances of acceptance. Thus, how much time is available for negotiations should be specified in an exact manner. The same principle applies to time for implementation. How long will the party itself have to implement the proposal? Twenty years for the phase out of old coal fired generators for the adoption of new gas powered turbines is more attractive than five years. One should try to identify the minimum and maximum time frame that the other party has or expects for implementation.

Timing is in some cases more crucial to assess than time frame and as the colloquial phrase goes, 'timing is everything'. Timing here refers to the opportune and inopportune moments for pushing your proposal (i.e. policy windows). This involves taking stock of what is happening within the larger policy and political environment surrounding the proposal that might help make it more attractive on the one hand or divert attention from it on the other. A few examples: A good time to try and force Type 3 (technology transfer) or Type 4 (technology deployment mandates, standards, or incentives) TOAs might be within the context of larger trade negotiations. An inopportune time to open negotiations on a proposal is prior to parliamentary elections, as there is a risk of having the deal undone by the new government. Perhaps an opportune moment for negotiations is just after a new government is formed. Another external condition that may facilitate an agreement is whether the countries involved find themselves in a period of economic prosperity; when budgets of governments are not too constrained and there is room for something extra. The downside of such a 'good timing' may be, conversely, that, in case government or economic conditions change, the agreement may not be complied with in the end. While these are just simple examples, the idea is that just as with time frame, one should take timing into account and if possible sketch out within the larger time frame the best and worst moments to advocate for the proposal.

2.1.4 Leverage points

Leverage points are preferably related but possibly unrelated issues that can be used to enhance the attractiveness of a proposal. A key question to ask of the proposal is what other policy problems or issues can it be linked to so as to leverage it. These leverage points can come in various forms. Perhaps the proposal helps to address other key issues on the policy agenda (e.g. greater use of local biofuels can help increase energy security). Perhaps a particular event has recently occurred that draws focus to the issue being proposed (focusing events) raising it on the policy agenda and giving it a sense of urgency (e.g. the 2003 heat waves in Europe highlighted the need for early warning systems and an adequate policy of dealing with the elderly and infirm, prior to this they were not on the policy agenda). Whichever the case, one should try to identify and enumerate any leverage points associated with the original proposal.

2.2 Constraints

Identifying constraints helps highlight what key difficulties the proposal might encounter during its promotion and thus aid in the design of a proposal that is more likely to win approval. In the end however, if there are too many constraints to be surmounted then the proposal will have little chance of success. Constraints are in most cases double edged and apply reflexively to the party promoting the proposal as well as to the parties being asked to accept the proposal. Thus they must be calculated for both sides.

2.2.1 Economic

It goes without saying that most transactions involved with promoting, adopting, and implementing a policy proposal involve some financial matters. The central questions surrounding this constraint are as follows: What are the economic resources and what is the budget for extending the proposal? What are the financial obligations for other parties associated with accepting the proposal? Do they have financial resources to accept it? What will be the cost for all involved if they accept the proposal? Do all actors have enough?

2.2.2 Physical and technical

While a proposal might be interesting and well received by all parties, there is the chance that some external factor could inhibit its likelihood of adoption or implementation. A carbon efficiency standard that is agreed to apply in 10 years time might not yet be technically achievable at present, so barriers need to be overcome. Assessing these constraints is very context-specific and it is difficult to make generalizations. Nevertheless, looking at it through the lens of TOAs a few generic questions emerge, although greater specification will be needed when looking at a specific TOA proposal. In general, are there any physical/technical barriers that could inhibit a Type 2, 3 or 4 agreement? Does the receiving party/country have adequate technical and physical infrastructure to comply with the proposal?

2.2.3 Legal and contractual

These constraints are concerned with any institutional or legal barriers that could prevent the adoption or implementation of the proposal. In short, is the institutional, legal and regulatory infrastructure equipped to address the proposal? Will any laws need to be changed so that it can be accepted? Would the proposal require regulatory approval and by whom? For example, the transfer of nuclear technology may require approval from the ministry of defence and may be inconsistent with earlier laws and regulations. These institutional hurdles should be enumerated so that the requisite steps can be taken. These are constraints that revolve around any prior commitments or obligations that might prevent or in some way hinder the proposal from going forward. For example perhaps there is a trade agreement that states that by doing X for one party one is obliged to do the same for another party. Or perhaps by doing Y for one party, that party will be required to do Z in return (but may not be in a position to fulfil that commitment). In addition, one must ask question of legal accountability of the actors that one will be negotiating with. Are they trustworthy? Will corruption be an issue?

2.2.4 Social and equity

Similar to factor of *Actor's Beliefs* social constraints are concerned with the beliefs and prejudices of the wider social audience or, possibly, the public at large. As with some of the other constraints this is very context-specific and difficult to generalize, however, it need only be taken into account for those issues that could be controversial. Thus the first question to ask is, could the proposal be socially controversial (either in one's own country or in the one receiving the proposal)? Some options, such as solar energy are general accepted, while nuclear energy is a lightening rod for attention. Second, is the proposal socially acceptable for the general public and the other parties? While nuclear energy itself is quite acceptable in some countries, the transfer of nuclear technology might not be.

Equity constraints may be difficult to judge yet it is still a point to be taken into consideration. It revolves around the notion of the fairness of a proposal and how it will be seen by those that might accept it. Essentially, will the proposal be seen as equitable and fair or will others feel cheated by it? Are the interested parties being given enough? Should one party, if possible, be offering more? Does the proposal offer economic benefits to already richer countries; does it enhance inequity in the world, or in a country? For example, a tax reduction for the upper income classes is usually not seen as equitable. A good way of judging this constraint is to have a good outline of the *actor's motivations* as well as your own *resources*.

2.2.5 Institutional

This is similarly linked to *Actor's Bargaining power* and is concerned with negotiating/bargaining powers and political clout. Is the negotiating party the right party to be advocating the proposal, and do they have enough weight to push it through? Is there a need to seek help from others to support the proposal? Is the proposal advocated to the right people on the right level; do they have enough clout to accept it? A junior staff member attempting to convince a deputy minister will most likely have more difficulties than a minister attempting to convince a deputy minister. Will the proposal be in a safe investment environment? Is, in terms of a country, the climate politically stable? Are the institutions that need to be formed or burdened with the agreement the right ones?

2.3 Political feasibility assessment framework

In the following sections, various proposals for TOAs will be assessed on their political feasibility. First, for a number of government actors involved, the constraints will be discussed in a matrix form as in the table below. The table also contains a summary of the constraints as well as the framework for the applicability of the constraints to the actors is included here:

Table 2.1 Overview of constraints for government actors. The constraints framework will be used for the political feasibility analysis of each TOA.

Constraints:	*Actors*	
	Actor 1	*Actor n*
Economic • What are the economic resources and what is your budget for extending the proposal? • What are the financial obligations for the other party associated with accepting your proposal? • Is there enough budget to accept it? • What will be the cost for the receiving party if they accept the proposal? • Do you have enough funding?		
Physical and technical • Are there any physical/technical barriers that could inhibit a Type 2, 3 or 4 agreement? • Does the receiving party/country have adequate technical and physical infrastructure to receive the proposal? • Does the receiving party have enough technical resources for the maintenance of the proposal?		
Legal and contractual • Is the institutional, legal and regulatory infrastructure equipped to address the proposal? • Will any laws need to be changed so that the proposal can be accepted? • Would the proposal require regulatory approval and from whom? • Are there any prior commitments or obligations that might prevent or in some way hinder the proposal from going forward?		
Social and equity • Could the proposal be socially controversial in any of the countries involved? • Is the proposal socially acceptable for the general public and the other parties? • Will the proposal be seen as equitable and fair or will others feel cheated by it? • Are the interested parties being given enough and if possible, be offering more?		
Institutional • Are the right parties involved to be advocating the proposal, do they have enough weight? • Is additional support required? • Is the proposal advocated to the right people, do they have enough clout to accept it? • Is the negotiation party/country politically and economically stable? • Will corruption be an issue?		

Subsequently, the other influencing factors will be discussed for the potential treaty. Based on the number of constraints for actors, and the extent to which the other influencing factors are relevant and conducive to the proposed treaty, the TOAs will be assessed for their political feasibility.

3. Cases of technology-oriented agreements

In this section, a variety of technology-oriented agreements (TOAs) for addressing climate change is explored. We distinguish four types of TOAs: 1) knowledge sharing and coordination; 2) research, development and demonstration; 3) technology transfer; and 4) technology mandates, incentives and standards (Coninck et al., 2007)

The technologies selected are:
a. Bioethanol from sugar cane (elements of type 2 and 3)
b. Nuclear energy: the US/India deal (elements of type 1, 2 and 3)
c. Cement industry (elements of type 3 and 4)
d. Ammonia production (elements of type 3 and 4)
e. CO_2 capture and storage in the electricity sector (type 4)
f. Carbon efficiency standards in cars (type 4)

It is assumed in the discussions that the institutional embedding of the TOA takes place in the UNFCCC, in a similar manner the Kyoto Protocol was agreed on but, often, with a subgroup of countries. In principle it possible to include agreements outside this context.

Each TOA description contains the basic rules for cooperation on technology. It will explore a case of a limited number of participating countries. It will describe the technology at hand, including the overall emission reduction potential the technology can achieve. It will then establish the emission reduction and costs that are associated with the case TOA. Each section will conclude with a discussion of the political feasibility framework that was introduced in Section 3.2.

3.1 Bioethanol from sugar cane

With rising oil prices and growing concerns regarding anthropogenic climate change, biomass transportation fuels (biofuels) have gotten increasing attention and policy support. For example in the US, the production of ethanol from corn has reached peak levels, while in the EU, the target of 5.75% biofuels in 2010 (equivalent to about 750 PJ) has caused a strong increase in the production of biodiesel from rape seed and ethanol from grains (EurObserv'ER, 2006). However, the feedstocks used in developed countries (corn, rape seed, wheat) only allow for small greenhouse gas emission reductions compared to fossil fuels (IEA, 2004). Also, given the recent ambitious new targets set by the EU, it is likely that the demand for biofuels beyond 2010 will only further increase (European Council, 2007). Even when taking into account additional production in the EU, expectations are that only about 414 of the required 750 PJ will be met by domestic production. Advanced biofuel technologies (so-called second generation technologies) based on cellulose material are expected to have more favourable energy balances and a higher production per hectare, but are only expected to be commercially available in another decade or so. In summary, it is expected that the EU will not be able to meet its ambitious biofuel targets by domestic production on its own.

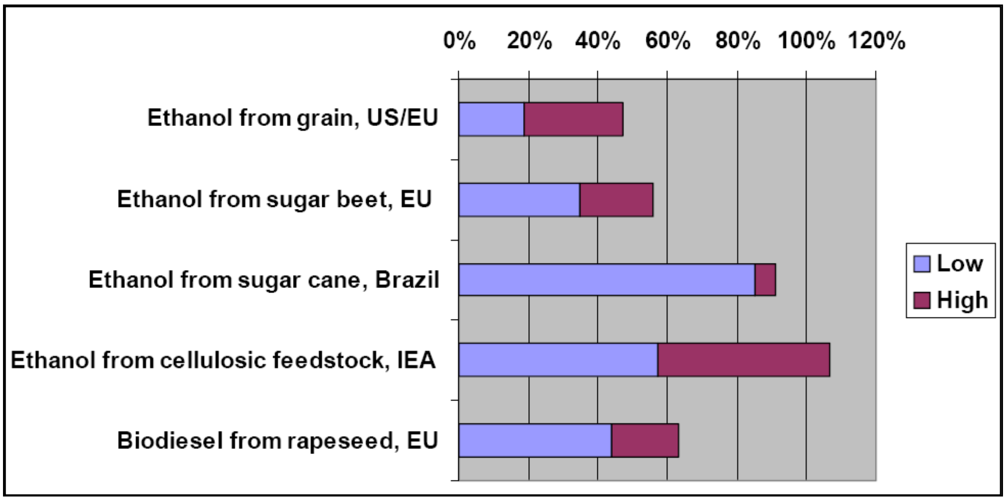


Figure 3.1: Reduction in well-to-wheel CO_2-equivalent GHG emissions per km, compared to gasoline (for ethanol) and diesel (for biodiesel) (IEA, 2004)

On the other hand, ethanol based on sugar cane in Brazil is a biofuel currently produced on a large-scale industrial basis that can already achieve GHG emission reductions of 80-90% (IEA, 2004, see figure 3.1). This is first of all due to the high photosynthetic efficiency of the sugar-cane plant, a perennial grass whose cultivation is limited by plant physiology to tropical and sub-tropical regions. The sugarcane stalks contain the cane juice from which sucrose is extracted and/or bio-ethanol is created (Johnson and Matsika, 2006). Second, the high GHG efficiency is also due to the development of new, high-yield varieties of sugar cane, and technological development and upscaling of the ethanol production process (van den Wall Bake et al., see also section 3.2). Next to a high GHG emission efficiency, ethanol from sugarcane is also highly competitive compared to oil-based gasoline. From 38 US$ per barrel, ethanol can compete with gasoline, and between 2004-2005, the consumer price of ethanol on energy content basis was only 50-80% of the price of gasoline (Walter, 2006, see figure 3.2).

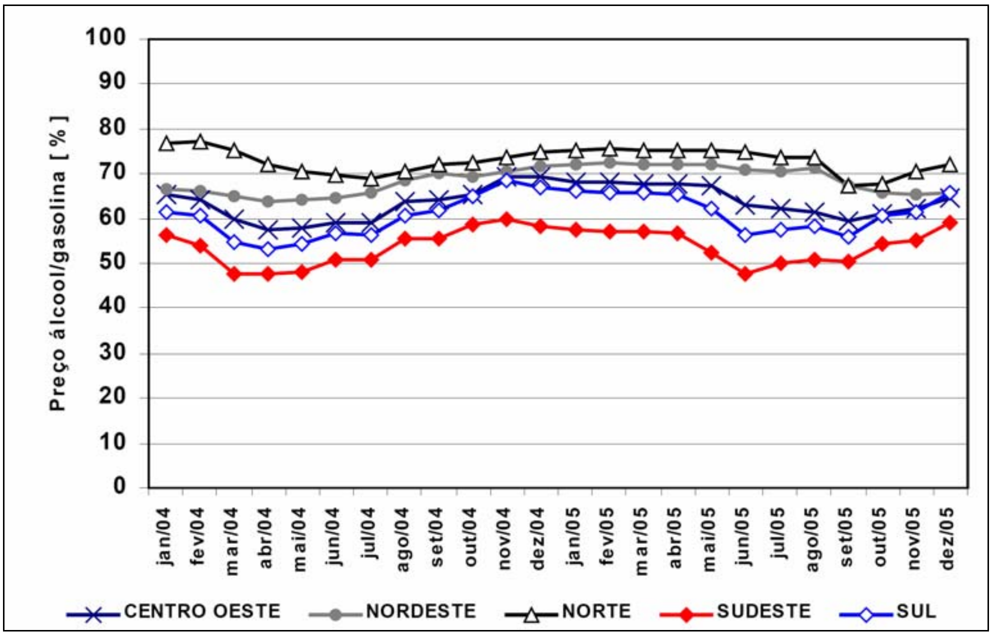


Figure 3.2: Ethanol prices as percentage of gasoline prices (on energy basis) in different parts of Brazil between 2004-2005 (Walter, 2006). ('Preço àlcool/gasoline' is 'price of ethanol/gasoline')

In 2006, Brazil produced about 17 billion litres of ethanol, using about 3 million hectares of land (Smeets et al, 2006b). This corresponds to an average yield of about 78 tonnes of cane and about 6,000 litres per hectare. Given the competitiveness of Brazilian ethanol and the demand for biofuels by the US and Europe, Brazil has increasingly exported ethanol to amongst others the US, Japan and Europe, about 2.5 billion litres in 2005, and about 3 billion litres in 2006

(Walter et al. 2006). Brazil expects to increase domestic production to 35 billion litres in 2015, of which about 6 billion litres (about 125 PJ) would be available for export. Thus, it is apparent that this will not be sufficient to meet the demand for biofuels in most EU/OECD countries.

Fortunately, Brazil is by far not the only country with soils suitable for sugar cane. Major other current producers include India, Thailand, Australia, and countries in the Caribbean and sub-Saharan Africa (see table 1 in the Annex). Especially in the Southern African Development Community (SADC), the potential for (additional) sugarcane production is huge, as in these countries the climatic conditions are (very) suitable, even with only marginal or no irrigation (Johnson and Matsika, 2006). Sub-Saharan has also been identified as one of the most promising regions in terms of future biomass producing potential (Hoogwijk, 2004; Smeets, 2006a). In many of these countries, the total cultivated land is only a fraction of the total agricultural land available (temporary and permanent pastures, permanent crops, and temporary crops). Given the relatively low population density, the large potential of available land, and the suitability of the region to grow sugar cane, it is concluded that sub-Saharan Africa offers in principle ample potential to produce (excess) ethanol for export to e.g. the EU.

The potential for biofuels production in sub-Saharan Africa has not gone unnoticed. For example, in July 2006 an association of 15 African nations signed a treaty to join the PANPP, an acronym of "Pays Africains Non-Producteurs de Pétrole" (in English: the "Pan-African Non-Petroleum Producers Association) (Biopact, 2006). Also, in December 2006, the first Pan-African biofuels conference was organized, at which numerous initiatives for biofuels production in Africa were presented (GreenPower, 2006). However, repeating the Brazilian experience in Africa will require support from Brazil. The Brazilian sugarcane/ethanol sector has been developed gradually over thirty years, and extensive knowledge transfer is required. Brazilian stakeholders have also emphasised that they do not intend to become an ethanol-producing monopolistic, but rather would like to share their experience with other countries in e.g. Latin-American and Asia (see e.g. Orellana, 2006, Walter, 2006), and also specifically in African countries (Daniel, 2006).

3.1.1 Scope of the technology[4]

The agricultural sub-system

Sugarcane cultivation in Brazil is based on a ratoon-system, which means that after the first cut the same plant is cut several times on a yearly basis. Before planting in the first year, the soil is intensively prepared, nowadays mainly mechanical. After this the soil is furrowed and phosphate-rich fertilizers are applied, seeds are distributed and the furrows are closed and fertilizers and herbicides are applied once again. The stock is then treated with artificial fertilizers or ´filter cake´[5] once or twice again during cultivation in the first year. After 12-18 months the cane is ready for the first cut. For this it is (still) common to burn down the cane in order to simplify manual harvesting. Mechanical harvesting can be applied, e.g. currently it is used for approximately 25% of all sugarcane in São Paulo. After cutting and sometimes chopping cane stalks by a chopped cane harvester, the cane stalks are loaded in trucks and transported by trucks to the industrial plant. Burning and delays before processing such as loading and transport lead to significant losses of the amount of sucrose per ton (TRS) stressing the importance of quick harvesting, loading and transportation. After the first harvest, the process is repeated excluding intensive soil treatments and planting. Depending on the rate of the declining yields the same stock can be used up to 5-7 harvests nowadays. Yields decline with approximately 15% in the year after the first harvest and 6-8% in the years that follow. Declining yields depend on treatment of the stock during maintenance and harvesting but are mainly determined by the combination of applied variety and type of soil (Van den Wall Bake et al., 2007).

The reductions achieved over time for the sugarcane production have been significant, about a factor of 3, from about 100 R$[6]/tonne cane (TC) to about 35 R$/tonne cane. Cost reductions for land rent, soil preparation and crop maintenance, were highly influenced by the increasing length of the ratoon system and the rising agricultural yields. Improved strength of new varieties

4 This section is largely based on Van den Wall Bake, Junginger et al. (forthcoming)
5 “Filter cake” is a residue of sugar and ethanol production, containing large amounts of nutrients.
6 Brazilian Real (1€ equals about R$ 2,5).

against pests and drought, special breeds for varying soils and application of advanced management systems form the main explanations behind these increased yields. Harvesting costs declined mainly because of increasing yields in the manual process. Yields increased from 4.5-6 TC/man/day in 1977 to over 9 TC/man/day in 2004. Due to increasing ethanol plant sizes, average transportation distances doubled from 10 km in 1977 up to 20 in 2004, but loads increased significantly from 10 TC/truck to 40 TC/truck. Transportation costs declined mainly because of upscaling, introduction of automated logistic systems, and improved infrastructure. All processes are described in more detail in Van den Wall Bake (2006).

The industrial sub-system
At the plant, the sugarcane is washed and shredded, and using a set of 4-7 mill combinations juice sugar is extracted. The main objective of the milling process is to extract the largest possible amount of sucrose from the cane, a secondary, and increasingly important objective is the production of bagasse[7] with low moisture rates in order to feed the boilers. The boilers supply enough electricity and steam for the process to be self-sufficient, and in some cases to deliver excess electricity to the grid. The cane juice is filtered and treated by chemicals and pasteurized. In the following process, the molasses are fermented to produce a 'wine' with an ethanol content of 7-10%. The wine is then distilled to 96% hydrated ethanol. Further dehydration up to 99.7% is achieved by addition of cyclohexane.

Industrial processing costs were reduced by approximately 70% during the past 30 years, from over R$1000 to R$250-350/m^3. First of all, the upscaling of the average ethanol plant has led to lower specific investment and operation & maintenance (O&M) costs. While the average plant size used to be 120 m^3 per day in 1980, nowadays, plant sizes have increased to 1000 m^3 per day, resulting in cost reductions through economies of scale. Strongly correlated to scale, load factors play an important role in cost reductions. Load factors of 90% were found in the late 1970s, while nowadays load factors are typically around 95%, mainly because the number of crushing stops was decreased as a result of introduction of automated feeding and milling processes. In addition, the amount of operational days per year was raised from 160 in 1975, up to 190 days/year in 2005 (Van den Wall Bake et al. 2007). This was mainly the result of the use new varieties, but also of a well-organized planting and harvesting logistics. Due to further development of new varieties and optimization of the harvesting logistic systems, the amount of operational days is expected to reach 200 days/year in the near future.

Total cost reductions and prospects for the future
As described above, significant cost reductions have been achieved in the Brazilian ethanol production system. Production costs have roughly been reduced by over a factor of three from 1975-2005 (see also figure 4). For the future, further cost reductions are expected with cumulative production. Already today, the cost of production of ethanol in Brazil is estimated as US$ 200/m^3 for the producers with best economic performance, while the average production costs in Brazil are around US$ 280/m^3 (Walter, 2006).

However, the experience for bringing costs down further does not necessarily have to be gained solely in Brazil. By enlarging the system boundaries, and applying knowledge (e.g. Brazilian cane varieties and ethanol plants) abroad, additional experience could be gained, which would likely lead to further improvements in the cane and ethanol production process.

3.1.2 Contents of the TOA

Given the problem description and rationale and the available technology, we propose the following type-2 and 3 (knowledge transfer) technology-orientated agreement:

Brazil will be the knowledge-supplying party. The knowledge transfer will include both expertise on the agricultural system (e.g. cane varieties for various soil types, pest control, use of vinasse as fertilizer etc.) and on the industrial ethanol production system (technical assistance with building large-scale ethanol plants)

7 Bagasse is the fibers left after milling.

The *Southern African Development Community (SADC)* will be the technology-receiving countries. As part of the TOA, Brazil and the SADC will sign a Memorandum of Understanding (MoU), in which they stipulate the intention to build up an ethanol industry.

As third party, the *European Union (EU)* will act as financing party of projects. In return, supply contracts are signed for the ethanol production to be exported to Europe to meet biofuels target and GHG emission reduction, possibly coupled to a fixed price (or a price range with minimum and maximum boundaries depending on the oil price developments). The commitment by the EU could be expanded by the introduction of flex-cars on its market; cars that can use both ethanol and gasoline.

The time horizon for this TOA will be 2020. The aim of the TOA is to utilize the Brazilian knowledge to set up an ethanol industry in the SADC countries. It is estimated that this could result in an increasing sugarcane/ethanol production, with an approximate (optimistic) annual growth rate of 23%, reaching about 67 million m^3 ethanol in 2020 in the SADC countries (see also figure 3.3). The production in 2007 will be based on 60 million tonnes of sugarcane (compared to 45 Mtonnes actually produced in 2004), and rises to 880 Mtonnes in 2020. This would require about 13.4 Mha in the SADC, equivalent to about 3.1% of their total agricultural area (see tables in the Annex). Note that yields/ha in some SADC countries are higher than the Brazilian average, so possibly less land will be needed.

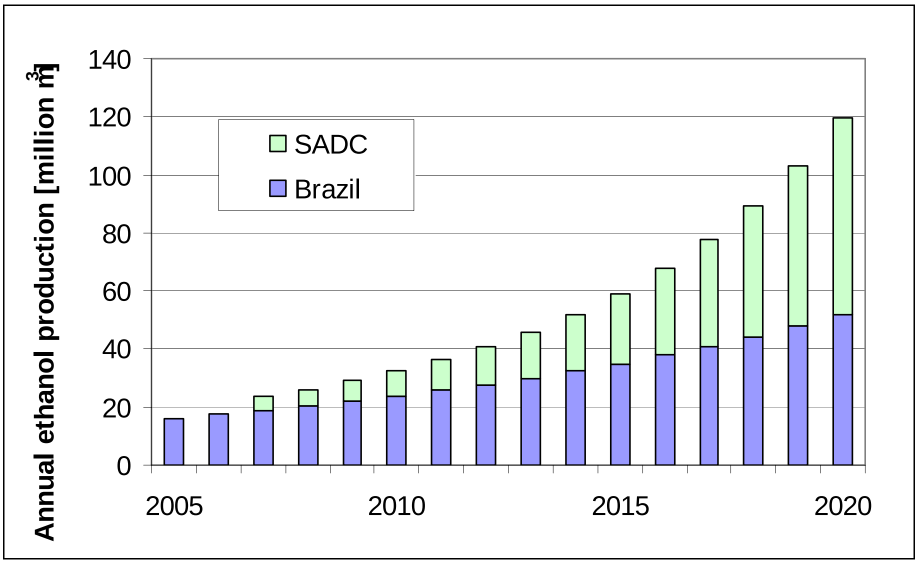


Figure 3.3: Anticipated ethanol production in Brazil and the SADC countries 2005-2020

3.1.3 Overall emission reduction potential and impact of the TOA

As mentioned earlier, the well-to-wheel GHG emission reduction range of ethanol from sugarcane compared to gasoline use is about 80-90% (IEA, 2004). In our scenario the ethanol will be transported to Europe. This will negatively influence the overall GHG balance, but in general, the losses of transporting a liquid with a high energy density by bulk freighter has a relatively small impact on the overall energy and GHG balance. In the scenario, a GHG emission reduction of 80% compared to gasoline is assumed.

This means that 67 million m^3 of ethanol could replace about 1400 PJ of fossil transportation fuels, which is equivalent to about 91 $MtCO_2$ emission reduction in 2020. Whether the ethanol is consumed locally or exported to Europe has only a marginal influence on the total emission reduction.

Next to this direct GHG emission reduction, the TOA will also have an impact on production costs of ethanol. It is expected that production costs will further decline with cumulative ethanol production. Taking the additional production in the SADC into account, it is expected that ethanol production costs will continue to follow the experience curve and decline approximately another 20-25% to about 230 US$/m^3 (see figure 3.4). This will further increase the competitiveness of ethanol in comparison to gasoline and other fossil fuels. On the other side, the higher demand for bioethanol may drive the prices of the feedstocks for sugarcane up, which may compensate some of the learning effects.

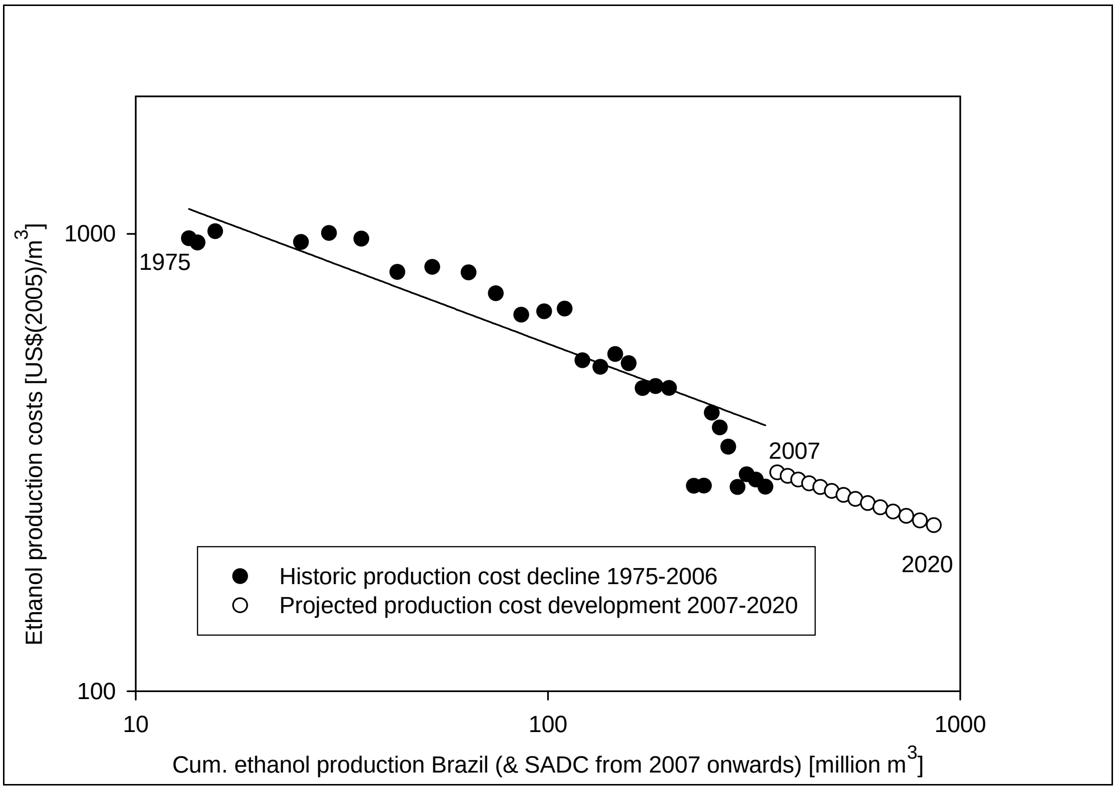


Figure 3.4: Historic ethanol production cost reduction in Brazil (1975-2006, based on Van den Wall Bake et al., forthcoming) and anticipated further production cost reductions based on anticipated production volumes in Brazil and the SADC

3.1.4 Expected costs of the TOA

As was discussed in section 3.1, ethanol can compete with oil-based gasoline from an oil price of 34 US$/barrel and higher. Given the current oil price developments, it is very likely that ethanol will be able to compete on the market on its own. However, still significant investments are necessary up-front. Current investment costs are about 125 R$/m^3 ethanol (about 45 €/m^3), and thus *investment* costs per tCO_2 avoided would roughly be 33 Euro/tonne, or (spread over the duration of the agreement (2007-2020) approximately 3000 M€. However, investment cost will further decrease over time as part of the total production costs (see above). Actual costs per tCO_2 could be zero or even negative, given the competitiveness of ethanol (i.e., producers could possibly gain extra income by selling the GHG credits). This calculation also assumes that costs for sugarcane remain stable over this period in time; if the costs for sugarcane production rise, so will the costs for ethanol production.

3.1.5 Political feasibility of the bioethanol-TOA

The above paints a favourable picture for an international bioethanol agreement. However, there are a number of real constraints that inhibit the realisation of such an agreement, or can possibly even provide a genuine and righteous showstopper for the agreement to go forward. Table 3.1 assesses the constraints to the TOA implementation per actor.

Table 3.1: Actor-specific constraints of the sugar-cane based bioethanol TOA

Constraints	*Actor* *Brazil*	*SADC*	*EU*
Economic		High interest rate and risk of investment	
Physical/technical		Land availability Food security	
Legal/contractual	Investment agreement with SADC needed		Trade agreement with SADC needed (i.e. change of current import barriers for ethanol)
Social/equity		Employment Land ownership Environmental issues; sustainable land-use	Concerns regarding the sustainability of sugar-cane and ethanol production
Institutional		Political stability in SADC countries	

Each of the main constraints is described in some more detail below:

- Economic constraints: As ethanol production is competitive from 38 US$/barrel, competitiveness may further improve over time. Thus, it is expected that this TOA could be realized without any net costs. However, large investments will have to be made in regions which often have a poor infrastructure and a mediocre governance track record. Thus the risks for investments are relatively high, which may be translated into high interest rates. Possibly, this could partially be avoided by low-interest loans from the EU (e.g. as part of an trade agreement)
- Physical and technical constraints: as was shown, the general land potential in the SADC countries is considered large, but within the frame of this study, no detailed analysis was carried out to accurately assess the amount of suitable land for sugar cane. Also, it should be avoided that current food production is displaced by sugarcane for ethanol. Another important constraint is the physical infrastructure (roads, pipelines, electricity supply) that is required to transport the sugarcane and ethanol efficiently.
- Legal and contractual constraints: Currently, Europe has import tariffs in place for ethanol. However, Europe could (within the boundaries of WTO rules) make agreements with the SADC for annual import quotas (a similar agreement exists e.g. also for the US and a number of Caribbean countries). There could be however considerable resistance from actors within the EU (e.g. farmers and ethanol producers).
- Social/equity constraints: sugarcane production is likely to cause a number of social, environmental and other impacts, as was shown for Brazil (see Smeets et al., 2006b), including issues of land ownership, environmental impacts (use of water, fertilizers, pesticides etc.), biodiversity and social issues (e.g. hard labour conditions; impact of ethanol production on food prices). Although in the state of Sao Paulo, these problems are not considered prohibitive, they may prove to be on other parts of the world. Also, the sugarcane and ethanol production would also create new employment opportunities. In various EU countries (e.g. the UK, Germany, Belgium, the Netherlands), currently criteria are developed for the sustainable production of biomass. The sugarcane production would likely have to comply with these criteria, or such criteria may have to be adapted for the specificities of this case.
- Institutional constraints: some SADC members (such as Congo or Zimbabwe) have a very poor governance track record, while others (such as Botswana and Mozambique) are politically more stable and feature less corruption. Also, the EU, which currently leaves energy supply issues to the discretion of the Member States, would have to operate as one in order to make the agreement worthwhile.

With regard to the non-actor factors, in terms of resources, it can be observed that:

- Brazil has the technology off the shelf as well as a thriving ethanol industry
- The SADC have the geographical potential, and interest in additional sources of income
- The EU is interested in fuel security, GHG emission reductions and has the financial means

Regarding timing and time frame, the agreement feels particularly timely given the recently set biofuels target of 10% in 2020 in the EU (European Council, 2007), and the anticipated extra costs and pressure on land. In terms of leverage, the agreement holds the promise of clear benefits for each of the three actors involved, especially the economic feasibility of the proposed TOA.

3.2 Nuclear energy TOA: the US/India deal

Radioactive waste, nuclear proliferation, reactor accidents, economic competitiveness, and public opinion continue to create concerns regarding the use of nuclear power and thereby hinder nuclear energy policy making. Still, worries over energy supply security, local air pollution, and global climate change provide reason to reassess its potential share in domestic power production. It is difficult to predict with any confidence what the 21st century will hold for nuclear power, both at the national and global level, and whether in the long run nuclear energy may contribute, along with other energy resources, to the establishment of sustainable development.

While many countries have presently no plans to build nuclear power capacity and some are committed to gradually phase out their current domestic nuclear power production, others decisively continue to preserve a significant part of nuclear energy in their national electricity generation portfolio or are at the start of building up a prospected domestic nuclear energy capacity. At any rate, recent policy directions in an increasing number of countries show that nuclear energy is reappearing on the political agenda. While at present the globally installed nuclear capacity is approximately in status quo, it may increase again over the next two decades given e.g. the expected new build in countries like China and India. Its prospects beyond 2025 will depend on the relative weights given to the benefits and drawbacks of nuclear power, as well as the long-term sustainability features of all energy resources.

TOAs in the field of nuclear energy could be particularly worthwhile between developed and developing countries would be inspected, as there are several large industrialising nations, among which notably China and India, that for decades have been showing interest in the development of nuclear energy and today have optimistic plans for a major expansion of their existing domestic nuclear power installations. A couple of recent developments suggest that nuclear energy TOAs may receive increased attention in the near future, such as the U.S.-India nuclear deal in 2005, under which three decades of restrictions on nuclear cooperation between these two countries would be ended, and China's multiple official declarations to augment its domestic nuclear energy capacity and purchase associated foreign nuclear technology, among which in 2006 the announcement to buy 4 nuclear reactors from Westinghouse-Toshiba. This chapter assesses the recent U.S.-India nuclear energy deal as case study in this context and as a potential model for a TOA in that field. In assessing this deal, it is eminent to also take into account the political consequences of this agreement for the Nuclear Non-Proliferation Treaty (NPT)[8], to which the United States is a signatory.

3.2.1 Scope of the US-India nuclear deal

The exact contents of the U.S.-India nuclear deal as announced by President George W. Bush and Prime Minister Manmohan Singh in July 2005, and agreed in detail in March 2006, are not public. What is clear that it would imply a major change in U.S. non-proliferation and export control laws and policies that until today have prohibited full nuclear cooperation with India. Since India exploded an atomic bomb in 1974, thereby violating U.S. and international efforts to prevent the spread of nuclear weapons, the U.S. has barred civil nuclear energy cooperation and trade with India. The U.S.-India nuclear deal would end these nuclear trade restrictions, and thereby allow a broader strategic and economic relationship between the U.S. and India, while the latter is informally accepted as a 'responsible possessor' of nuclear weapons. In exchange for this recognition, India ought to assume the practices related hereto, such as distinguishing its military nuclear facilities from civilian ones and putting all civilian nuclear plants under International Atomic Energy Agency (IAEA) safeguards (see e.g. Perkovich, 2005). After a process of collaboration between the U.S. Congress and administration to address some of the deal's major nuclear proliferation concerns, and correspondingly the introduction of some adaptations, the deal has now been approved by Congress (Levi and Ferguson, 2006). The resulting agree-

8 For the full text of the treaty, see http://www.un.org/events/npt2005/npttreaty.html.

ment still needs to be formally accepted by the Indian authorities before it can go into force. Furthermore, it needs approval from the Nuclear Suppliers Group (NSG), the international cartel of 45 countries that controls most global trade in nuclear technologies. The U.S. President has stated that his administration would work with its allies to adjust the relevant international nuclear regimes, notably that of the NSG, to enable nuclear reactor and fuel sales to India (Ganguly and Mistry, 2006).

3.2.2 Proliferation concerns and benefits

The U.S.-India nuclear deal does not only fundamentally transform the relationship between the two countries, but represents a challenge to the international nuclear disarmament and non-proliferation regime, as it could motivate other countries to proceed in their attempts to produce sensitive nuclear material and acquire nuclear weapons in the hope of eventually being recognized as a 'responsible possessor' of nuclear weapons. Whether with or without this deal, India would anyway most likely proceed with the production of weapon-grade fissile material. It has been pointed out, however, that the U.S.-India nuclear deal would allow India to potentially accelerate the buildup of its stockpile of nuclear weapons materials (Mian et al., 2006). India's production of weapon grade plutonium is currently constrained by the competing demands of India's nuclear power reactors for its limited domestic supply of natural uranium. If India could import fuel for its civilian nuclear reactors, it could use more domestic uranium for the production of nuclear weapons materials.

India has also not made definite commitments on whether reactors that are built in the future will be opened for inspection under IAEA safeguards agreements. Alternatively, India could decide to use these new reactors for nuclear weapons production and correspondingly exempt them from international inspections. Nor did India make promises to end its production of nuclear weapons material, whereas the five official nuclear weapons states have de facto stopped producing such material.

Positive aspects of the U.S.-India deal are that India agreed in principle to bring its civil nuclear plants – 14 of its total number of 22 nuclear facilities – under international safeguards as performed by the IAEA, to adhere to international guidelines on nuclear and missile export controls as prescribed by the NSG, to maintain a moratorium on nuclear testing (as long as other states do so too), and to support talks on proposals for a Fissile Material Cut-off Treaty (FMCT).

3.2.3 Emission reduction potential

In the foreseeable future coal is expected to provide most of India's electricity. For various reasons nuclear energy would probably become among the prime climate-friendly substitutes for the conventional use of coal for power production, rather than e.g. hydropower, renewables, or natural gas (Chikkatur, 2005). There is considerable uncertainty regarding the new nuclear capacity likely to be realized under the U.S.-India nuclear deal, but the significance of new nuclear build in terms of CO_2 emissions savings is likely to be large. For example, the construction by the U.S. of two 1 GWe reactors under the U.S.-India agreement achieves a reduction of about 15 $MtCO_2$ per year (under the assumption that a coal-based power plant emits approximately 7.5 $MtCO_2$/yr, and that India would not build those reactors without the deal). When all reactors built under the deal by either foreign or domestic constructors are taken into account, one may reach much higher figures. Accounting for India's track record of installing nuclear power plants, as well as the difficulties that are likely to arise when India shifts to a truly commercial nuclear power program, analysts claim that new nuclear capacity could be in the range of 10-20 GWe by 2020 (Victor, 2006). Such studies don't take into account the lengthy licensing procedures that characterize the Indian electricity sector, and that could lead to delays once the political clout and the resulting momentum have declined. Prime Minister Manmohan Singh has suggested that the U.S.-India nuclear deal could have even larger implications, perhaps the installation of up to 40 GWe nuclear power capacity over this time frame. Figure 3.5 depicts the expected annual CO_2 emissions reduction as function of the total capacity of newly installed nuclear power plants.

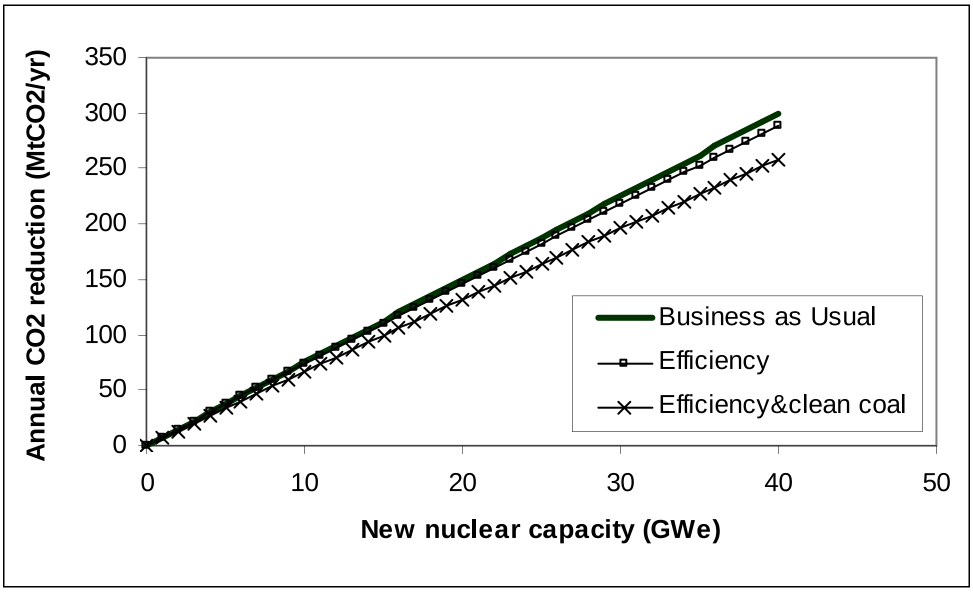


Figure 3.5: CO_2 reduction potential (in MtCO2/yr) of new nuclear capacity (in GWe) in India (after Victor, 2006). Central case and two different baseline assumptions.[9]

There is important interference between the cases, as the extent of CCS application determines the baseline for the nuclear case and thus determines the emission reduction potential of the (in this case, nuclear) TOA under consideration.

3.2.4 Emission reduction costs

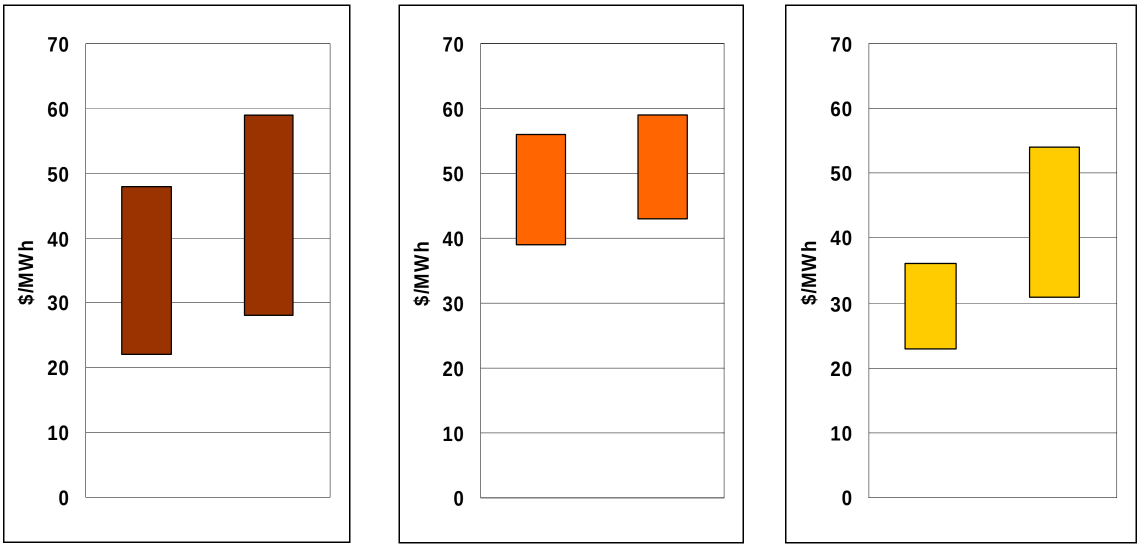
The construction of a new nuclear power plant requires large upfront investment costs. When in a liberalized power sector a limited planning role is reserved for government, it is often difficult to ascertain low costs of capital, which constitutes an impediment for the acquisition of the funds required for construction. Typically, capital requirements per unit of capacity are two times higher for nuclear power plants than for coal plants and three times higher than for natural gas based power plants. In order to render the difference in capital requirements between nuclear and fossil-based power production capacity surmountable, a significant role of government by creating the right investment environment seems essential. In the case of India, the power sector is not fully liberalized. State Electricity Boards control the electricity supply of the various states. Although capital is generally more difficult to get by in developing countries than in OECD countries, the state-controlled character of the Indian electricity sector may actually be conducive to nuclear electricity.

In terms of levelised production costs, nuclear energy is able to compete well with its two main counterparts in the electricity sector, coal and natural gas based power generation, basically as a result of the low fuel cost component. Figure 3.6 depicts the range of total levelised electricity production costs for coal, natural gas, and Generation-II[10] nuclear power plants, for two different discount rates. The electricity costs presented in Figure 3.6 cover all investment, fuel, and operation & maintenance costs over the entire lifetime (of typically 40 years) of the power plant (including costs associated with waste disposal and reactor decommissioning), do not include CO_2 emission prices or potentially other external environmental costs, do not account for possible power plant lifetime extensions, and account for modest fossil fuel price increases with respect to the prices for oil and natural gas prior to their high rise in 2005. For all three alternatives a dependency exists on especially where and under what operating conditions the electricity has been produced. The cost ranges indicated by the bars in the three charts of Figure 3.6 mostly

9 N.B. The two other baseline assumptions correspond to, n * 0.1% efficiency gain of coal power plants for n installed GWe nuclear power plants, respectively, this efficiency gain plus a 1 GWe coal power plant equipped with CCS (at 100%) for every 10 GWe of installed nuclear power plants).

10 Commercial nuclear power reactors, developed and built in the years 1965 – 1995, such as Pressurised or Boiling Water Reactors or Advanced gas-cooled reactors. Future generations include Generation IV, which involves inherently safe reactors and might be deployed from 2030 onwards.

reflect different domestic circumstances in OECD countries. On the basis of the data presented in this Figure one can conclude that there are in principle no costs involved with the reduction of CO_2 emissions per unit of generated electricity through the use of nuclear power. It may be assumed that power generation costs in India fall within the broad ranges as depicted in this Figure.



(a) Coal: 5% and 10% (b) Gas: 5% and 10% (c) Nuclear: 5% and 10%

Figure 3.6: Range of total levelised electricity generation costs (in US$/MWh) for (a) coal, (b) natural gas, and (c) (generation-II) nuclear power plants for two discount rates (left bar 5%, and right bar 10%). Source: van der Zwaan, 2007; Data from OECD, 2005

3.2.5 Political feasibility of the nuclear-TOA

While nuclear agreements are unlikely to be of a type 2 TOA (no common research funds are built for new reactor development), they probably are of a type 1 TOA (since through e.g. the Generation-IV (see footnote 8) program R&D is coordinated between different member states). If under formal government agreement advanced nuclear reactors are exported from the EU to e.g. China or India, then the agreement involved would clearly be of a type 3 TOA. On the other hand, since nuclear power plants involve negligible GHG emissions, they would intrinsically not be of a type 4 TOA (there are no standards to be set - standards could, on the contrary, apply to e.g. reactor operation safety and waste disposal, but these do not fall under climate change based TOA's).

Table 3.2: Actor-specific constraints of the nuclear TOA

Constraints	*Actor*	
	India	*United States*
Economic	Potential capital constraints to build the reactors	US industry is likely to benefit from the bill as a new export market is opened
Physical/technical		
Legal/contractual		The US is a signatory to the NPT, with which this deal is inconsistent.
Social/equity	Parliament is asking questions about the deal.	
Institutional	It's unclear whether bureaucratic licensing procedures in India pose challenges to the full implementation of the deal.	

In terms of resources, no large sums of money are involved in the deal. Only the investments that might take place as a result of the agreement could become considerable, but that is more of an enhancing factor than a constraint. The timing of the agreement seems to be conducive as the Indian electricity demand is growing rapidly (IEA, 2004), and US industry is deprived of an internal market for nuclear plants as a result of hampering domestic progress in that field, and uncertainties about nuclear waste management. As the deal does not have a final date, the time frame is not relevant. The leverage factor works positive on both sides as long as political consequences of violating the NPT are not considered.

Like perhaps with other cases of TOAs, there is the issue whether ‘the deal’ is made with a role for government, or whether it is struck solely between industrial partners. In the latter case the deal may not be seen as a TOA as referred to in this report. In the former case, however, it would qualify as an example of a TOA.

This section only aimed to describe some of the aspects of the recent deal between the U.S. and India. Other countries are imaginable as well, if concerns about NPT violation can be taken away. China has much potential for nuclear power plant construction. The question, however, is to what extent the U.S. and/or Chinese governments would be involved in such a deal[11]. In addition, not only deals between developing and developed countries are imaginable (as the above examples), but also between developed and developed (e.g. between the U.S., EU, Japan, Russia; within the EU recently between e.g. France and Finland), and even between developing countries (e.g. between South Africa and China). Accounting for all possible deals, the total emission reduction potential could in principle run in units of $GtCO_2$. An open question for this and other cases is whether plants will be sold under normal (liberalised) market conditions or whether special deals are struck or discounts applied. Varying assumptions on these imply different reduction cost estimates.

3.3 Cement industry

World production of cement in 2004 was 2.2 billion tonnes, resulting in 1.9 $GtCO_2$ emissions, or 5.5% of global CO_2 emissions (Price & Worrel, 2006). Cement production increased over 50% since 1990 or approximately 3% per year. This increase almost exclusively comes from developing countries, as the production in industrialised countries is more or less stable. China currently accounts for 44% of world cement production. It is projected China’s share in world cement production maintains this level until 2020 and then slowly decreases (IEA, 2004).

Approximately 50% of cement CO_2 emissions are process-related: in the calcining process $CaCO_3$ is decomposed into CaO and CO_2. The other emissions are from fuel combustion in the clinker production process, where the different mineral components of clinker are formed at 1500 °C. The dominant fuel in most countries is coal or lignite, with significant shares of oil and gas in some countries. Different waste sources are also increasingly used, as the high temperatures in the kiln decompose most substances. In addition, in the production process large amounts of electricity are used (in raw meal grinding, rotating kiln, and finish grinding).

3.3.1 Scope of the technology

This TOA is applicable to the cement manufacturers. CO_2 emissions per tonne of cement produced can be reduced by application of a range of technologies:

- Efficient kiln types: state-of-the-art dry kilns with new suspension pre-heaters and pre-calciner make more efficient use of the kiln heat and use significantly less energy than other types of kilns. These are standard technology for new plants in Japan, but much less used in China (Tanaka, 2006). However in China the smaller-scale vertical shaft kilns are the preferred technology for the lion’s share of production.
- Further waste heat utilisation to generate electricity (co-generation)
- More efficient use of electricity by improved grinding and cooling devices. This would however result only in reduced CO_2 emissions from power production.
- Alternative fuels: biomass ‘waste’ or fossil waste. However, no technology adjustments are needed, as all wastes can be burned in the standard kiln, except for maybe additional end-of-pipe measures to abate air pollutants.

[11] The author’s estimate is that it would probably not be made based on a purely industry-industry interaction, as at various levels governments would intervene.

- Blended cement: replacement of clinker with alternative minerals such as fly ash and blast furnace slag. No technological adjustments in the production process are needed, only infrastructure for sourcing, and perhaps market barriers such as acceptability. Note that in unblended cement 5% gypsum is used, and therefore 95% clinker content is the maximum.
- CO_2 capture and storage (CCS). CO_2 concentration in flue gas is relatively high, compared to coal-fired power plants, therefore post-combustion capture may be cheaper (but typical emissions per kiln may be lower). Retrofitting existing cement plants is possible, but some issues need to be looked into (e.g. impurities in flue gas, heat requirement for solvent regeneration. Oxy-fuel combustion may also have advantages, but impact on kiln design and calcination process needs to be assessed (Davidson, 2006).

3.3.2 Contents of the cement-TOA

The kiln technology options and CCS are the most applicable options for the TOA. The co-generation and electricity efficiency technology can be included if the reduction in power emissions is properly accounted for. Alternative fuel use is more difficult to include as it depends only on local conditions of waste sourcing. Blended cements also do not require a certain technology but may be included by agreeing on blending targets and cooperation on removal of market barriers and sourcing.

Efficient kilns are commercially applied in many countries, therefore TOA type 3 (technology transfer) or 4 (technology mandates, standards, incentive agreements) would be preferred. Blended cements and alternative fuels can also be included in this type as there as no technological barriers. CCS however has not been applied in cement plants yet and is still in the research phase, therefore Type-2 appears to be more applicable. Assumed timeline is 2013-2020. An alternative could be to extend the timeline (e.g. to 2030) and include CCS after 2020 in a Type 4 TOA.

Components of the cement agreement would be:

- Three large-scale demonstration plants with CCS in Annex-I countries (Japan, US and EU) before 2020;
- Technology mandates (state-of-the-art kiln) for new large-scale plants (e.g. >0.1 Mt cement/yr) in all participating countries;
- Technology transfer and financial assistance, e.g. from Japan to China and from US/EU to India, to achieve these targets;
- Targets for low-clinker cements (i.e. blended cement), e.g. 75% clinker content average across 8 years for Annex-I and 85% for non-Annex-I;
- Option for emissions trading: non-Annex-I countries exceeding their target can sell credits to Annex-I countries that are short of their target;
- Targets for alternative fuel use.

In principle all countries can be included. The most relevant are listed in table 3.3 with important characteristics.

Table 3.3: Approximate cement production data of important world regions

	% of world cement production in 2004	*tCO_2/t cement*	*Share efficient kilns (dry and new dry)*
US & Canada	5	0.95	65
EU	6	0.62	60[a]
Japan	3	0.66	100
China	44	1.03	44
India	5	0.88	50

Sources: Price & Worrell (2006), WBSCD (2002); Tanaka (2006)
[a]: average of Western Europe and Eastern Europe (Humphreys & Mahasenan, 2002)

3.3.3 Estimated emission reduction of the TOA

Assumed is that 50% of world cement production is included (large-scale plants in China, India, EU, North America).

- Efficient kilns: if roughly 500 Mt/yr capacity (large-scale plants) is added in developing countries from 2013 to 2020, with specific CO_2 emissions 10% lower (estimate) compared to otherwise applied technology, then impact in 2020 can be 50 $MtCO_2$/yr.
- Blended cements: from currently 10% (baseline) to 20%, or 5% to 15% in non-Annex-I, 5% of emissions will be saved (across 50% of global emissions of 3 $GtCO_2$), so impact can be 75 $MtCO_2$/yr in 2020.
- Alternative fuels: similar (at 10% increase against baseline)
- If CCS is included, large reductions after 2020 are achievable

Overall potential is in the order of 200 $MtCO_2$/yr. Including CCS after 2020 increases potential significantly (e.g. if 50% of all included capacity uses CCS reduction potential is more than 1 $GtCO_2$/yr). Impacts of the TOA will also be on the removal of non-technical barriers for blended cement and alternative fuels and technological learning for CCS.

3.3.4 Expected costs of the cement-TOA

Costs for blended cement and alternative fuels are very difficult to determined, and cost is likely not the most important factor for its utilisation. Efficient kiln technology is somewhat more expensive compared to other technology, and may be calculated and expressed in $/$tCO_2$. For CCS this can also be calculated (according to Davidson (2006) costs are in the same range as for CCS in power plants).

3.3.5 Political feasibility of a cement-TOA

A technology-based agreement on CO_2 emission from cement production has attractive elements for several important world regions, in both the industrialised and emerging economies. The potential impact on CO_2 emissions ranges from approximately 200 to more than 1000 Mt/yr, depending on the design of the agreement. Other important impacts include technological learning for application of CO_2 capture and storage in cement plants. The economic costs are likely to be relatively modest.

The constraints of a cement-TOA from the perspective of the most relevant actors are outlined in Table 3.4.

Table 3.4: Actor-specific constraints of a cement-TOA

Constraints	*Actor*		
	Japan	*China/India*	*United States*
Economic	Limited financial resources for international support; financing for 1 CCS demonstration plant	Some financing for national use	Limited financial resources for international support; financing for 1 CCS demonstration plant
Physical/technical	Sufficient infrastructure for waste material (fly-ash/slag) and fuel?	Infrastructure for waste fuel may not be sufficient	Sufficient infrastructure for waste material and fuel?
Legal/contractual	In case of CCS CO_2 storage might need to be institutionalised		In case of CCS CO_2 storage might need to be institutionalised; positive vote by senate needed
Social/equity		Are mandatory blending targets acceptable?	Acceptance of blended cements?
Institutional	Interaction with cap-and-trade mechanisms might need to be considered	China and India might consider possible reduction under the CDM	

Potential issues in terms of resources for the TOA include financing for implementation of technologies, technology transfer, including capacity building and knowledge transfer, and resources for demonstration plants. As all TOAs assessed here, there is a potential interaction in the timing of the agreement with potential post-2012 agreements such as a follow-up of the Kyoto Protocol. In terms of leverage points, the global cement industry might support a TOA more than a (sectoral) greenhouse gas emission limit.

3.4 A TOA on ammonia production

Because of its many uses, ammonia is one of the most highly-produced inorganic chemicals. The worldwide production in 2004 was 163 million metric tons (ChemWeek, 2004). China produced 27.1% of the worldwide production followed by India with 8.4%, the United States with 8.6%. Large producers in the EU are Germany (2.5%), Poland (1.7%) and the Netherlands (1.7%). Most production takes places in large-scale plants. About 80% or more of the ammonia produced is used for fertilizing agricultural crops. Ammonia is also used for the production of plastics, fibers, explosives, and intermediates for dyes and pharmaceuticals. In 1974, the developing countries accounted for 27 % of ammonia capacity. By 1998, their share had increased to 51 %. In these countries, ammonia is used to produce urea for rice growing (IPTS, 2006). Also for the future, basically all new ammonia plants are to be built in developing countries.

3.4.1 Scope of the technology

Ammonia is synthesized from nitrogen and hydrogen by the following reaction:

$N_2 + 3H_2 \rightarrow 2\ NH_3$

The best available source of nitrogen is from atmospheric air. The hydrogen required can be produced from various feedstocks but currently it is derived mostly from fossil fuels. Depending on the type of fossil fuel, two different methods are mainly applied to produce the hydrogen for ammonia production: steam reforming or partial oxidation.

As it can be seen from Table 3.5, currently, about 80 % of the ammonia production capacity worldwide is provided by the well-developed steam reforming process. High level process integration, innovative equipment design and improved catalysts are the main characteristics of ammonia plants today.

Table 3.5: Applied processes and feed stocks in the production of ammonia. The third column shows the related share of world capacity (1990) (European Commission, 1997, in IPTS, 2006)

Feedstock	*Process*	*% of world capacity*
Natural gas	Steam reforming	77
Naphtha, LPG, refinery gas	Steam reforming	6
Heavy hydrocarbon fractions	Partial oxidation	3
Coke, coal	Partial oxidation	13.5
Water	Water electrolysis	0.5

There has been limited development work of the partial oxidation process in integrated plant concepts. At present, a typical plant is a blend of techniques offered by different licensors assembled by the selected contractor. Specific energy consumption (SEC) varies between about 28 GJ/tonne NH_3 for best available technology (BAT), to about 34 GJ/tonne NH_3 for the industry average, see table 3.6 and Figure 3.7 (Ramirez and Worrell, 2006). The achieved energy consumptions reported in Table 3.6 suggest that, compared to the steam reforming process, there is a potential for improvement of the energy efficiency of partial oxidation processes.

Taking the average SEC of 34 GJ/tonne NH_3, the total specific energy consumption for worldwide ammonia production was about 3.7 EJ in 2004, representing more than 1% of the worlds total final energy consumption (IEA, 2006a), or about the energy demand of the Netherlands.

Table 3.6: Cost differences and total energy demands for ammonia production (European Commission, in IPTS, 2006)

Feedstock	*Process*	*Net primary energy cons. (GJ/t NH_3) (LHV)**	*Relative investment*
Natural gas	Steam reforming	28[a]	1
Heavy hydrocarbons	Partial oxidation	38	1.5
Coal	Partial oxidation	48	2-3

[a] Best achieved values; * LHV: Lower Heating Value

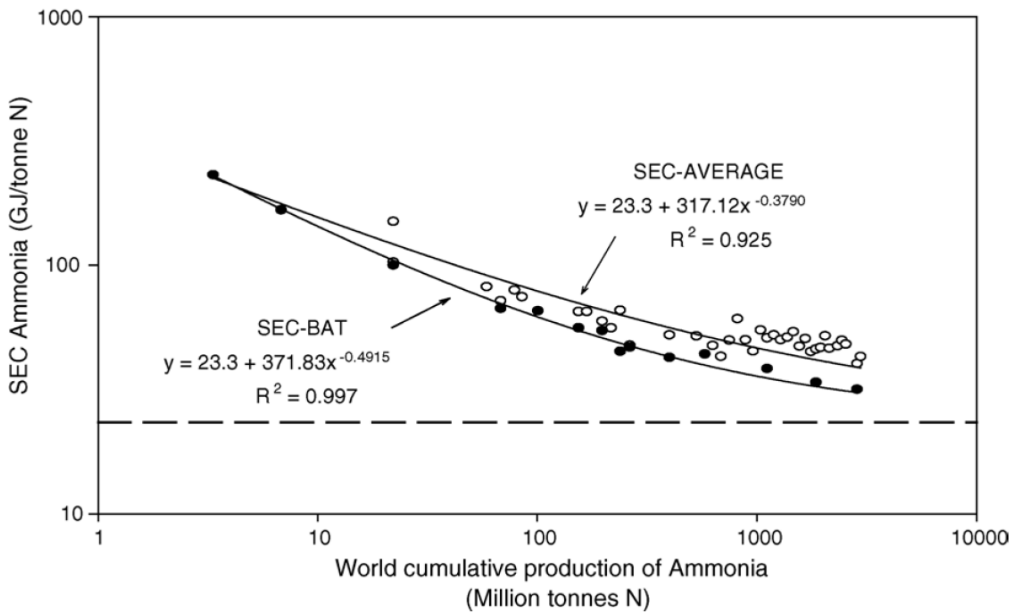


Figure 3.7 Trends in SEC and cumulative production of ammonia, BAT and average technologies from 1913-2001. Data in LHV, expressed per tonne N (Ramirez and Worrell, 2006)

However, there is no clear definition of a best available technology (BAT) plant, as these depend strongly n the chosen plant layout, feedstock etc. To achieve specific energy consumption (SEC) levels of 27.6-31.8 GJ/tonne NH_3, the BAT is to apply a combination of the following techniques (IPTS, 2006, not exhaustive):

- extended preheating of the hydrocarbon feed
- preheating of combustion air
- installation of a second generation gas turbine
- modifications of the furnace burners to assure an adequate distribution of gas turbine exhaust over the burners
- rearrangement of the convection coils and addition of additional surface
- pre-reforming in combination with a suitable steam saving project
- improved CO_2 removal
- low temperature desulphurisation
- isothermal shift conversion (mainly for new installations)
- use of smaller catalyst particles in ammonia converters
- low pressure ammonia synthesis catalyst
- use of a sulphur resistant catalyst for shift reaction of syngas from partial oxidation
- liquid nitrogen wash for final purification of the synthesis gas
- indirect cooling of the ammonia synthesis reactor
- hydrogen recovery from the purge gas of the ammonia synthesis
- implementation of an advanced process control system

3.4.2 Proposal for a TOA on ammonia production in China and India

The European Union's ammonia industry produces approximately 11 million tonnes ammonia per year (2001), from around 50 plants, i.e. approximately 9% of current global production. While no new ammonia plants have been built in the EU after 1991, many of the existing plants have been revamped, and in general, expert knowledge is available on how to built BAT plants (IPTS, 2006).

Most new ammonia production capacity is expected to be built in developing countries, and in China and India. In 2004, three new ammonia plants were opened in 2004: a 0,7 Mt/yr plant in Iran, a 0,68 Mt/yr plant in Qatar, and a 0,2 Mt/yr plant in Turkmenistan. In addition, several companies announced in 2005 capacity increases in Bolivia, Brazil, China, Egypt, Lithuania, Russia, and Trinidad and Tobago that would add about 2.7 million tons of ammonia production capacity (USGS, 2005).

For the future, according to the 2006 world capacity survey of the international fertilizer association (Heffer and Prud'homme, 2006), global ammonia capacity is projected to increase by 35 Mt from 167 Mt in 2006 to 202 $MtNH_3$ in 2010. The annual capacity increase will average 7 $MtNH_3$ between 2006 and 2009. In 2010, an additional 15 Mt is anticipated, assuming all announced projects are completed on schedule. During the period from 2006 to 2010, the global consumption of nitrogen fertilizers is projected to increase at an annual rate of 1.8 per cent, reaching 99.1 Mt N in 2010 (Heffer and Prud'homme, 2006).

In figure 3.8, the growth of ammonia production in China and India is displayed, while in figure 3.9, the global ammonia production per world region is presented.

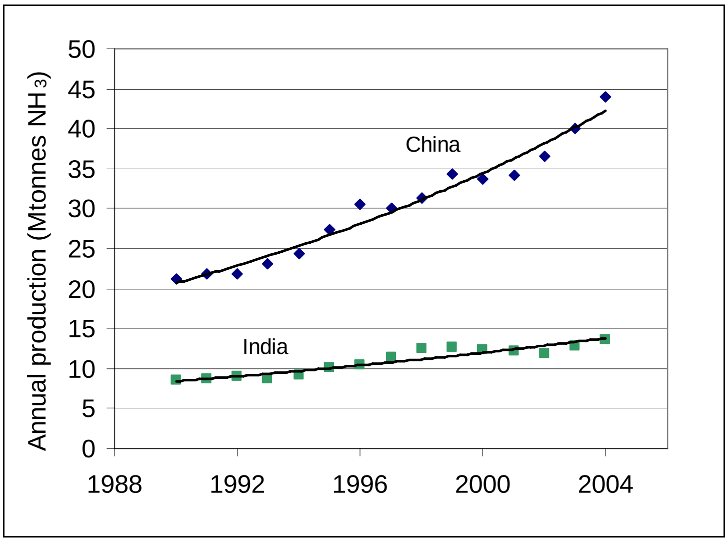


Figure 3.8: Growth of ammonia production in China and India (source data: Kramer, 2004)

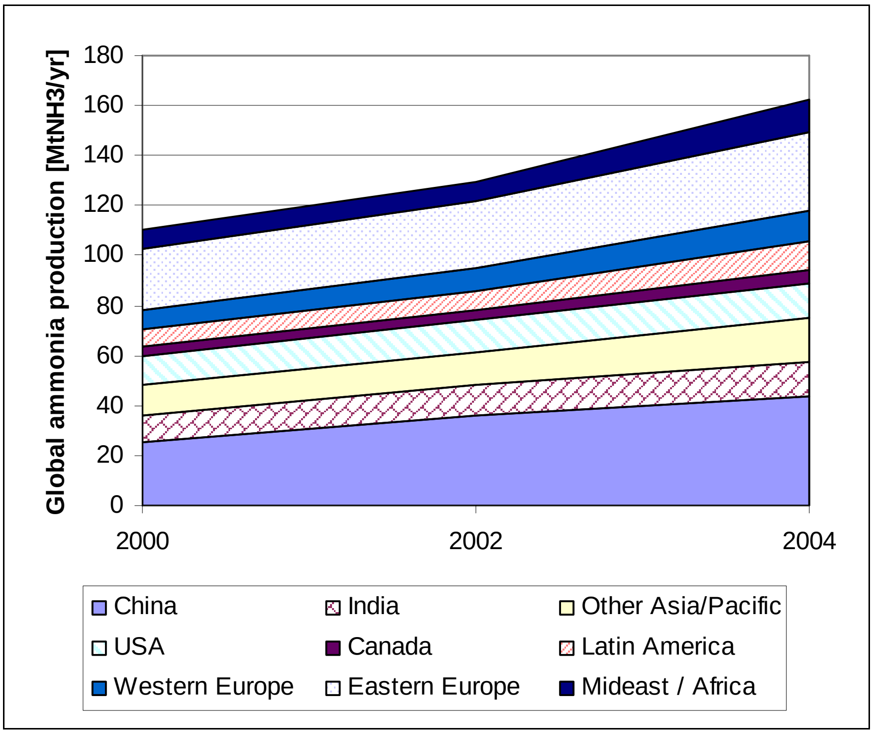


Figure 3.9: Global ammonia production per world region (source data: Chemical week, 2000-2004)

As argued above, most expertise on BAT technology is present in the industrialized countries such as the EU, while the main further growth in production is expected in developing countries, and especially in China and India.

Thus a technology-orientated agreement (TOA) is envisioned between the EU on the one hand, and China and India on the other. The TOA would include that existing capacity is revamped and new capacity is built by BAT standards in these countries (containing elements of TOAs types 3 and 4), technology transfer within the next 5 years and mandate for only BAT plants until 2020. The BAT technology would be provided by EU manufacturers. Possible additional costs could be covered by EU governments in exchange for tradable emission permits. Possibly, the TOA could be carried out under the umbrella of the clean development mechanism (CDM), potentially in a sectoral-CDM context.

Next to the direct benefits of shifting from average to BAT, this would also mean that the BAT experience curve (see figure 3.7) would be 'extended' (i.e. more cumulative production with BAT technologies), which would result in further increases in energy efficiency and CO_2 emission reductions.

3.4.3 Overall reduction potential and expected impact of the TOA

Carbon dioxide is produced in accordance with stoichiometric conversion and can be recovered for further use as feedstock in a urea plant, for use in fertilizer production (ODDA process). The emission of CO_2 per tonne of ammonia cannot be given straightforward, as it depends on the plant layout and the further use of the ammonia. Furthermore, CO_2 can be used as reactant for ethanol production or liquefaction, in the beverage industry or as a coolant gas in nuclear reactors (IPCC, 2005). There is, however, an inevitable excess of CO_2 which is released as an emission from the process (IPTS, 2006).

The carbon dioxide production in the steam/air reforming of natural gas is 1.15 – 1.40 kg/kg NH_3, dependent on the degree of air reforming (the figures do not include carbon dioxide in the combustion gases). A CO_2/NH_3 mole ratio of 0.5 (weight ratio 1.29), the stoichiometric ratio for urea production, is obtainable in the heat exchange reformer concepts. In partial oxidation of residual oils, CO_2 production is 2 – 2.6 tCO_2 per tNH_3, dependent on the feedstock C/H ratio.

When taking into account both the use of CO_2 in Urea production and emissions from combustion gases and other energy inputs, and using US specific data, a net emission of about 1.82 tonnes CO_2 per tonne of ammonia can be calculated, i.e. as a rough estimate, 300 $MtCO_2$ of global ammonia production. For these 300 $MtCO_2$, China and India currently contribute about 105 $MtCO_2$. By extrapolating the production trends for China and India (see figure 3.8) to 2020, we estimate that combined production will increase to 120 Mt of ammonia in 2020 (i.e. more than a doubling of annual production). Assuming business as usual (the same ratio of 1.82, i.e. no process improvements, use of CCS technology etc.) this would result in a CO_2 emission of about 220 Mt in 2020.

As shown in Figure 3.7, both the BAT and industry average technology have shown significant improvements in energy efficiency in the last few years. However, compared to the BAT, the industry average consumes still about 30% more energy (about 7 GJ/tonne NH_3). In case a plant changes from average to best available technology, a reduction of about 0.43 tonnes CO_2 / tonne ammonia can be achieved, i.e. about 70 Mt based on current annual ammonia production year. The global energy demand for ammonia production would be reduced by about 20% (0.75 EJ).

Specifically for China and India, the CO_2 reduction potential by revamping all currently existing capacity would be about 30 $MtCO_2$, and, if all new capacity will also be based on BAT technology, total annual reductions in 2020 could be above 50 $MtCO_2$.

Next to this direct emission reduction, the proposed TOA would have other impacts as well:

- First of all, the BAT technologies necessary to achieve lower CO_2 emissions also bring other benefits, such as lower NO_x emissions, more efficient use of materials (e.g. recycling of catalyst) and reduced emissions to water (IPTS, 2006).
- Second, in the calculations above, we have assumed that the level of the average and BAT technology remains constant, i.e. no technological learning. However, if the projected production scenario for China and India (and the Rest of World (ROW) assumed at 1.8% growth per year), this would lead to 1 cumulative doubling of production (from 3 to 6 $GtNH_3$ per year). Following the experience curve, this would imply that the achievable specific energy consumption of BAT could be lowered approximately by another 1.7 GJ per tNH_3.

3.4.4 Expected costs of the TOA

The costs of revamping existing plants are very difficult to estimate, as they depend to a large extent on the individual plant layout and technology, economic depreciation, technical lifetime of the plant, feedstock used and other factors. For a number of the BAT improvements mentioned in section 3.4.1, in IPTS (2006) it is stated that cost benefits can be achieved, though only in a few cases payback times of the investment are estimated. Finally, profitability and pay-back time of investments depend strongly on (local) feedstock prices and (international) ammonia prices.

As a general example, the costs of revamping a 20 year old reduced primary reforming ammonia plant (1100 tonnes/day) are estimated at 5.7 M€ corresponding to approximately 17 €/tonne. Such a revamp would result in an energy efficiency improvement from 36 to 31.1 GJ/tNH_3 (IPTS, 2006). According to Vroomen (2004, in Ramirez et al. 2006), general ammonia production costs in 2001 were around 100 US$/tonne ammonia (about 100 €/tonne in 2007, taking exchange rates and inflation into account).

For this specific example, in the case that all costs for the revamp are attributed to avoided CO_2 emissions, the costs would hypothetically be 48 €/tCO_2. However, as was discussed above substantial benefits can be gained by the lower fuel requirements, the extended life time of the plant etc. It is likely that revamps are already economical at high fuel prices, as the European experience has shown.

3.4.5 Political feasibility of the ammonia-TOA

The feasibility of this TOA is determined by a number of constraints, as summarized in the feasibility matrix. No in-depth analysis has been performed of all possible constraints, so the feasibility matrix is not necessarily complete.

Table 3.7: Actor-specific constraints of the nuclear TOA

Constraints	*Actor*	
	China and India	*EU*
Economic		Implementation of BAT technology may be detrimental to competitiveness of EU ammonia industry
Physical/technical	Feedstock changes may be required (e.g. from coal to natural gas)	
Legal/contractual	Legal requirements needed in India /china to comply with BAT level	
Social/equity	If CCS might be applied, there may be public acceptance issues associated with CO_2 storage.	
Institutional		

The potentially high costs of the revamp of ammonia plants may be a problem for all participating parties. In terms of timing and time framing of the TOA, the high current growth of ammonia production in India and China may constitute a window of opportunity. Leverage points may be the co-benefits of applying BAT.

3.5 Carbon dioxide capture and storage in the electricity sector

3.5.1 Scope of the technology

CO_2 capture and storage (CCS) comprises the capture of CO_2 from a large CO_2 point source, its subsequent transport, and storage in a geological reservoir. In this TOA, we limit the capture of CO_2 to newly built capacity[12] in the power sector, but it could also be applied to other sectors. Notably, there is much potential in refineries, ammonia production, hydrogen and gas processing. Transport will likely to be done through pipelines, and storage is expected to be done in either depleted gas- or oil fields or in saline formations. It is assumed that storage in coal beds will not be technically feasible in most locations, and that the potential for Enhanced Oil Recovery (EOR) is too limited to make a big economic difference. The costs of CCS are therefore the sum of the capture cost from a (new) gas- or coal-fired power plant, the transport cost and the storage cost. Data from the IPCC Special Report (IPCC, 2005) are used for this.

3.5.2 Contents of the CCS-TOA

The type of TOA that is relevant for the technology at stake depends on the maturity of the technology. When it is still in the research phase and needs to proceed to demonstration, a Type 2 agreement might be best suited. When the technology is technically feasible but still faces economic or institutional barriers, a Type 4 agreement, targeted at overcoming those barriers, might be best suited.

The different components of CCS each have different levels of maturity (see IPCC, 2005). Transport and the storage options that are selected for this TOA are generally regarded as technically mature. In capture, the situation is more complex. Major technological hurdles are not expected, but capture of CO_2 with a full-scale gas- or coal-fired power plant currently remains to be demonstrated. It is expected, however, that by the time this TOA is in operation (2012 – 2020), there will be several large-scale demonstrations of CCS in operation. Also, the

12 Including replacement

instruments considered on the EU and the national level do consist of Type-4 instruments. It is therefore assumed that CCS is mature enough to be included in a Type-4 TOA, meaning a mandate, incentive or standard aimed at CCS deployment should be employed.

The generally cited proposal for a technology-oriented agreement was discussed and explored by Edmonds and Wise (1998). This agreement involves the following:

1. Any new fossil fuel electric power capacity in Annex I nations installed after the year 2020 must scrub and dispose of the carbon from its exhaust stream;
2. Any new synthetic fuels capacity must capture and dispose of carbon released in the conversion process; and
3. Non-Annex I nations that participate must undertake the same obligations that Annex I nations undertake when their per capita income, measured by purchasing power parity equals the average for Annex I nations in 2020*.*

Edmonds and Wise conclude that it can be environmentally effective (i.e., concentrations can remain below 550 ppm CO_2-eq) but the overall costs will be higher than the costs for an cap-and-trade-based approach. They explicitly consider the protocol as a 'backstop' option – an emergency agreement if other, more cost-effective ones, turn out to be difficult to realise politically or institutionally. We may have arrived at the point where this is relevant, as it is projected that a GHG concentration level of 550 ppm CO_2-eq is probably not low enough to prevent serious impacts of climate change, and there is no global follow-up to the Kyoto Protocol in sight.

The TOA is inspired by what Edmonds and Wise propose, but treats a number of issues differently. Firstly, reflecting the higher urgency of emission reductions and the open situation after 2012, the TOA proposes to let the protocol start in 2013 and run until 2020, when it will be renewed and expanded, or replaced by something better. Secondly, the country involvement is different. A smaller group of countries is envisaged, and major emitters that are developing countries also get a mandatory target. However, mechanisms are included to compensate for the costs made by those countries. A graduation mechanism, as in the proposal by Edmonds and Wise, is not envisaged. If new countries report to participate in the protocol, their entry conditions need to be negotiated. Thirdly, because the TOA is restricted to the power sector, synfuel plants are not included (but could be covered in a different protocol).

The elements of the 'Low-Emission Power' protocol are the following:

1. Annex I countries involved commit to enact domestic legislation that requires all new and replacement fossil-fuel-based power capacity, as well as all fossil-fuel-based capacity that is older than 35 years[13], to install CO_2 capture and to store the CO_2.
2. Up to 50% of the target for Annex-I countries involved can be done by providing for an equal amount of low-carbon power capacity implementation (renewables or CCS) in the non-Annex-I countries involved[14].
3. Involved non-Annex-I countries commit to enact domestic legislation that requires 50% of new and replacement fossil-fuel-based power capacity to capture and store their CO_2, in addition to the capacity that is installed as a consequence of point 2.
4. Annex-I and non-Annex I countries commit to cooperate to facilitate technology transfer by:
   a. Establishing a fund to which Annex-I countries contribute and which non-Annex-I countries can apply to for help in realising their commitments under 3[15], and for capacity building and awareness raising programmes. The required contributions are not established in detail here, but should be significant in relation to the aim of the fund;
   b. Making provisions to ensure that intellectual property rights for renewable and CCS-related technologies are guaranteed in the involved Annex-I and non-Annex countries alike, but do not form a barrier to implementation of those technologies anywhere;
5. All countries involved enact legislation that arranges for sufficiently permanent storage of the CO_2. This legislation should meet internationally developed and agreed standards for best practice.

13 This can be done by replacing the power plant, but also by retrofitting CO2 capture when a plant is undergoing major refurbishment or repowering.
14 This could be expanded to a CDM-type mechanism where equivalent reductions in GHG or CO2 emissions could be traded.
15 This fund is a replica of the Multilateral Fund of the Montreal Protocol.

In terms of geographical coverage of the agreement, CCS might be relevant for all countries that depend heavily on fossil fuels for their electricity production. However, some countries are more likely candidates for participation in a TOA, for instance those countries with fast-growing and substantial greenhouse gas emissions, ample national fossil fuel resources, growing gas- or coal-fired power capacity, and with much potential for CO_2 storage. For this agreement, the following countries and regions are selected:

- China
- European Union (EU)
- India
- Russia
- United States (USA)

It is assumed that all countries involved have sufficient national CO_2 storage capacity. India appears to be the only country for which this may be problematic as there are no reliable capacity estimates for that country, and initial scans do not reveal a large area of suitable underground.

3.5.3 Emission reduction of the CCS-TOA

The overall reduction potential in the five countries and regions in section 3.5.2 is calculated based on the IEA World Energy Outlook (2006b). Given some rough assumptions, through the incremental and replacement capacity that is likely to be built in the years 2013 – 2020, the overall emissions of CCS-prone capacity are calculated. What happens without the TOA or any other climate policy in place is outlined in Table 3.8.

Table 3.8: Calculation of baseline emissions of new and replacement fossil-fuel-based electricity generation from 2013 to 2020

Country	*New capacity 2005-2030*[16]	*Intra polation for 2013-2020*	*Yearly electricity generation*[17]	*Assumed share in the mix*	*Assumed emission factor of electricity*[18]	*Yearly electricity generation*	*Yearly baseline CO_2 emissions*
	GW	GW	TWh		$kgCO_2/kWh$	TWh	$GtCO_2/yr$
COAL							
China	1089	348	1307	80%	0,762	1045	0,80
EU	862	276	1034	40%	0,762	414	0,32
India	330	106	396	80%	0,762	317	0,24
Russia	153	49	184	20%	0,762	37	0,03
USA	750	240	900	60%	0,762	540	0,41
Total			*3821*			*2353*	
GAS							
China	1089	348	1307	10%	0,367	131	0,05
EU	862	276	1034	20%	0,367	207	0,08
India	330	106	396	10%	0,367	40	0,01
Russia	153	49	184	70%	0,367	129	0,05
USA	750	240	900	20%	0,367	180	0,07
Total						*686*	

Given an assumed emission reduction of about 86% for both coal- and gas-fired power plants, the annual technical potential for emission reductions of the CCS protocol is 1.8 $GtCO_2$ over the period 2013-2020, and the cumulative potential is 14 $GtCO_2$.

16 Reference scenario, IEA WEO 2005
17 Number are halved because of the linear increase in new capacity from 2013 to 2020 (so in 2016 50% of the capacity has been added)
18 Based on IPCC (2005), table TS3, Pulverised Coal (PC) for coal-fired electricity generation, Natural Gas Combined Cycle (NGCC) for gas-fired.

If the TOA was implemented as outlined in section 3.5.2, emissions from newly built coal- and gas-fired power generation would decrease by 86%. The overall emission reduction for the five regions and countries evaluated here would amount to an annual 1.3 $GtCO_2$, with a cumulative result of 10 $GtCO_2$ over the period 2013-2020. The results are in Table 3.9. Because of the wide coverage of the TOA, and the stringent targets, the emission reduction is large, and the CCS-TOA can therefore be qualified as environmentally effective.

There are a number of impacts that have not been taken into account in the calculation in Table 3.9. Firstly, if there is a view at an agreement, there may be a potential perverse effect: before 2012, countries (or companies in countries) may rapidly install fossil-fuel-based power plants to avoid the obligation after 2012. In addition, since the agreement involves only a small number of countries for this analysis, leakage to countries not involved in the agreement could happen. Electricity import from countries not involved has not been taken into account.

Table 3.9: Emission reduction for the CCS-TOA

Country	*Assumed emission factor of electricity with CCS*[19]	*%CCS implementation in CCS Protocol*	*Yearly CO_2 emissions under CCS protocol*	*Yearly CO_2 emissions reduction*	*Cumulative CO_2 emission reduction 2013-2020*
	$kgCO_2/kWh$	%	$GtCO_2/yr$	$GtCO_2/yr$	$GtCO_2$
COAL					
China	0,110	50	0,46	0,34	2,7
EU	0,110	100	0,05	0,27	2,2
India	0,110	50	0,14	0,10	0,8
Russia	0,110	100	0,00	0,02	0,2
USA	0,110	100	0,06	0,35	2,8
Subtotal				*1,09*	*8,72*
GAS					
China	0,052	50	0,03	0,02	0,2
EU	0,052	100	0,01	0,07	0,5
India	0,052	50	0,01	0,01	0,0
Russia	0,052	100	0,01	0,04	0,3
USA	0,052	100	0,01	0,06	0,5
Subtotal				*0,19*	*1,51*
Total				**1,28**	**10,23**

3.5.4 Expected costs of the TOA

Table 3.10 expresses the costs for the CCS-TOA in US$/$tCO_2$. These costs have been established by multiplying the additional investment in CO_2 capture installations per MW installed with the total capacity of power generation with CCS that will be installed under the TOA, based on IPCC (2005). The numbers in IPCC, however, are global numbers, and do not take into account differences in investment costs in countries where material, labour and land may be cheaper. Based on the capital costs of coal-fired power plants in various countries (EIA, 2001; IAEA, 2000), however, the incremental costs for CO_2 capture are indexed to the unity value of the United States and the European Union (which are assumed to be equal). In that way, different capital costs for China, India and Russia are obtained (0.63 for China, and 0.85 for India and Russia).

It should be noted that the calculation is rather rough and has a large uncertainty for a number of reasons. Firstly, it is based on 'best estimate' numbers in the IPCC Special Report of 2005, and does not take into accounting learning effects that may have taken place by the time of the

19 Based on IPCC (2005); table TS3

start of the TOA, in 2013. In addition, the mitigation costs are only calculated over the period 2013 – 2020, rather than over the lifetime of the power plant (30 to 40 years). The numbers are also not discounted. Given these simplifications, Table 3.10 probably overestimates the costs.

On the other hand, although the capital costs of CO_2 capture make up the largest share of the costs of CCS, transport and storage costs are not taken into account in Table 3.10, and are likely to add significantly, especially in countries where storage locations are not amply available and large distances may need to be overcome through pipelines.

Table 3.10: Rough calculation of the mitigation costs over an 8-year crediting time of the TOA without taking into account cost reductions through learning, transport and storage costs

Country	*Yearly additional capital costs*	*Cumulative additional capital costs*	*Cumulative CO_2 emission reduction 2013-2020*	*Average mitigation costs*
	Billion US$	Billion US$	$GtCO_2$	$US\$/tCO_2$
COAL				
China	9	71	2,7	26
EU	11	88	2,2	41
India	4	29	0,8	35
Russia	1	7	0,2	35
USA	14	115	2,8	41
Total	*39*	*309*		
GAS				
China	1	5	0,2	29
EU	3	24	0,5	46
India	0	2	0,0	38
Russia	2	12	0,3	38
USA	3	21	0,5	46
Total	*8*	*63*		

3.5.5 Political feasibility of the CCS-TOA

In table 3.11, the actor constraints of a CCS-TOA are outlined. It should be born in mind that CCS is a costly technology, and the economic constraints will therefore be substantial. The investment flows that have to be realised to comply with the agreement, both domestically and internationally, are very large. The negative consequences for competitiveness, however, are restrained by the level-playing field that is created by the agreement. Table 3.11 shows the actors and the constraints.

Table 3.11: Actor-specific constraints on a CCS-TOA

Constraints	*Actor* *China/India*	*EU*	*Russia*	*US*
Economic	The costs of the TOA are high, but not if compared with the big competitors: USA and EU.	The treaty will have high costs for the EU, but this might be counteracted by first-mover advantage perceptions.	Costs are high, but Russia can use its ample storage capacity to store CO_2 from neighbouring countries and can thus potentially achieve economic benefits.	The treaty will have high costs for the USA, but this might be counteracted by first-mover advantage perceptions.
Physical/ technical	China and particularly India may encounter storage capacity constraints	CO_2 storage capacity is likely to be sufficient over the whole EU, but may be constrained locally. CO_2 storage reservoirs may compete with other underground functions.		
Legal/ contractual		If the EU wants to continue the EU ETS in this period, measures need to be taken to avoid double-counting of the CCS obligation in the case of non-100% auctioning.		
Social/ equity	The risks and public acceptance of CCS may become a problem at the scales of implementation.			
Institutional	There is a need for an international set of guidelines for CCS projects, which might be enabled by such a TOA.			

Although in terms of resources, the lower availability of resources in China and India is partially covered by a fund and by technology transfer through a flexible mechanism, and this will compensate for the difference in both financial and technical resources between Annex I and non-Annex I countries, the absolute cost burden on all countries involved is substantial (see section 3.5.4). For timing of the agreement, the planned construction of power plants may be taken into account, as well as a scheme to allow for further development of the

Costs are high for this agreement, but leverage points may be important. The agreement will ensure a level-playing field among the participating countries. Technological development and progress, and export potential, may be a big asset for the countries that have heavier targets. The first-mover advantages will be greater for those countries with stricter targets, which may compensate for the costs. The technology of CCS is one of the few low-carbon technologies that is compatible with the vested interests of the fossil-fuel industries in countries like the US, China and Russia.

3.6 Carbon efficiency in cars

3.6.1 Scope of the technology

The technology addressed in this agreement applies to all person cars (petrol and diesel) and includes all measures that reduce CO_2 emissions per km[20]. Some of the measures relate to the engine, but also efficiency gains can be made in transmission, weight, aerodynamics, additions, and tires (IEEP/TNO/CAIR, 2005). Also, because this is not a fuel economy agreement but a CO_2 emission agreement, the fuelling with sustainably grown biofuels or low-carbon hydrogen could also be used to reach the target. However, the adoption of other fuels depends on the engine and the provisions therein, which the car manufacturers control, but also on the fuels available at the pump. The agreement therefore contains commitments of both car manufacturers and countries.

3.6.2 Contents of the Cars-TOA

The type of TOA that is relevant for the technology at stake depends on the maturity of the technology. When it is still in the research phase and needs to proceed to demonstration, a Type 2 agreement might be best suited. When the technology is technically feasible but still faces economic or institutional barriers, a Type 4 agreement, targeted at overcoming those barriers, might be best suited.

It is clear from a number of studies that the technologies required for the improvement of fuel efficiency in cars are largely mature. The fuel economy of cars in Japan, for instance, is almost a factor 2 better than that of the United States (Sauer, 2005) – as an indication of the emission reduction potential that is there just by bringing the entire world on the level of the current best available technology. It also seems, by comparison of Japanese, European and US programmes, that mandatory standards are more effective than voluntary ones (Kuik, 2006; Dings, 2006). Strict targets lead to higher innovation levels in industry, so even acknowledging that deeper emission reductions would still need research and development, a Type-4 agreement seems most appropriate for an international agreement on fuel efficiency in cars.

The contents of the agreement that we examine might be as follows:

1. All car manufacturing industries agree that their new person cars on average emit less than 80 gCO_2/km in the year 2020[21]. The target is made with non-mandatory intermediate targets of 120 gCO_2/km in 2012 and 100 gCO_2/km in 2016.
2. All countries involved agree that, in addition to point 1, they will provide tax incentives for smaller and more efficient cars, and that they will promote the availability of low-carbon fuels at fuelling stations.
3. If a car manufacturer in a one of the participating countries does not comply with the mandatory provisions, the country's government will apply an appropriate CO_2-tax to each car that exceeds the target for that year. If a car manufacturer doesn't comply with the non-mandatory targets, it is left to the discretion of the government to stimulate the company to stay on track.

Cars are only produced in a small number of countries around the world. Since it is an agreement under the UNFCCC, the discussions should take place between Parties. However, the car manufacturing industry is highly globalised, and there are only a small number (<20) large car manufacturers worldwide. The number of actors to involve in the agreement is therefore small.

For this agreement, the following countries are relevant:

- China
- European Union
- India
- Japan
- South Korea
- United States

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20 In fact, according to our definition, this is not so much a technology-oriented agreement as an emission standard.
21 This corresponds to a linear improvement according to the European Automobile Manufacturers Association (ACEA) schedule (120 gCO2/km in 2012, 100 gCO2/km in 2016 and 80 gCO2/km in 2020).

3.6.3 Emission reduction potential of the TOA

The WBCSD (2004) indicates that about 45% of all global energy use in the transport sector originates from cars (or light-duty vehicles). According to the IPCC Fourth Assessment Report's final draft (2007[22]), a global 50% increase in energy efficiency in cars could reduce global greenhouse gas emissions by 0.7 to 0.8 $GtCO_2$ in 2030. Others indicate that a 50% energy efficiency increase in new light-duty vehicles would be achievable by 2020.

A simple calculation can shed light on the assumptions and emissions reductions as a result of the Cars-TOA. If we assume, based on data in the IPCC Fourth Assessment Report, the IEA World Energy Outlook data, and incorporating some assumptions on replacement rates of cars, that a reduction of CO_2 emission per passenger-km from current levels to 80 gCO_2/km in 2020 corresponds to a 50% reduction, given that presently, emission levels in the EU-15 are around 160 gCO_2/km. Bear in mind, however, that emission levels in developing countries but notably in the US, are significantly higher, but that they are lower in Japan (Kuik, 2006). Given the weight of the US demand on worldwide car sales, it is likely that the emission reductions are an underestimation of the actual emission reductions.

Table 3.12: Calculation of emission reduction as a result of the Cars-TOA

	2004	*2010*	*2015*	*2020*
CO_2 emission transport sector worldwide ($MtCO_2$)[23]	5289	5900	6543	7111
Share of LDV[24]	45%	46%	47%	48%
Total CO_2 emissions by LDVs worldwide ($MtCO_2$)	2380	2708	3063	3396
Number of LDV (billion)[25]	0.7	0.8	0.9	1.1
Vehicles added to the fleet, plus those replaced	-	-	0.2	0.5
Cumulative emission reduction through 50% efficiency improvement ($MtCO_2$)	-	-	255	695
Resulting worldwide CO_2 emissions from LDVs ($MtCO_2$)	2380	2708	2808	2701

It is clear from Table 3.12 that the Cars-TOA realises a small decline of total emissions in a sector which is normally on the rise, and a significant diversion from the baseline scenario emissions. The treaty can therefore be regarded as environmentally effective.

3.6.4 Expected costs

The costs of this TOA at this point cannot be estimated. The IPCC Fourth Assessment Report (2007) argues that a 50% reduction of carbon emissions from cars can be achieved by 2030 at a cost of less than 100 US$/$tCO_2$. This excludes possibilities of biofuels, which might result in reductions of a similar magnitude, also below 100 US$/$tCO_2$. Costs are therefore significant, but are not exorbitant compared to other options. In addition, because the costs of cars will increase, there might be a decrease in car sales, which would enhance the emission reductions further, and make alternatives such as mass transit more competitive.

Costs distribution among the different countries involved will most likely not be equal. Countries with a large portion of their LDVs in heavier classes, notably in the United States, might have difficulties changing the sales to smaller types of cars, and will have to rely on further technological advancements, and make more costs, to reach the targets. On the other hand, costs are not only made on the country level, but will, due to the level-playing field, burden those consumers that have a preference for large cars more. In that sense, the agreement does right to the polluter pays principle.

Apart from the benefits in terms of greenhouse gas emission reductions, there are several cobenefits to this type of agreement. One major benefit in terms of economic effectiveness com-

22 The report is still under embargo, but the body text of the report has been finalized.
23 Numbers are based on the IEA World Energy Outlook 2006 Reference Scenario: page 81.
24 Number in 2004 is based on WBCSD (2004), assuming a 2% per year increase in share.
25 Numbers from IPCC Fourth Assessment Report Final Draft (2007): Figure 5.5.

pared to national regulation (which has been the case so far) is that there will be a global level playing field if all countries participate. Another benefit, particularly in developing countries with increasing urban air pollution problems, is the effect on the emissions of health-damaging air pollution. In terms of energy security of supply, and the conservation of hydrocarbon resources, the agreement would have benefits as efficiency improvements reduce oil use.

3.6.5 Political feasibility of a Cars-TOA

It appears that the carbon efficiency of cars could be improved significantly by implementing an international agreement with a limited number of countries (those that manufacture cars), which is environmentally effective and has a number of co-benefits. The costs are substantial, but mainly fall to those consumers with the most carbon-intensive preferences, and the level-playing field ensures that country's industries are not disadvantaged.

The agreement is flexible in the sense that new countries can enlist easily without extra costs to the car industry. The compliance check could be simple and straightforward, although there are potential barriers in terms of agreement on testing procedures for cars (An, 2006). The likelihood of enforcement is enhanced by keeping the punishment on the domestic level. Although a country can decide not to enforce, this will probably not help its own industry much as the requirements still goes for the other participating countries. The free-riding incentive of the agreement is therefore not very large.

One note should be placed here – the treaty discussed here is not a technology-oriented agreement according to the definition used in this report, as it does not prescribe a technology. It can better be classified as a sector-based carbon efficiency agreement.

The political constraints for a number of actors are addressed in Table 3.13.

Table 3.13: Political constraints for a selection of actors in the Cars-TOA treaty

Constraints	*Actor*		
	EU and Japan	*United States*	*India*
Economic		High costs because of larger reductions	Difficulties in freeing development costs for domestic car industry.
Physical/technical	The treaty is a technology-forcing treaty, which means that there is uncertainty on whether the goals will actually be achieved.		
Legal/contractual			
Social/equity		Employment issues may be at stake	
Institutional	There is a tendency that technology-forcing agreements are later weakened for protectionism reasons. This is most likely to apply to the US. Also, the compliance mechanism is not particularly strong and there are likely to be issues with testing procedures.		

The other factors that have been identified as relevant for the political feasibility of agreements are resources, time frame and timing, and leverage points. The resources that companies will have to spend in case they will need to make profound adjustments to the cars they produce will likely be substantial. The time frame allows for sufficient time to implement the agreement, and seems appropriate given the literature around this issue. In terms of leverage points, the co-benefits for consumers and ample possibilities for first-mover advantages is hopefully driving both car manufacturers and countries towards an ambitious solution.

Part II: Technology in the climate regime: fatal fragmentation or enhanced cooperation?

4. Introduction

Part I of this report has discussed political feasibility and environmental effectiveness of several hypothetical TOAs separately. To address the whole of the climate regime, we examine the institutional options for co-existence in this Part II of the report. We will discuss three variants of cap-and-trade regimes, and two hypothetical examples of TOAs. We distinguish between four levels of integration of TOAs and cap-and-trade regimes. These four levels range from no integration (‘Separate’), to full institutional, organizational and operational integration (‘Joined’). In-between these extreme levels of integration are two levels of partial, but increasing (operational) integration (‘Linked’ and ‘Integrated’) (see Section 5.3).

Apart from the organization and embedding of the treaty, there are different ways of co-existence of agreements. We make a distinction as to whether the TOA and cap-and-trade agreements are *instrumentally* or *geographically* additional. With instrumentally (or sectorally) additional we mean that the TOA is applied in the country where also a cap-and-trade agreement is implemented. For this case, as it implies a supplementary role of a TOA, we can use a qualitative game-theoretic exercise in Chapter 6, which will examine whether the overall attractiveness of a climate agreement will increase as a result of the technology issue linkage, and draws a conclusion on whether the approaches could or should be ‘linked’ in one overarching agreement.

Geographically additional agreements represent the case that country A pursues a TOA whereas country B pursues a cap-and-trade agreement, as well as the TOA. This will be approached based on institutional analysis, where the consequences of various modes of co-existence will be assessed based on the effectiveness and functioning of the institutions (Chapter 7). A conclusion of both parts of the report is in Part III.

5. Approach and starting points

5.1 Methodology: subsequent steps taken in the analysis

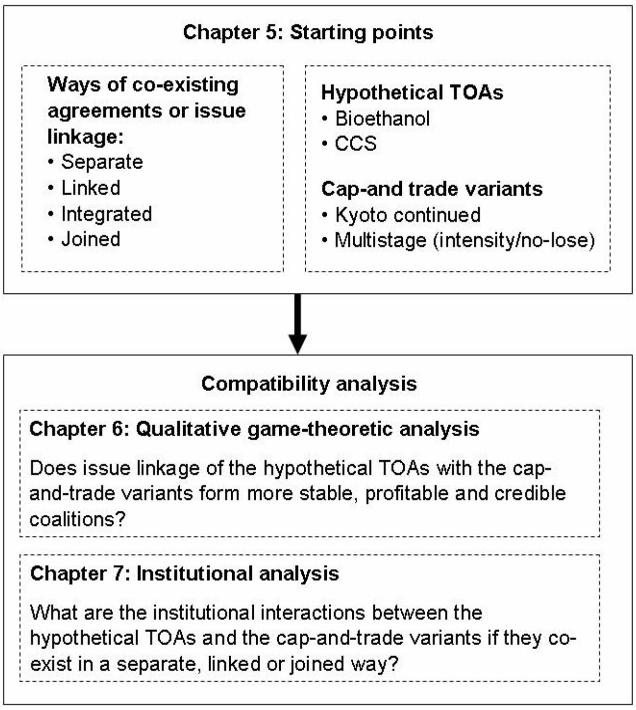
We established that the compatibility of various approaches for international climate policy has several aspects: the approaches can co-exist in the same or in different countries, and the extent of linkage can vary greatly. In order to shed light on the interactions, we have identified a number of concrete cap-and-trade and TOA approaches (see sections below).

For each of the possible combinations of these approaches, we will discuss the coming about of the agreements in the different contexts, as well as the institutional consequences of co-existence. The coming about of a treaty is examined through game-theory analysis, and the co-existence through analysis of institutional interaction.
This report will go through the following steps:

- The game-theoretic issue linkage analysis will address whether the possibility of entering into a favourable technology-oriented agreement provides sufficient incentive for countries to also sign up to a cap-and-trade agreement. The two TOA types (sugarcane-based bio-ethanol and CCS) and the three cap-and-trade approaches (KyotoPlus, multistage with no-lose and multistage with intensity targets) will be compared in this way.
- In the institutional issue linkage discussion, the consequences of having the different TOAs and the various cap-and-trade approaches in different countries will be discussed in the case that they are completely separate, institutionally linked, or institutionally joined.
  - In the separate case, interactions only take place because the mere existence of the one treaty influences the outcome of the other.
  - In the linked case, institutional challenges for linking are addressed.
  - In the joined case, the treaties would have to be negotiated in parallel, and there is interaction between the two in terms of the negotiated outcome.

  The discussion will be framed in the context of advantages and disadvantages of fragmentation in the international institution area, and in the context of political feasibility of Parties under different conditions.
- Lastly, the mere situation of more regimes on one issue area might have consequences, and these will be discussed in a conclusion, based on literature on fragmentation, and linked to the earlier outcomes on separate, linked or joined regimes.

The steps are illustrated in the scheme below.



5.2 Description of the technology and cap and trade agreements

For the cap-and-trade agreements we selected three different approaches: a ‘Kyoto-continued’, where the Annex I countries and the treaty design remain the same, and only deeper targets are agreed (5.2.1); and two multi-stage approaches with an intermediate stage for emerging economies that is either an intensity target or a no-lose target (5.2.2).

Part I of this report outlined six potential technology-oriented agreements and evaluated them for costs, environmental effectiveness and political feasibility. The TOAs were agreements on ammonia production, bioethanol from sugarcane, carbon efficiency in cars, the cement industry, CO_2 capture and storage (CCS) in the power sector, and nuclear energy. From these TOAs, we selected the bioethanol (5.2.3) and CCS (5.2.4) cases. Before going into the compatibility of the agreements, this section will describe the proposals based on their most important characteristics.

The agreements will be described in general terms, and not in terms of quantitative targets, although we would like to emphasise that the legal nature of both the cap-and-trade and the technology-oriented agreements is binding. The TOAs can therefore be regarded as ‘technology-pull’ rather than ‘technology-push’ agreements. Because in that sense they serve the same purpose as a cap-and-trade agreement (which is also technology-pull), the activities in the TOA could in one way or another be credited in a similar way as the cap-and-trade efforts.

The reasons for not going into the details regarding quantitative targets in the cap-and-trade variants here are twofold. Firstly, we would like to steer clear of the discussions around the exact percentage of emissions reductions required to comply with the UNFCCC, i.e., “to prevent dangerous anthropogenic interference with the climate system”, and the allocation of the emission reductions over countries. We will however assume that the agreements lead to reductions of emissions relative to the baseline. Secondly, as we will assess the interactions between the agreements in a qualitative way and no single technology-oriented agreement has the potential to fully meet the assumed cap on its own, the outcome will not change fundamentally if the emission reductions or technology implementation levels are small or large; the result depends on whether there is implementation taking place.

5.2.1 Cap and trade: Kyoto-continued

The ‘Kyoto-continued’ agreement is included as a representation of a continuation of the mindset that let to the current state of affairs around Kyoto. Although times have changed since 1997, and doubts can be expressed around whether a treaty like Kyoto would be achieved again, we assume that there is a possibility that the current situation will continue. Kyoto-continued represents no divergence from the design of the Kyoto Protocol, and assumes essentially the same ratifying countries in Annex B and the same rules for international emissions trading and CDM. The only difference with the current Kyoto Protocol is that the emission targets will be stricter, and the commitment period will be stretched to 2013-2020. The Kyoto-continued agreement is likely to offer the same benefits and difficulties as the present Kyoto Protocol. Although doubts can be cast on whether the same countries that have currently ratified the Kyoto Protocol will also ratify its successor, and the same countries that have not participated so far will not, we will assume for this case that this is the case.

5.2.2 Cap and trade: Multi-stage with intensity or no-lose targets

The multi-stage variant of a post-2012 regime is extensively described in various publications (Berk and Elzen, 2001; Elzen et al., 2004). Recognising the unlikelihood that emerging economies will participate in a system with fixed and binding caps, a Kyoto-type of agreement is proposed with more differentiation. In addition to the two stages that Kyoto has, i.e. fixed caps for Annex-B countries, and voluntary participation through the CDM for non-Annex-B countries, the multi-stage approach is extended with an intermediate category. This intermediate category might be linked to the targets of the original Annex-B countries through emissions trading.

In this variant of the multi-stage approach, the intermediate stage would comprise intensity targets (in terms of CO_2 emission per GDP or unit of product) that show some diversion from the baseline (which already includes an endogenous reduction of energy use per GDP). The reason why emerging economies, with rapid economic growth, are thought to be more inclined to agree to intensity targets than to an absolute emission reduction target is that an intensity target is more amenable to uncertainty on future economic growth – and related changes in emissions. It remains to be seen if emerging economies, such as China, India, Brazil and South Africa, are willing to agree to such an agreement. Some countries have indicated that they might sign up to such an agreement, whereas others have not shown any interest. It is also uncertain whether the commitment of a country like China to comply with intensity targets is enough to make the United States agree to an absolute target. However, for the sake of this analysis, we assume full participation.

In the second variant of multi-stage agreements, the intermediate level receives a no-lose target (or non-binding target, or 'emission budget'). Each country signing up to a no-lose target negotiates a target (allowed amount of emissions, or assigned amount), very likely above current emission level and probably close to a baseline scenario of emissions. If it emits more than the target, it will not be punished. If it emits less, it can sell the credits on the international market; i.e. to Annex-B countries (Philibert, 2000).

The no-lose targets don't punish economic growth, which is important, but it is likely that the establishment of the target scenario is a very difficult and highly politicised action. The permits generated by the no-lose system can be easily integrated with the international carbon market, although there might be concerns that the additionality check for CDM projects is currently more easily implemented and stronger than the check for an economy-wide target such as in the case of no-lose targets. For example, 'windfall' emission reductions in some sectors could compensate for rising emissions in other sectors. In the case of the CDM, these would not be credited; in the case of no-lose targets, they would. Also here, we assume that all countries agree to the conditions of this agreement and that broad participation is achieved.

5.2.3 TOA: Sugarcane-based bioethanol in Africa

The first TOA that will be assessed for compatibility with cap-and-trade-based systems is an agreement between Brazil, the European Union and countries in the Southern African Development Community (SADC). The aim of the TOA is to utilize the Brazilian knowledge and the European biofuels targets and finance to set up a sugarcane-based bioethanol industry in SADC countries in order to supply Europe with sustainable biofuels. The time horizon for this TOA will be 2020.

Brazil will be the knowledge-supplying party. The knowledge transfer will include both expertise on the agricultural system (e.g. cane varieties for various soil types, pest control, use of vinasse as fertilizer) and on the industrial ethanol production system (technical assistance on building large-scale ethanol plants, infrastructure, etc.). The SADC will be the technology-receiving countries. As part of the TOA, Brazil and the SADC will sign a Memorandum of Understanding (MoU), in which they stipulate the intention to build up an ethanol industry. As third party, the European Union (EU) will act as financing party of projects. In return, supply contracts are signed for the ethanol production to be exported to Europe to meet targets for biofuels and GHG emission reductions, possibly coupled with a fixed price (or a price range with minimum and maximum boundaries depending on the oil price developments). The commitment by the EU could be expanded by the introduction of flex-cars on its market: cars that can use both ethanol and gasoline.

Even without carbon crediting in the EU, the TOA may be economically feasible at high oil prices because it provides the EU with guaranteed and affordable biofuels, which is good for energy security of supply, the African countries with a new source of income and Brazil with a market for the technology with which they have unique, decades-long experience. The SADC countries might also use part of the biofuels for own consumption, which would lead to emission reductions in African countries rather than in the EU. It is therefore essentially a win-win agreement which would only require minimal coordination. Drawbacks, however, include environmental and social consequences of large-scale sugarcane cultivation in Africa.

5.2.4 TOA: CO_2 capture and storage in large users of coal

A TOA on CCS might be relevant for all countries that depend heavily on fossil fuels for their electricity production. However, we have identified a small number of countries with fast-growing and substantial greenhouse gas emissions, ample national fossil fuel resources, growing gas- or coal-fired power capacity, and with much potential for CO_2 storage as the most likely candidates: China, the European Union, India, Russia and the United States. Other possible countries are thinkable, but we will restrict the analysis to these.

The elements of the CCS agreement are the following:

- Annex I countries involved commit (in a binding agreement) to enact domestic legislation that requires all new and replacement fossil-fuel-based power capacity, as well as all fossil-fuel-based capacity that is older than 35 years[26], to apply CO_2 capture and to store the CO_2.
- Up to 50% of the target for Annex-I countries involved can be done by providing for an equal amount of low-carbon power capacity implementation (renewables or CCS) in the non-Annex-I countries involved[27].
- Involved non-Annex-I countries commit to enact domestic legislation that requires 50% of new and replacement fossil-fuel-based power capacity to capture and store their CO_2, in addition to the capacity that is installed as a consequence of the actions stipulated in the second bullet.
- Annex-I and non-Annex I countries commit to cooperate to facilitate technology transfer by establishing a fund to which Annex-I countries contribute and which non-Annex-I countries can access to realise their commitments under the third bullet[28], and for capacity building and awareness raising programmes. The required contributions are not established in detail here, but should be significant in relation to the aim of the fund; and making provisions to ensure that intellectual property rights for renewable and CCS-related technologies are guaranteed in the involved Annex-I and non-Annex countries alike, but do not form a barrier to implementation of those technologies anywhere[29];
- All countries involved enact legislation that arranges for sufficiently permanent storage of the CO_2. This legislation should meet internationally developed and agreed standards for best practice.

It is assumed that all countries involved have sufficient national CO_2 storage capacity. India appears to be the only country for which this may be problematic as there are no reliable capacity estimates for that country, and initial scans do not reveal a large area of suitable underground.

Incentives for participation are not there if there is no urgency for emissions reductions at all. However, what might convince some countries is that there are difficult targets for China as well as for the EU and the US, which would improve the level-playing field, and hence compliance. The US and the EU may perceive the enormous market for all aspects of CCS technology as an opportunity for technology export, e.g. of gasifiers, CO_2-separating membranes, and underground management services.

5.3 Ways of co-existence

It is our contention that under any future climate regime the current system of cap and trade will continue to form the foundation of the regime's architecture. We also believe that TOAs could in some capacity be part of that framework, either by supplementing cap-and-trade efforts in countries, or by having an environmentally effective policy in countries that have not signed up to the cap-and-trade agreement. The question then arises at what level and in what form TOAs could possibly co-exist with cap-and-trade. Could they fit, both institutionally and economically, within

26 This can be done by replacing the power plant, but also by retrofitting CO2 capture when a plant is undergoing major refurbishment or repowering.

27 This could be expanded to a CDM-type mechanism where equivalent reductions in GHGs or CO2 emissions could be traded.

28 This fund is a replica of the Multilateral Fund of the Montreal Protocol.

29 This report does not go deeply into IPR issues. This may be regarded as an important omission, as an acceptable arrangement with regard to IPR in the context of a technology transfer agreement is essential to its success, and there is currently no clear solution.

the framework of a regime such as the Kyoto Protocol? Or would they work better outside of the regime? Using Kyoto as our frame of reference we have identified four potential scenarios of co-existence for TOAs: Separate, Linked, Integrated and Joined.

5.3.1 Separate

As the name suggests in this scenario the cap and trade (CAT) regime and the TOA would operate in parallel and have no institutional or economic linkages. There would be separate unrelated secretariats and separate unrelated accountancy and reporting schemes. The only potential for overlap would be that countries might opt to be signatories to both the CAT and the TOA. Current examples of this can be seen in the relationship between the Kyoto Protocol and the Asia-Pacific partnership.

5.3.2 Linked

The Linked scenario can be characterized by two separate agreements operating under two separate institutional regimes (a TOA regime and a CAT regime) with two different reporting and accounting schemes for emission reduction credits. The links between the CAT and TOA could exist in two forms. The first is that all projects or actions under one of the institutions, for example the TOA, would receive emission reduction credits under the CAT but not vice-versa. In the current Kyoto design, this is automatically the case for Annex-I countries but could also be made the case for non-Annex I countries through the CDM. The second form it could take is that only a certain number or type of projects under either the TOA or CAT would be mutually recognized and receive corresponding emission reduction credits. These would have to be agreed upon between the two institutions.

There is also a third way of establishing linkages between the regimes: in terms of fulfilment of capacity building, technology transfer, awareness raising and other means of achieving the 'softer' targets often included in cap-and-trade agreements, including the Kyoto Protocol. However, without denying the relevance of these activities, we do not regard this in this research as it is not central to emission reductions.

5.3.3 Integrated

Similar to the 'Linked' scenario above, the 'Integrated' scenario would also consist of two independent institutional regimes, one for TOAs and one for CAT. The integrated nature of this arrangement would come in the combined or singular commonly agreed upon emission reduction reporting and accountancy scheme. Thus regardless of whether a country is a party to either or both a TOA and a CAT, the results, in terms of technology or emission reduction credits, would be shared between the two institutions.[30] In principle, the 'integrated' agreements could be part of one overarching convention such as the UNFCCC, but this is not necessarily the case.

5.3.4 Joined

Under the 'Joined' scenario the TOA would be an integral part of a larger climate agreement that combines CAT elements. One could envisage a regime that has quantified and binding emission reduction targets and that the instruments to reach those targets would be a combination of the current 'flexible mechanisms' as well as the employment and/or transfer of agreed technologies. Institutionally then the TOA would not be an agreement as such but rather an article in a convention or a protocol and overseen by either an executive board or supervisory committee administered by the convention's secretariat, much the way JI and CDM are handled under the UNFCCC. The institutional oversight of TOAs in this form would serve to certify that technology 'implemented' was meeting its set goal. Economically, the specific parties undertaking the initiative would manage the TOA.[31]

30 From an institutional viewpoint (the approach taken in section 4), it matters whether the TOA and CAT agreements are integrated or joined, but it doesn't matter whether they are linked or integrated, as the institutional setting is the same. In section 4, therefore, only the separate, linked/integrated and joined variants will be discussed.
31 For a game-theoretic approach as the one taken in section 3, it doesn't make a difference whether the agreements are "Integrated" or "Joined", as in game theory there are no economic inefficiencies between integrated and joined regimes, as the carbon or technology markets are the same.

6. Issue linkage in international climate change agreements – a game-theoretic perspective

6.1 Introduction

This chapter applies game theory to the question of the compatibility between post-2012 technology and cap-and-trade-oriented approaches. In particular, it examines whether the approaches could or should be somehow 'linked' in one overarching agreement. It is the assumption of this chapter that many social interactions among people, firms, and countries can be viewed as games with their own structures and rules, their players' strategies, and their winners and losers. The 'game' analogy has proven to be useful in analysing many social situations, including international negotiations among countries. With respect to 'issue linkage' in international negotiations, the central question that game theory addresses is whether issue linkage can help to reach a mutually beneficial agreement, where agreement would be more difficult, restricted or impossible without issue linkage.

The structure of this chapter is as follows. Section 6.2 provides a brief introduction to non-cooperative game theory. The game-theoretic approach to the analysis of international environmental agreements is illustrated in Section 6.2.2. Section 6.2.3 specifically focuses on issue linkage between international climate change and technology agreements, while section 6.2.4 specifies the conditions for successful issue linkage. Finally, sections 6.3 and 6.4 apply non-cooperative game theory to two case studies of issue linkage.

6.2 Non-cooperative Game Theory and International Environmental Agreements

6.2.1 Non-cooperative game theory

Game theory is a theory of situations in which the utility of the decision maker not only depends on his or her actions but also on the actions of others. In the language of game theory the decision maker -- a consumer, a firm, a government, or any decision-making body -- is somewhat disrespectfully called a 'player'. In a situation of strategic interaction, the best action of the player depends on what he or she thinks the other players will do, or perhaps, already did. A 'game' is a formal representation of such situations and can be described by (i) the players involved, (ii) the rules of the game (what moves can be made? who moves when? and what do the players know when they move?), (iii) the outcomes of the game for each possible set of actions by the players, and (iv) the payoffs, i.e., the players' preferences over the possible outcomes. A player is assumed to have a 'strategy', that is a complete contingent plan, or decision rule, that specifies how the player will move in every possible circumstance in the game. How do players play the game, or in other words, how do they form their strategies? Although there are various possibilities (see, e.g., Mas-Colell et al., 1995, Chapter 8), the central solution concept of so-called non-cooperative game theory is the Nash equilibrium [named after Nash, 1952]. In a Nash equilibrium no player can do better (improve his or her payoff) by unilaterally changing his or her strategy. In this equilibrium, each player's strategy is a best response to the strategies actually played by the other players. The Nash equilibrium therefore assumes that each player correctly anticipates the strategies (and therefore the moves) of the other players. The usefulness and popularity of the Nash equilibrium lies in the fact that it can be shown that Nash equilibriums exist in a wide range of (economic) applications (see Mas-Colell et al., 1995: 252-253). The assumption that players correctly anticipate each other's moves may seem to be strong at first sight and it has indeed led to deep theoretical discussions. Up till now however, the Nash equilibrium (including various refinements) has survived all critique, and has firmly remained by far the single most important solution concept in game theory. Even if the assumption of perfect rationality of governments in the climate change 'game' may be considered to be too strong, the Nash equilibrium still provides an important benchmark against which alternative policy proposal can be assessed.

An important distinction among games is that between static and dynamic games. In static – or simultaneous-move – games, players simultaneously choose their strategies at the onset of the game; in dynamic games, players can choose actions over time: they can therefore revise their strategies in the light of what has happened before. An important issue in dynamic games is the credibility of a player's strategy. In dynamic games, the simple Nash equilibrium concept that was introduced above does not suffice to rule out noncredible strategies. To rule out these strategies, in dynamic games a slightly more demanding solution is used: the subgame perfect Nash equilibrium. In a subgame perfect Nash equilibrium, equilibrium strategies should specify optimal behaviour from any point in the game onward. Without going into details about this solution concept, we note that credibility is an important issue in the theoretical debate about issue linkage, as will be clarified later in this chapter.

To conclude this very brief introduction to some core elements of game theory, it should be noted that the discussion so far concerned non-cooperative game theory. There is also a branch of game theory that analyses cooperative games. Cooperative games are games between coalitions of players. While, at first sight, this would seem to be very relevant for the present discussion, it is not because cooperative games are defined as games in which players can make enforceable contracts. One of the characterising features of international cooperation is that there is no international authority that can enforce cooperative behaviour. In the language of game theory: cooperation should be self-enforcing. Notwithstanding this fundamental divide, some elements of cooperative game theory are often used in the analysis of issue linkage, e.g., regarding the division of payoffs between members of a coalition, and also the concepts 'coalition' (a group of players) and 'grand coalition' (the group of all players in a game) originated in this branch of game theory.

6.2.2 International environmental agreements

To understand why issue linkage might be beneficial for a post-2012 climate change regime, we start by considering the problem of establishing a global, pure cap-and-trade regime. We begin by assuming that such a global regime would be a first-best solution to address the problem of climate change: the joint benefits of such a regime (in terms of avoided climate change damage and other ancillary benefits) would exceed the joint costs. The problem of forming a 'grand coalition' is caused by three main reasons (see, e.g., Buchner and Carraro, 2004: 7-8):

1. Economic and environmental asymmetries between countries complicate negotiations over an equitable distribution of burden sharing;
2. The public good nature of climate change control (non-excludable benefits) provides an incentive to countries to free ride (benefit from cleaner environment without paying the cost); and
3. There is no supra-national authority that can enforce an international environmental agreement.

One of the big problems in climate change policies is the asymmetry between countries. It is commonly assumed that developing countries will be the big losers of climate change[32] and they would therefore benefit most from its mitigation. Most of the near-term cost of mitigation should, however, be carried by rich, industrialised countries that emit most greenhouse gases. While this burden sharing can be seen as equitable and fair because of many reasons, it does not make negotiations any easier.

Even without these apparent asymmetries, it is widely recognised that an international agreement on the provision of a global public good (climate change mitigation) provides strong incentives for 'free riding'. So even when the benefits of participation of a country would exceed its costs, a country that wants to maximise its own welfare could often do even better by not joining the coalition (or defecting from it) and thereby foregoing the costs of participation while it would still benefit from the mitigation efforts of the other countries in the coalition. Because each potential coalition member can make the same calculation, the Nash equilibrium predicts that in many of such situations defection would be the optimal strategy for all potential coalition members. Theoretical and applied research therefore find as a rule that stable coalitions to provide a

32 Africa IPCC 2007 and other references

global public good areeither very small in number or the level of provision of the public good in larger coalitions is very low (Dellink et al.,2007).[33]

These disincentives for the provision of public goods also exist at the domestic level. Here, however, the government can enforce the socially optimal provision of the public good and take care of any distributional issues by standard mechanisms (e.g., taxes and subsidies). At the international level, no such central (supra-national) authority exists and so a globally optimal provision cannot be *enforced*. An agreement should be to the mutual benefit of all parties. In this sense, it should be *self-enforcing*. Asymmetries and free rider issues should be dealt with in the agreement itself to the satisfaction of all individual, *sovereign* parties.

In theory, parties to an international agreement could agree on a system of side-payments to solve distributional issues. This would mean that those parties that would most gain from the agreement would transfer a part of their potential gain to parties that would otherwise loose from the agreement or that would have strong free rider incentives. In international politics, such explicit side-payments are not very common, however, for a variety of reasons. In the climate change context it could mean that poor countries, as the potential ‘winners’ in an agreement (see footnote 32) would have to make side-payments to rich countries (the near-time ‘losers’). This would not only be politically infeasible and unethical, but it would most likely also be practically impossible.[34]

It has also been argued that in dynamic, repeated games such as the climate ‘game’, international cooperation could be enhanced if countries would play a so-called ‘tit-for-tat’ strategy, that is, if countries would punish defectors by defecting themselves in the next round of the game (Axelrod, 1984). The ‘tit-for-tat’ strategy has aroused much (theoretical) debate; we will not delve into this issue deeper, but just note that ‘tit-for-tat’ is not a common strategy in international *environmental* negotiations.

Several authors have considered the use of ‘issue linkage’ as an alternative to explicit side-payments. The basic of issue linkage is to combine negotiations on one issue with asymmetric benefits with negotiations on another issue with a different profile of benefits so that the joint agreement is easier to achieve than the individual agreements. Tollison and Willett (1979) and Sebenius (1983) did pioneering work on mutually beneficial issue linkage in international negotiations over economic and military issues.[35] Cesar and de Zeeuw (1996) applied an explicit game-theoretic model to the question of issue linkage in an international environmental problem such as river pollution. In this example, cooperation between riparian countries would increase joint welfare (joint gains exceed joint costs), but would not increase the welfare of each individual country. The benefits of environmental measures would likely fall on the ‘downstream’ country, while the costs of these measures would likely fall on the ‘upstream’ country. Without side-payments from the ‘downstream’ country to the ‘upstream’ country, it may be difficult to reach agreement on cooperation. Cesar and de Zeeuw (1996) demonstrate that the zone of possible agreement on such issues might be enlarged if the negotiation on the environmental issue would be linked to another negotiation that would somehow ‘mirror’ the payoff structure of the first issue. An example could be trade concessions from the ‘downstream’ country to the ‘upstream’ country. To be ‘renegotiating-proof’ (i.e., subgame perfect), it would be best to link two issues where each player has one issue it cares about and one where it does not care about.

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33 The Kyoto Protocol seems to be a case in point. Although ratified by 146 countries, only the EU, Japan and Canada have binding emission reduction targets under the Protocol (and it is very uncertain whether Canada will actually comply). Some other international environmental agreements have a larger effective participation; this has been alternatively explained by the presence of equity-preferences of countries; by the presence of positive, social externalities of entering into an international agreement; and, indeed, by the presence of issue linkage incentives (cf. Cabon-Dhersin and Ramani, 2006).

34 Tol et al. make the point that the global gains of the agreement should be expressed in “utility”. An agreement is globally efficient if the total utility of the agreement exceeds total disutility. But utility cannot be transferred, only its money-equivalent. As the money-equivalent of utility differs greatly between giving and receiving country (as will likely be the case between rich and poor countries), the amount of money that a poor country can spare may simply not be enough to offset the money-equivalent loss of utility in the rich country.

35 Before these contributions, issue linkage had primarily been considered in situations where one group of parties attempted to use its dominant bargaining or veto power in one area to achieve maximum advantages in other international interactions (Tollison and Willett, 1979).

6.2.3 Climate change policies and R&D

A relatively large number of studies has examined issue linkage in international climate change policies (e.g,: Carraro and Siniscalco, 1993, 1995, 1997; Barrett 1995,1997; Katsoulacos, 1997; Tol et al., 2000; Buchner et al., 2002; Buchner and Carraro, 2003). A common starting point of these studies is the free rider problem in international climate policy, because of its public good nature. A potential way to mitigate this problem is to combine the agreement on the public good 'climate protection' with an agreement on a private club good such as "innovation and diffusion of technologies". The difference between a public good and a club good is that while the benefits of public good are nonrival and non-excludable, the benefits of the club good (technological innovation and diffusion) are at least partially excludable, i.e., the benefits cannot be reaped by free riders (Buchner and Carraro, 2004). An international technology agreement may therefore be self-enforcing, while an international climate agreement may not . Yi (1997) provides a theoretical analysis.

Yi (1997) distinguishes between economic coalitions based on the sign of their external effects to non-members. In many instances, coalition formation either creates positive or negative externalities for non-members. Coalitions that aim to provide a public good, such as environmental protection create a positive externality, while coalitions that provide a club good to their members (such as research coalitions) create a negative externality to non-members. In case of a research coalition, a member firm gains access to all complementary research assets of all member firms, thereby conferring a competitive edge against nonmember firms and reducing the profits of non-member firms. Yi examines the conditions and rules that determine the stable size of these two types of coalitions.[36] An important rule concerns the admission of new members. In the Open Membership rule non-members can join with out the permission of the existing members, while in the Unanimity Rule non-members can only join by agreement of all members. In the case of coalitions with positive externalities (the public good coalition), the 'grand' coalition is rarely an equilibrium outcome under both membership rules, due to free-rider problems. In the case of coalitions with negative externalities (research coalitions), the 'grand' coalition is an equilibrium outcome under the Open Membership rule, but typically not under the Unanimity Rule. The reason for this last result is that while the average research costs per member decline as the coalition increases, the competitive advantages (i.e., the possibilities to increase its market share) also decline if more and more countries join the coalition. Hence, the optimal size of the club under the Unanimity Rule would be that size where the benefits of the marginal member – the reduced average costs of research–would equal the costs – a reduced competitive advantage for the existing members. A combination of negotiations on public and club goods may result in a larger 'zone of agreement' than negotiation on the public good alone. While the logic of this issue linkage seems undeniable, there is a major pitfall. Ironically, this pitfall is related to the synergies between climate change and technology agreements.

The size and nature of the climate change problem has led many observers to believe that its solution needs technological changes in key areas of production and consumption. Efficient innovation and diffusion of climate-friendly technologies is hindered by market failures in the markets for new technologies. These market failures include knowledge spillovers, resulting in less than optimal levels (or rates) of innovation and diffusion (Coninck et al., 2007; Golombek and Hoel, 2004).[37] Technology-oriented agreements primarily deal with the innovation and diffusion market failure. Some analysts consider the free riding incentives of international climate agreements to be such an insurmountable problem that they propose to replace the Kyoto 'cap-and-trade' approach by a technology-oriented agreement approach (Barrett, 2001; 2003). While this may be extreme, progress on climate-relevant technologies is of major importance for especially those countries that have committed to (costly) greenhouse gas reductions. In fact, other things being equal, technological progress in this area seems to be more important to the public good coalition than to the non-coalition parties that are being 'lured' into the coalition with the promise of an attractive technology deal.

36 For sake of simplicity, a third rule that is examined by Yi (the Equilibrium Binding Agreements rule) is not discussed here.

37 Knowledge spillovers create a wedge between private and social returns on innovation because the innovator cannot appropriate all profits from his or her invention (so the social gain is greater than the private gain). A profit-driven innovator would therefore invest less in innovation than he or she would do if he or she could appropriate the total social return on his or her innovation.

The strategy for any successful trader is to buy cheap and to sell dear, so to give away something of less value to him or her in exchange for something of more value. 'Giving away' cooperation on technology by a climate coalition in exchange for a larger coalition may not be a credible strategy. A non-coalition party may reason that technology cooperation might be of such value for the climate coalition parties, that they would not abandon the technology cooperation just because one of the parties of this cooperation refused to join the climate coalition.

Carraro and Marchiori (2003) have formalized the above ideas and arguments in a game-theoretic model. They examine under which circumstances players have an incentive to link two negotiations instead of negotiating on two issues separately. If all players have such an incentive, the choice of issue linkage can be said to be a (Nash) equilibrium of the 'issue linkage' game and will hence be the preferred strategy of all players. The game is as follows.

In the first stage of the game, countries decide whether or not to link two international negotiations: one on a public good (climate change) and the other one on a club good (technology). If they decide to link, in the second stage of the game they decide whether they sign the linked agreement. If they decide not to link, they decide whether to sign either or both of the separate agreements. In the third stage of the game, the countries set their policy variables (e.g., their CO_2 reduction targets). In this third stage, countries within a coalition act as one player. To simplify the analysis, the countries are assumed to be identical before the game starts.

Within this model, the first proposition that Carraro and Marchiori (2003) derive is that the equilibrium number of players in the linked agreement is always smaller than number of players in the technology (club good) agreement. The intuition behind this result is that the linked agreement still contains some incentive to free ride, while the technology agreement does not. Given this proposition, there are two further crucial elements in the issue linkage game. First is the relative change of the coalition sizes. The larger the increase in the linked coalition and smaller the decrease in the technology coalition, the more likely is linkage. Second is the relative change in the players' payoffs. Linkage is more likely, the larger the increased payoffs in the linked coalition and the smaller the loss from reduced cooperation on the technology agreement. And finally, linkage is more likely the higher the excludability of the benefits of the technology agreement. Or, reversely, linkage is less likely to be an equilibrium strategy if advances in technological knowledge easily spill over to non-members.

So there appears to be some trade-off implied in issue linkage. While the linkage of negotiations on the provisions of public and club goods might increase the equilibrium number of countries that want to provide the public good, it might also decrease the number of countries that engage in technology cooperation. So there is ambiguity in the outcomes of issue linkage, both in the economic as well as in the environmental domains. Issue linkage can increase the size of a Kyoto-like 'cap-and-trade' coalition, but only at the cost of a reduced size of the technology coalition. It cannot be said *a priori* whether this is good or bad for the environment.

How do these trade-offs work out in an empirical example? Buchner et al. (2002) applied a similar model to examine whether issue linkage between a greenhouse gas reduction agreement and an international R&D agreement could persuade the United States to revise its decision not to participate in the Kyoto Protocol. Using a computable general equilibrium (CGE) model, Bucher et al. suggested the answer would be 'no'. The main reason is that for the Kyoto coalition partners, the expected losses of foregoing R&D cooperation with the USA would be too high. Hence, the implicit 'threat' in issue linkage ("if you don't sign the Kyoto Protocol, we will not sign a Technology-Oriented Agreement with you") would not be 'credible', in the sense that in the event that the United States would decide not to join the linked agreement, the optimal strategy of the original coalition would in fact be to enter into a separate R&D agreement with the United States.[38] If the United States knows this in advance (and recall that the Nash equilibrium assumes that all players can anticipate each other's actions correctly), the linkage proposal offers no additional gains to the United States and so it would be rejected.

38 The strategy {link, no R&D agreement if not linked} is not a sub-game perfect Nash equilibrium.

6.2.4 Conditions for successful issue linkage

Issue linkage can enlarge the zone of possible agreement in a joint negotiation, where this zone would be absent in the separate negotiations. Issue linkage can be the equilibrium outcome of a game when it is profitable to all players, when it is stable (there is no incentive to deviate), and when it is credible. Linkage between negotiations on a climate agreement and technology-oriented agreements can enhance profitability and stability, but only if the implicit threat in linkage is credible. It has been suggested that while linkage could increase the climate change coalition it would most likely decrease the size of the technology-oriented agreement. Linkage would be a credible strategy if the latter effect would be relatively unimportant for the original climate change coalition that offered the possibility of linkage.

International technology-oriented agreements can be classified as clubs. All countries would like to join, but, depending on the rules of admission, not all countries would be welcome. However, coalitions on club goods are stable and easy to form. Climate change agreements provide public goods. Public goods coalitions are typically not stable because of free-rider incentives. Linking the negotiations about club and public goods could enhance the profitability and stability of the linked coalition in comparison to the separate public good coalition, but it would reduce the profitability and stability of the club good coalition. Whether linking is a worthwhile (and credible) strategy depends on the relative preferences of the original members of the climate change coalition over both approaches to address the climate change problem.

6.3 Case study I: Issue linkage with TOA bioethanol

The TOA bioethanol is a type-2 (knowledge transfer) technology-orientated agreement. Its members are Brazil, supplying knowledge on sugarcane crop production and the industrial ethanol production system, the Southern African Development Community (SADC) supplying the land and resources, and the European Union (EU) supplying the finances in return for a supply contract to buy the ethanol to meet its domestic biofuel targets and its GHG emission reduction commitments. The details of this TOA can be found in Part I of this report.

There would be incentives for the parties to cooperate on the TOA. Brazil would be rewarded for its technological knowledge, SADC would benefit from increased economic activities, and the EU would create a secure import source of bioethanol. We assume that these advantages would exceed the potential disadvantages mentioned in Coninck et al. (2007) so that the TOA would, by itself, be profitable for all parties. What could be the reasons to link this TOA to the post-2012 negotiations on an international climate change regime? A reason could be to let the TOA be conditional upon Brazil's willingness to agree to some sort of greenhouse gas reduction targets under this future regime.[39] Many observers of the climate change problem have expressed the opinion that it is essential that fast-growing developing countries such as China, India and Brazil slow the growth of their emissions in order for the world to be able to stabilize greenhouse gases in the atmosphere at safe levels. We assume further that Brazil would not be willing to commit to emission standards in the period 2012-20 without some sort of compensation. Could the TOA on bioethanol provide this compensation? And would Brazil consider EU's linking strategy credible?

We can represent this problem in a simple two-stage non-cooperative game. The players are Brazil, the EU, SADC, and other Annex B countries (OAB). We assume for simplicity that SADC has no strategic interest in the matter apart from that it would like to join the TOA bioethanol irrespective of whether it is linked or not. Although OAB is not an envisaged partner of the TOA bioethanol, it would be a partner in the 'linked' regime and it would therefore also have a strategic interest in the linking proposal. In the first stage of the game Brazil, EU, and OAB decide whether to link the TOA and the negotiations on a cap-and-trade (CAT) type climate change agreement or not. In the second stage of the game, they decide, if linked, whether to sign the linked agreement or not; and if not linked, whether to sign any one of the agreements or both.

In the business as usual game – without issue linkage – we have a coalition structure where EU and OAB cooperate on GHG reduction, but do not cooperate on technology, that is, they decide

39 It could also be possible to subject SADC to the same sort of conditionality. But given the relatively small contribution of SADC to the climate change problem and for the sake of simplicity we ignore this possibility.

non-cooperatively on technology policy. Brazil decides non-cooperatively on both GHG reduction and technology. This coalition structure can be compactly written in formula:[40]

$[(EU, OAB)_k, EU_t, OAB_t, Brazil_{kt}]$

where a coalition of more than one region is placed between round brackets (…) and where non-cooperating regions are depicted as singletons. GHG emissions reduction policy is depicted by subscript k, while technology policy is depicted by subscript t.

If issue linkage is effective, a coalition structure forms where EU, OAB and Brazil cooperate on GHG reduction (k) and EU and Brazil cooperate on technology (t).

$[(EU, OAB, Brazil)_k, (EU, Brazil)_t, OAB_t]$

Issue linkage is profitable to all countries if all countries prefer issue linkage above business as usual.

$P_i\ [(EU, OAB, Brazil)_k, (EU, Brazil)_t, OAB_t] > P_i\ [(EU, OAB)_k, EU_t, OAB_t, Brazil_{kt}]$

Where $P_i[.]$ is the welfare function (payoff) of country i = {EU,OAB,Brazil}.

We have assumed that linkage is profitable for the EU. Whether issue linkage is profitable for Brazil depends on the balance of the cost of joining the CAT and the benefits of participating in the TOA. We assume that Brazil perceives net costs in joining the CAT because otherwise issue linkage would not be necessary. An interesting question pertains to the OAB region. Are the benefits that the OAB countries receive from the expansion of the CAT coalition with Brazil enough to compensate them for a possible loss of competitiveness in the market for bioethanol?

Next we check the stability conditions of the linked agreement. If Brazil would either free ride on the TOA or on the CAT it would lose all benefits because of issue linkage. In this case the coalition would return to the business as usual coalition that was described above. Consequently, Brazil has no incentive to free ride if linkage is profitable (see the profitability assumption above for i = Brazil).

The other countries are committed to CAT cooperation. Therefore the EU can only free ride on the TOA, and the OAB countries cannot free-ride on anything. If the EU free rides on the TOA, the coalition structure is again the business as usual coalition. Therefore, the EU has no incentive to free ride if linkage is profitable. In fact, in this case the stability conditions are not very interesting. Free-riding in this case means killing the agreement. Therefore stability is assured because the linkage proposal is profitable to all players.

Finally we check the credibility of the issue linkage proposal by the EU. Is it credible that the EU would exclude Brazil form the TOA bioethanol if Brazil would not comply with the CAT? The issue linkage is credible if the EU would prefer to 'kill' the TOA bioethanol in case Brazil would defect from climate (CAT) cooperation. And this is a critical condition. It basically says that the EU should not care very much for the TOA bioethanol if it wants to use it for issue linkage. If the EU does care about the TOA bioethanol as a means to meet its domestic biofuel targets and as a means for complying with its international GHG emissions reduction commitments, it should not link the TOA to the CAT negotiations, but negotiate the TOA separately on its own terms. In fact, this result confirms the conclusion of Cesar and De Zeeuw (1996) that it is best to link two issues where each player has one issue it cares about and one where it does not care about.

The conclusions on issue linkage in the TOA bioethanol case in the different CAT variants are summarised in Table 6.1. Conditions for successful issue linkage relate to profitability, stability and credibility. The essential condition for a separate TOA is profitability for all parties to the TOA. Essential conditions for a linked agreement (in one of the multi-satge variants) are profitability for all parties to the TOA *and* the CAT, stability and credibility of the implicit threat.

Table 6.1:

40 Note that we neglect SADC for reasons outlined above.

Table 6.1: Discussion of conditions of successful issue linkage between cap-and-trade variants and the bioethanol TOA

Cap-and-trade variants		Separate	Linked
Kyoto-continued		Profitability: All regions could potentially benefit from TOA. Profitability would depend on alternative options for Brazil and SADC (which have not been examined in this chapter). Stability: Assured because agreement is a club.	Not applicable (in Kyoto-continued it is assumed that Brazil and SADC do not take on reduction commitments).
Multi-stage	No-lose	Idem as Kyoto-continued	Profitability: TOA might increase profitability for Brazil and SADC; unclear for OAB region. Stability: no problem if profitability condition is met. Credibility: Issue linkage could be successful if EU would in itself not be very interested in TOA bioethanol. Otherwise, the credibility of the implicit threat in issue linkage is questionable
	Intensity	Idem as Kyoto-continued	Idem as No-lose

6.4 Case study II: Issue linkage with TOA CCS

The TOA CO_2 Capture and Storage (CCS) was described in Section 5.2.4. It is an agreement between a group of countries to install CO_2 capture on new fossil fuel-driven power plants in the period 2012-2020 and to store the captured CO_2 and to retrofit old (>35 years) power plants with this technique. The group of countries include EU, Russia, USA, China and India.. Annex I countries should install CCS on all new and old (>35 years) plants, but can choose to offset up to 50% of their obligation by financing CCS (or renewables) in the non-Annex I countries. China and India agree to install CCS on 50% of their new power plants. There is also a fund to which Annex I countries contribute and from which technology transfer to non-Annex I countries is financed. All countries enact legislation to this purpose and also enact legislation to store the CO_2 in a responsible way, according to internationally agreed standards for best practice. Part I of this report contains a full description of this agreement.

The incentive structure of this TOA is complex. The TOA focuses on a specific technology (and therefore provides a club good) but it also provides a public good as the technology directly reduces GHG emissions. We may assume, however, that countries have no incentive to free ride on the TOA once they have perceived it as profitable. In this sense, the TOA CCS provides a club good to its coalition members.

What is striking, however, is the mutual interdependence between the TOA and the CAT in this case. The profitability of the TOA for countries such as China and India seems to be conditional on their cooperation in a CAT. Hence, for China and India the TOA is not only an incentive to join the CAT (traditional issue linkage), the CAT is also a condition for the TOA to be profitable. China and India need the CAT to be able to sell emission reduction credits that will be generated with the CCS technology. We assume that the sale of the emission reduction credits is a necessary condition for the TOA CCS to be profitable for India and China. But the interdependency of CAT and TOA means that once India and China perceive the TOA as profitable, they have no incentive to free-ride on the CAT (without the CAT the TOA would be worthless). Hence, in this direction there is no credibility problem for the EU: there is no danger that India and China would defect from the CAT but would like to remain in the TOA. There may be a credibility problem with respect to the US. Would the EU want to kill the TOA CCS if the US would defect from the CAT?

In this case, the compatibility of the CAT and the TOA is natural. The TOA needs the CAT to be profitable. But while issue linkage in this case seems to be a necessary condition for profitability of the TOA we do not know whether it is a sufficient condition. To examine these conditions more closely, we need to distinguish between the different groups of countries and alternative designs of the post-2012 climate change regime.

6.4.1 Kyoto-continued

In the Kyoto-continued regime, the EU and Russia (RU) have reduction commitment (a 'cap'), India (IN) and China (CH) do not have reduction commitments, but can host CDM projects, and the US is not part of the coalition. In our terminology, the TOA CCS is therefore partly instrumentally additional and partly geographically additional. In the Kyoto-continued regime, the EU and Russia can, if they so wish, enact CCS legislation as a way to conform to their reduction targets. If allowed by the CAT Agreement, they could use the CDM instrument to finance CCS in India and China.

The TOA CCS would commit the US, China and India to more emissions reduction efforts than under the Kyoto-continued regime. We examine why it could nevertheless be profitable for these countries as well as for EU and Russia:

US: the TOA could be profitable for the US because of its technological lead in fossil fuel, especially coal-based technologies, including CCS technologies. A TOA CCS could open-up a huge market for US-based technologies. If the US would perceive the TOA CCS as profitable, issue linkage might be a way to buy the US into a CAT, but the US itself would not need the CAT to enjoy the benefits of the TOA CCS.

India and China: the TOA would be profitable for India and China if they believed that it would bring more secure benefits than achievable under the CDM mechanism under the Kyoto-continued. Hence the benefits of the TOA CCS should be considerably larger for these countries than non-cooperatively (unilaterally) enacting CCS legislation and selling emission reduction credits through the CDM mechanism (if Kyoto-continued would allowed CCS as a CDM project). Once the countries perceive the TOA as profitable, there is no reason for them to free-ride on the CAT.

EU and Russia: For the EU and Russia the TOA can be profitable because of climate concerns and because of technological expansion. The TOA might stimulate the interest of India and China in a CAT and it might, if linked, give an incentive to the US to participate in a linked agreement. While TOA-CAT combination would be natural for India and China, it would not be so for the US which would still have an incentive to free ride on the CAT agreement.

6.4.2 Kyoto-multistage

An alternative to the Kyoto-continued regime is the Kyoto-multistage regime in which non-Annex I countries take on reduction commitments if they pass some threshold in terms of per capita wealth and/or emissions. In the Kyoto-multistage regime, the TOA becomes more attractive for India and China, provided that these countries pass the said thresholds and take on intensity or no-lose targets. For the other regions there is no difference with the Kyoto-continued regime.

The conclusions on issue linkage in the TOA CCS case in the different CAT variants are summarised in Table 6.2. The main conclusions are that the profitability of the TOA for India and China increases, the more they are integrated into the CAT and have a secure market for their emissions credits, and that although a linked agreement might be attractive for the US, much depends on the relative costs and benefits of the TOA and the CAT.

Table 6.2 Discussion of conditions of successful issue linkage between cap-and-trade variants and the TOA CCS

Cap-and-trade variants		Separate	Linked
Kyoto-continued		Profitability: TOA CCS would not seem to be very interesting for India and China without further integration into CAT agreement. The alternative for these countries would be non-cooperative CCS and the sale of credits through CDM (if allowed). Stability: Assured because TOA is a club.	Profitability: Explicit linkage is not necessary for India and China, because participation in CAT is necessary condition for TOA to be profitable. The gain for EU and Russia would be wider participation in CAT. Stability: US might still have incentive to free-ride on CAT. Credibility: Would the implicit threat to the US be credible?
Multi-stage	No-lose	Profitability: TOA CCS would potentially be interesting for India and China (sale of credits), and for US, EU and Russia for different reasons (market expansion for technology). Stability: Assured because TOA is a club.	Profitability: Possibly more profitable for China and India because of secure market for emissions credits. Stability: US might still have incentive to free-ride on CAT. Credibility: Would the implicit threat to the US be credible?
	Intensity	Idem as No-lose	Idem as No-lose

6.5 Conclusions

In this chapter we tried to approach the question of compatibility of TOA and CAT approaches in international climate change policy by non-cooperative game theory. This theory provides a clear and logically consistent framework to think about situations of strategic interaction. The chapter confirms one important conclusion from the literature on issue linkage in climate policy: issue linkage can increase cooperation on emission reduction, but will decrease cooperation on technology development and diffusion. In the case study of the TOA bioethanol we concluded that this aspect of issue linkage could face the EU with a real dilemma. In fact, if the EU would have strong preferences for both a CAT agreement and a TOA on bioethanol, it would be probably wise not to link them together, but to pursue them separately on their own merits.

The case of the TOA CCS is more complex. Different groups of countries have different incentives and so the profitability, stability and credibility of a linked agreement become difficult to analyse. We tentatively concluded that linkage of CAT and TOA for India and China are 'natural' (without CAT no TOA), but that the linkage would be problematic (or at least ambiguous) for the US.

Our application of the theory did not lead to firm predictions of behaviour of countries and regions with respect to TOAs and issue linkage. For firmer predictions we would need more information on costs and pay-off functions and we would need a deeper understanding of the strategic incentives of some of the options. Moreover, we would also need to have a better understanding of the institutional challenges and constraints regarding the compatibility question. It is to these institutional challenges and constraints that we turn to in the next chapter.

7. An institutional compatibility assessment of technology agreements and cap-and-trade approaches

Chapter 6 has described a game-theoretic perspective on the co-existence of TOAs and cap-and-trade regimes. It has primarily addressed the reasons why a country might be persuaded into agreeing to a cap-and-trade regime through issue linkage with technology. It therefore primarily examined the game-theoretic approach of shifting interests of various parties in the climate negotiations, in an instrumentally additional context; i.e., for a country to participate in the TOA, it has to participate in the cap-and-trade agreement as well.

This chapter takes the notably different view of geographically additional agreements. It assumes that the treaties have already been agreed and discusses, for different ways of co-existence, how the TOAs and cap-and-trade agreements interact, and, contrary to Chapter 3, doesn't speculate on the process of agreeing on the treaty.

The theoretical framework of the study is the situation of fragmented international regimes, and applies the insights resulting from that literature to the climate regime. First, therefore, the chapter provides a review of the existing, theoretical literature on the co-existence of international institutions. Secondly, it asks the question: what happens to the institutions involved if different countries sign up to cap-and-trade agreements and TOAs? How would such a landscape affect the entire climate regime?

7.1 Fragmented regimes for climate change

There is an ongoing academic debate on the consequences of the increasing density of organizations in the international institutional playing field. There seems agreement in the literature that this increasing density leads to fragmentation of the regime complex, in the sense that there is more overlap and specialization of international treaties, and less international coordination. There is, however, by no means a definite answer as to whether such large variety of partially overlapping treaties would decrease the effectiveness of reaching solutions. The answer whether centralization or fragmentation leads to a better outcome depends on the perspective taken; i.e. an international lawyer will look at the issue differently than a political economist. It also depends on the specifics of the issue area. Where for economic trade issues, a fragmented regime may be adequate, for a more fundamental issue such as human rights, a centralized regime may be regarded as more appropriate (Tahvanainen, 2004).

It is regularly argued for fragmentation that a plurality of regimes results in healthy competition for influence, resulting in the most effective means to reach a target (Charney, 1996). It is also seen as a logical symptom; an "institutional expression of political pluralism internationally" (Koskenniemi and Leino, 2002). Any problems caused by such plurality of international regimes, such as isolation and lack of coordination, would supposedly be solved by the increasing number of networks that impact the regimes and that would solve problems of coordination (Raustiala, 2002).

In response to these rather optimistic earlier publications, however, a number of political theorists started pointing at weaknesses in fragmented regimes. It started with highlighting a methodological problem: Keohane and Nye (2001) elaborate on the increasing difficulty of contemplating and studying single international organizations, as they should be seen in an increasingly important and complex context. Raustiala and Victor (2004) invented the term 'regime complex' as a substitute for an international organisation. They use the example of the various treaties impacting on plant genetic resources as an example of how changing insights in an issue area result in a dynamic regime complex with a host of different rules and a lack of legal consistency. This conveniently leaves room for all nations involved to interpret the rules as they like it, but it doesn't provide a consistent backdrop for a common solution. Benvenisti and Downs (2007), finally, even go beyond this and argue that fragmentation is detrimental for the interests of small states, and is even used by powerful states as a strategy to further their own goals at the expense of weaker others. Such purposeful use of fragmentation as a power-enforcing strategy, they argue, makes it resistant to reform by consistency-enhancing features such as networks, and moreover obscure implementation of treaties and reduce accountability.

In the light of the above, the move of the United States to found the Asia-Pacific Partnership on Clean Development and Climate (AP6), as well as a number of one-issue technology-oriented agreements, could be interpreted as a deliberate strategy to pull Parties out of the Kyoto Protocol and even the UNFCCC context into a more attractive, because less ‘deep’ agreement. This inference is confirmed by some observers (Asselt, 2007). However, it is also clear that the AP6 falls short of providing a credible solution for the climate change problem and the reduction of greenhouse gas emissions.

A requirement of the TOAs we will discuss further on in this chapter is therefore that they should be environmentally effective (or: having a significant global impact on GHG emissions), which, we established in Part I, is the case for the CCS and Bioethanol TOAs. This in itself reduces the chance that the TOAs are used as token agreements to divert attention from the cap-and-trade regimes, but it doesn’t rule out the possibility that other negative impacts of the emergence of a climate regime complex manifest. This we investigate in the sections below.

7.2 Separate

As explained in section 5.3.1 in the case of separate co-existence of the CAT and the TOA there are no institutional or economic linkages and the regimes operate in parallel. The main interactions are potential overlap when countries are signatories to both regimes, and a ‘technology bias’ introduced by the TOA compared to the more market-based approach in the CAT.

For countries that are part of both regimes there will be no possibility to transfer carbon credits generated in one regime to the other. They will have to achieve both their commitments independently. This could be less than optimal from an economic point of view, but prevents difficulties of finding ways to link the schemes (Philibert, 2005). A point of attention should be the long-term view: if it is envisaged that the regimes be linked in the future, it could be useful to stimulate some interaction between the bureaucracies so that GHG accounting and policies may become more easily linked in the future.

In TOA countries also having a CAT target, a technology bias is likely to be introduced by the TOA compared to the CAT-only scenario: higher diffusion of the TOA technology, and lower diffusion of other mitigation technologies, and thus, theoretically, a higher price of emission reductions. Although there is a theoretical possibility that a CAT agreement could push a technology so far to make the TOA on that technology obsolete, normally a TOA for such a technology would not be necessary so such a TOA would not be agreed. Also, if participation of the TOA does not fully overlap, the TOA would still have an effect in the country that has not signed up for the CAT agreement.

A new additionality question also needs to be answered: to what extent are GHG reductions created by TOA technologies implemented still eligible for trading? E.g. can India claim CERs for CCS implemented under the TOA to which it has signed up? This is a similar question as currently in the CDM additionality test, which says that reductions should go beyond current domestic policy in place. The presence of a TOA gives a new international context. In the ‘separate’ case it is not decided *a priori* that these reductions are non-additional, as it can be argued that there are no interactions between the regimes. If the reductions go beyond what was agreed under the TOA, all countries (under both regimes) should be able to claim carbon credits eligible for trading.

The interactions are for the bioethanol and CCS case are further specified in Table 7.1.

Table 7.1 Institutional interactions in separate TOA and cap-and-trade combinations

Cap-and-trade variants		TOA-variant	
		Bioethanol	CCS
Kyoto-continued		All countries in the TOA are also Kyoto countries. The **EU** will achieve their Kyoto target partly by using bioethanol (technology bias). In the case of own use of the biofuels, **African countries** could produce the biofuels both for export to EU and claim CERs, which introduces the possibility of double-counting (which could be difficult to resolve in the 'separate' case).	All countries except the **US** are covered by both regimes. A technology bias will be created in the **EU and Russia**. Also, demand for carbon credits may decrease as the required reductions are fulfilled through the TOA. The supply potential for CDM in **India and China** may or may not be reduced, depending on the outcome of the additionality debate.
Multi-stage	No-lose	No difference with Kyoto-continued as **Brazil** – with a no-lose target – is only technology supplier.	The **US, EU and Russia** have both an absolute GHG target and a commitment under the TOA which creates a technology bias. Whether signing up to the TOA will have an impact on the stringency of the no-lose target for **India and China** is an issue to be resolved. In one case, they are likely to achieve and go beyond their targets easily due to their TOA commitments, which will result in a larger supply of carbon credits to the international market. Double dipping is not an issue in the no-lose case
	Intensity	Similar to no-lose case	**India and China** are likely to achieve their intensity target with more ease, and will be able sell more carbon credits compared to the CAT-only case, assuming that the targets of the TOA and the CAT are set independently. If not, India and China may accept stricter targets in the CAT if they know they have to comply with the TOA.

7.3 Linked

In the case that separate institutions exist for the TOA and the cap-and-trade regime, but decisions on linking or integration of the two regimes are made, the TOA, similarly to the 'separate' case, would still introduce a technology bias in the (supposedly) otherwise perfectly competitive market of the cap-and-trade agreement, in the case that a country engages in both a cap-and-trade regime and a TOA. For the remainder, interactions would take place in the field of availability of technologies. This is a consequence of spill-over effects of technological change in the country implementing the TOA, which, if effective, brings down the costs of technologies needed to comply with the cap-and-trade regime.

For other effects, we first explore how links between the technology regime and the cap-and-trade agreement may look like. The next step is to determine the nature, scope and consequences of the linking or integration specifically for the selected TOAs and cap-and-trade examples, which is done in Table 7.2.

If there is to be a link between the institutionally separate regimes, it would mean that part of the TOA commitment of country can be met through buying credits in another country on the CAT-based carbon market. Conversely, it could mean that part of the commitment undertaken as part of a cap-and-trade agreement can be met through implementation of the TOA.

This might not be straightforward. In both of the cases above, one needs a metric that allows for conversion of the one target into the other. The first metric that comes to mind for this is emission reductions (tonnes CO_2-eq emissions reduced), although this is by no means unproblematic. The advantage is that the metric of cap-and-trade agreements is already stated in terms of tonnes of greenhouse gas emissions, or emission reductions, and that the technologies implemented also lead to reductions in emissions. It gets more problematic if the details are taken into regard. What baseline, for instance, for the emissions would need to be assumed in the country that only signs up for the TOA, and that wants to sell credits on the market of the cap-and-trade country? When can such credits be regarded as additional? And how do we deal with the fact that the bioethanol-TOA regulates supply or production of fuel, whereas the cap-and-trade agreement measures the demand or consumption?

The most likely outcome might be, in the case of the cap-and-trade variants, to treat the TOA obligation as a policy and apply procedures similar to the first, hesitant proposals for ‘Policy CDM’ as they are now discussed and might be implemented in the context of improving the Clean Development Mechanism (CDM). It could even be decided that the policy baseline would be the sectoral baseline of the country that signed up to the cap-and-trade agreement. In the specific case of the bioethanol-TOA, the reductions of emissions take place in the Annex-I countries, so they are automatically accounted for in their national inventories.

If the country that signed up to the TOA wished to achieve part of its agreement through the purchase of carbon credits from the cap-and-trade system, a similar operation would have to be done, although it could also be argued that the compensation would be one-way. Based on a baseline, the amount of credits required to compensate for the non-implementation of an action under the TOA would be calculated, and non-compliance with the TOA would only be established if the amount of carbon credits is insufficient. Creating a linkage in general means that part of the risk of signing up to a TOA or a cap-and-trade agreement is mitigated through allowing compliance through the other.

Both in the case of the TOA-country buying or selling into the cap-and-trade treaty, and the reverse, the TOA or the cap-and-trade agreement could include a limit to the amount of compliance that can be done outside of the agreement itself. If there is a limit, the agreements are linked. If there is no such limit, they qualify as integrated.

Table 7.2 Institutional interactions in linked/integrated TOA and cap-and-trade combinations

Cap-and-trade variants		TOA-variant	
		Bioethanol from sugarcane	CCS
Kyoto-continued		In this case, all countries in the TOA are also Kyoto countries. A policy-CDM type of arrangement could be agreed between **African and EU countries**, where the African countries would sell any emission reductions by using more biofuels in their own countries, as well as selling biofuels to the EU. The TOA introduces a technology bias in the EU Kyoto-continued-implementation, and possibly also a geographical bias in policy-CDM towards Africa, which can be perceived as correcting the current low representation of Africa. The agreement has no direct consequences for **Brazil**, except potential consequences for Brazil in selling less CERs to the EU.	The countries in the TOA are not all Kyoto-countries; the US is not. The question therefore is how to link with a non-Kyoto party. If **the US** would like to buy credits from, or sell them into the Kyoto-continued agreement, a baseline would have to be established which may be methodologically challenging. To guarantee environmental integrity of the Kyoto-continued agreement, the baseline of the **EU or Russia** could be adopted. A policy-CDM-type of agreement could be agreed between **China and India**, as Kyoto-ratifying countries without a binding target.
Multi-stage	No-lose	**African and EU countries** can trade similarly as in the Kyoto-continued case. The TOA introduces a technology bias in the EU Kyoto-continued-implementation, and possibly also a geographical bias in policy-CDM towards Africa. **Brazil** has a no-lose target under multi-stage but the TOA does not affect that as Brazil is only technology supplier in the TOA, and there are no consequences in its own emissions.	For the **US, Russia and the EU**, the treatment would be the same as in the Kyoto-continued agreement. **India and China** are subjected to a no-lose target, and sales of emission reductions below the no-lose baseline scenario would lead to double-dipping (or: double funding for the same effort) . This can be avoided through taking account of the TOA emission reductions in the no-lose baseline scenario. One could also decide to allow double-dipping to provide an extra incentive to sign up to the TOA and the multi-stage agreement.
	Intensity	Similar to the no-lose variant of multi-stage.	Similar to the no-lose variant of multi-stage. The accounting of carbon credits is likely more complex because of the use of relative (intensity) rather than absolute targets.

Recalling the factors and constraints used to determine the political feasibility of the stand-alone TOAs, the advantages of linked regimes in terms of political feasibility lie primarily in the flexibility regarding timing and number of actors. In terms of timing, the treaty agreed on first would be determining the linking rules laid down in the other treaty. (Would they be negotiated simultaneously, they would count as a 'joined' regime.) The number of actors in the TOA can be kept flexible as well (assuming that the participation of cap-and-trade regimes is broader), which allows for easier negotiations, but possibly also to equity constraints as late entrants would have to play by the rules of the club that initially started the agreement. This was also mentioned as one of the problems of fragmentation (Benvenisti and Downs, 2007).

7.4 Joined

It will be recalled that under the Joined scenario the TOA and the CAT are institutionally one and the same, as they form different but integral parts of the larger rubric of the climate agreement. It will also be recalled that countries subscribing to this larger Joined agreement have the option to employ, as with the linked scenario, one or both means of emissions reduction strategies, CAT or TOA. Although this is not necessarily a simple task, for the sake of the argument we will assume here that the problem of the conversion metric encountered in the linked scenario is essentially solved. The issues of targets (either intensity or absolute) and baselines are also predetermined or pre-negotiated as well as the manners in which those targets will be achieved; either through CAT or TOA. This though is also the main political and technical drawback of this Joined scenario.

Whereas with the linked approach, baselines and targets are agreed upon by the parties under the framework of either a TOA or CAT agreement, within the joined scenario a commonly agreed upon set of targets, baselines and deadlines would have to be negotiated before the joined regime could begin. For example the USA would need to agree to a specified baseline and target if it were to participate in the joined agreement.

Table 7.3 Institutional interactions in joined TOA and cap-and-trade combinations

Cap-and-trade variants		TOA-variant	
		Bio ethanol	CCS
Kyoto-continued		As all the countries under this scenario are Kyoto signatories this arrangement affects very little the actions of the countries. The only significant interactions to note is that since the TOA is an integral part of the climate agreement the accounting of carbon credits (if the African countries decide to use the biofuels itself) is made easier if compared to the linked scenario.	In this case, since the US is not a party to Kyoto and has no general baselines or targets but wishes to participate in the joined regime, a baseline and target would need to be negotiated on the amount of CO_2 that could be reduced by the use of the CCS-TOA. The **EU** and **Russia** still have their full range of commitments of which CCS will deliver a portion. The amount agreed upon by the US could be a correlated matrix of that which either the EU or Russia as Annex I parties believe can be achieved through CCS. Any ‘extra’ reduction stemming from CCS in the US could be ‘sold’ to third party Annex I countries, via a mechanism similar to JI. Alternatively, if the US were to aid **China** or **India** in implementing CCS through the flexible mechanism in the CCS-TOA, then the US itself could gain credit to be applied to their pre-negotiated emissions reduction target, similar to CDM.
Multi-stage	No-lose	Similar to the linked scenario, **SADC** and the **EU** can trade carbon credits; it is only made easier as the accounting scheme is under one regime.	For the **US**, **Russia** and the **EU** situation is as above. As with the integrated scenario, China and India have no-lose targets of which a portion can be achieved by the use of CCS. In this case however reductions below an agreed no-lose baselines would simply go into the common pot of credits for the Joined agreement, no double dipping could occur, resulting in a standard CDM-type arrangement, if the other sectors to which the no-lose target applies perform according to expectation.
	Intensity	This situation would not vary from the ‘No-lose’ above.	Again for the US and Annex I countries the situation remains as under KP. For China and India any credits gained by the use of CCS would be attributed to the common accounting scheme under the Joined agreement. The accounting of carbon credits may be more complex because of the use of relative rather than absolute targets.

Politically speaking, the Joined regime might be more feasibly implemented than the Linked regime, regardless of the actual TOA case involved, but assuming that the TOA is a technology-pull agreement (for a R&D agreement, linked or separate agreements are sufficient). One can postulate that the administrative and transaction costs of creating two institutionally separate yet compatible carbon accounting schemes might be prohibitively high thus making such an option unattractive, especially if participation in TOA schemes is low.

Referring back to Part I of this report, the discussion of political feasibility revolves around a discussion of key factors and constraints. What then are some of those factors and constraints associated with the implementation of a Joined regime? The first is that a convincing enough argument is made that TOAs are environmentally effective enough to be fully incorporated into the global climate regime, that their value added would be broadly applicable to a diversity of parties. This we have endeavoured to show by highlighting the technical additionality of TOAs as well as the range of actors that have the potential to participate in them. The second issue has to do with advocacy and timing. If TOAs are a path to pursue, the discussion of them in the post 2012 regime needs to be advocated or lobbied for by a coalition and must be brought to the negotiating table at the earliest opportunity.

It is conceivable that the discussion of TOAs emerges after an initial framework for a new regime is settled. This would in all likelihood lead to either the Separate or Linked scenario as discussed earlier. At present there have been no obvious, broad, policy windows to leverage the issue of a Joined regime. Nevertheless, the time and timing for engaging in such a discussion is opportune. The one main institutional constraint, as stated above, would be the necessity for defined baselines and targets to be associated to particular TOAs, especially for those countries that would still choose not to employ cap and trade mechanisms. Institutionally then there would need to be a strong body within the regime to oversee the accreditation of all potential TOAs. In which case, TOAs could be taking the route of policy-based CDM for CAT-parties without a target, or a means of participating in the same regime for non-CAT parties.

7.5 Conclusion

In this chapter, we have outlined how two different hypothetical TOAs might co-exist with three potential post-2012 cap-and-trade variants. When the TOAs and cap-and-trade agreements are institutionally completely separate, but there is overlap in participation, the interactions will be limited to 1) technology bias in the realisation of emission reductions under the cap-and-trade agreement, and 2) impacts on baseline setting and CDM additionality for non-Annex I countries in the Kyoto-continued case, and all countries that do not have an absolute target in the multi-stage case. When the TOAs and cap-and-trade agreements are linked or joined, there are will be challenges in agreeing on a metric for conversion of the achievements under the TOA into the achievements under the cap-and-trade variant. These challenges are likely to be greater in the case of the bioethanol-TOA compared to the CCS-TOA, as the implications of the bioethanol-TOA are on the demand-side and are inherently more uncertain than the CCS-TOA, which directly regulates emissions.

Part III: Conclusion

The objective of this report was to explore what would be the political feasibility, environmental effectiveness, and institutional interactions of the international climate regime complex, if TOAs and cap-and-trade approaches co-exist. Hypothetical proposals for climate-change TOAs have been evaluated for their environmental effectiveness in Part I of the report. In the scheme below, the environmental effectiveness, costs and political feasibility are summarised in a qualitative way.

The environmental effectiveness (i.e. the emissions reduction the agreement is to achieve) depends on the type of agreement. If the agreement is certain to lead to emission reductions (because inherent in the agreement), the environmental effectiveness is described as 'guaranteed'. However, if the agreement only aims to take away political or legal barriers to deployment of the technology, the environmental effectiveness cannot be guaranteed. The emission scope of the agreement is also assessed here; as the ammonia agreement only covers a small amount of greenhouse gas emissions, its effect is small, whereas the scope of a CCS agreement is much larger, and its effect is large.

Cost burden is partly dependent on the scope of the emission reductions, especially if they cannot be achieved at low or negative mitigation costs. Sometimes, such as in the case of bioethanol, the costs depend on domestic policies (biofuels obligation in EU) or on oil and gas commodity prices. Although the cost effectiveness is not comparatively assessed in this report, and cost effectiveness of TOAs is almost certainly significantly lower than the cost effectiveness of a global cap-and-trade agreement, the likelihood that emissions reductions are complied with in areas where they are relatively cheap are estimated to be higher in the case that a TOA is agreed on them.

The outcome of the political feasibility assessment is also summarised in the below scheme, where in most cases it is a diffuse balance between positive and negative aspects.

	Environmental effectiveness	*Cost burden*	*Political feasibility*
Bioethanol	Large and guaranteed	Medium	High, although concerns on social/equity constraints should be taken into account
Nuclear energy	Potentially large but not guaranteed	Small	High as agreement is in place; low if NPT problems is considered
Cement	Large and guaranteed	Small	High because of low cost burden; low for large number of actors
Ammonia	Small but guaranteed	Small	High
CCS	Large and guaranteed	Large	Low because of cost burden, may be medium because of positive technology perception and high for good compatibility with vested interests in fossil-fuel sector
Cars	Large and guaranteed	Large	High because of small number of actors; low as technology forcing agreement meet resistance

The scheme above shows a striking variability in TOAs. TOAs are not a straightjacket for a climate regime: they offer flexibility to align the incentive structure with both the technology or sector that is targeted and the countries that participate. Part I of this report thus concludes that a number of TOAs could be explored and, through balancing factors and constraints, might be politically feasible as well as environmentally effective. Costs can be high, and can pose barriers to implementation. In addition, and again depending on the design, various TOAs would have social and legal consequences that would need to be addressed.

The flexibility that TOAs offer, however, also has downsides. Although costs and environmental effectiveness of a single TOA are predictable, upon agreement of the TOA it is unclear whether the overall regime will reduce emissions sufficiently, and cost predictability deteriorates if patchwork of TOAs is considered. It is therefore relevant to consider TOAs in the context of a full post-2012 regime, which was done in Part II of this report.

In Part II, we discussed the compatibility of TOAs with a number of post-2012 cap-and-trade variants. Apart from the organization and embedding of the treaty, where we have distinguished separate, linked, integrated and joined institutions, there are different ways of co-existence of agreements. We make a distinction as to whether the TOA and cap-and-trade agreements are instrumentally or geographically additional.

With instrumentally additional we mean that the TOA is applied in the country where also a cap-and-trade agreement is implemented. Based on qualitative game-theoretic analysis, we have examined whether the overall attractiveness of a climate agreement will increase as a result of the technology issue linkage. The outcome of the analysis tells us whether the approaches could or should be 'linked' in one overarching agreement. The analysis confirms one important conclusion from the literature on issue linkage in climate policy: issue linkage can increase co-operation on emission reduction, but will decrease cooperation on technology development and diffusion.

In the case study of the TOA bioethanol we concluded that this aspect of issue linkage could face the EU with a real dilemma. In fact, if the EU would have strong preferences for both a CAT agreement and a TOA on bioethanol, it would be probably wise not to link them together, but to pursue them separately on their own merits, as the EU threat to not take part in the TOA is not credible. The case of the TOA CCS is more complex. Different groups of countries have different incentives and so the profitability, stability and credibility of a linked agreement become difficult to analyse. We tentatively concluded that linkage of CAT and TOA for India and China are 'natural' (without CAT no TOA), but that the linkage would be problematic (or at least ambiguous) for the US.

Geographically additional agreements represent the case that country A pursues a TOA whereas country B pursues a cap-and-trade agreement, as well as the TOA. This has been approached based on institutional analysis, where the consequences of various modes of co-existence are assessed based on the effectiveness and functioning of the institutions. The interactions that have been identified can be readily solved by explicitly relating the cap-and-trade and the TOA, but the effort of making the full 'climate change regime complex' internally consistent with several TOAs, and varying membership, ambition and substance, would be significantly more difficult. In such a situation, the problems of fragmentation and the potential consequences in terms of accountability and increase of power of already powerful states could be severe.

Neither our application of game-theory nor our institutional analysis allowed us to make firm predictions of behaviour of countries and regions with respect to TOAs in combination with cap-and-trade variants. For such predictions, we would need more information on costs and pay-off functions, we would need a deeper understanding of the strategic incentives of some of the options, and we would have to dive deeper into the detailed developments of the various TOAs. Moreover, we would also need to have a better understanding of the institutional challenges and constraints regarding the compatibility question. An additional challenge is understanding the role of the private sector. Technologies are often not owned by states (although states often represent the interests of their private sectors), leading to a different dynamic, including complicated IPR issues, than would be the case if states would be the proprietor of the technology. Although some scholars are looking into this problem of "multi-level decision-making", this has not yet resulted in usable recommendations for international agreements that have a bearing on company competitiveness.

Although an ultimate answer to the question whether TOAs combined with a cap-and-trade regime can provide a way out of the logjam in the climate negotiations cannot be given, our analysis does give us a clue that TOAs can help. In the case that the design of the TOA introduces a beneficial reciprocity in the cap-and-trade regime, the combination of both types of agreements can lead to a better environmental outcome than a cap-and-trade treaty only, through wider participation and a dual emission target and technology diffusion target, notwithstanding the less cost-effective outcome.

This potentially positive result should be weighted, however, against the possibility of regime fragmentation and the threat that might entail to consistency and accountability of the international institutions. Responsible linking, although potentially costly in terms of administration and transaction costs, would be essential to safeguard that adding TOAs to the climate change regime would constitute a credible solution. Although there are clear benefits to trying such responsible linking, it would be challenging to bring such consistency into a more complex regime.

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Appendix A Data relevant to bioethanol TOA

Table A.1 *Sugar Cane production in 2004 in SADC* and selected other countries (from Johnson and Matsika)*

	Area harvested	Total production	Average yield	Shares of total production	
	1000 ha	*1000 tc***	*tc/ha*	*Share of SADC total*	*Share of world total*
Angola	10	360	38	0,8%	
Congo DR	43	1786	42	3,9%	
Madagascar	69	2460	36	5,4%	
Malawi	20	2100	105	4,6%	
Mauritius	72	5199	73	11,4%	
Mozambique	30	400	13	0,9%	
South Africa	326	20419	63	44,8%	1,5%
Swaziland	48	4500	93	9,9%	
Tanzania	17	2000	118	4,4%	
Zambia	17	1800	106	4,0%	
Zimbabwe	45	4533	101	10,0%	
SADC total	**696**	**45557**	**65**		**3,4%**
Australia	448	36995	83		2,7%
Brazil	5371	396012	74		29,1%
India	4608	281600	61		20,7%
Thailand	1139	74259	65		5,5%
World	**20822**	**1359120**	**65**		
Sources: FAOSTAT 2005					

*SADC: Southern Africa Development Community (SADC)
** tc: tonne cane

Table A.2 *Land Use summary for SADC countries and other selected countries*

Country/ Region	*Total Land Area*	*Forest Area*		*Agricultural Areas (a)*		*Cultivated Area (b)*	
UNITS:	***Million ha***	***Million ha***	***share of total land area***	***Million ha***	***share of total land area***	***Million ha***	***share of total land area***
Angola	124,7	69,8	56%	57,6	46%	3,6	2,9%
Botswana	56,7	12,4	22%	26,0	46%	0,4	0,7%
Congo	226,7	135,2	60%	22,8	10%	7,8	3,4%
Lesotho	3,0			2,3	77%	0,3	11,0%
Madagascar	58,2	11,7	20%	27,6	47%	3,6	6,1%
Malawi	9,4	2,6	27%	4,4	47%	2,6	27,5%
Mauritius	0,2			0,1	56%	0,1	52,2%
Mozambique	78,4	30,6	39%	48,6	62%	4,6	5,8%
Namibia	82,3	8,0	10%	38,8	47%	0,8	1,0%
South Africa	121,4	8,9	7%	99,6	82%	15,7	12,9%
Swaziland	1,7			1,4	81%	0,2	11,2%
Tanzania	88,4	38,8	44%	48,1	54%	5,1	5,8%
Zambia	74,3	31,2	42%	35,3	47%	5,3	7,1%
Zimbabwe	38,7	19,0	49%	20,6	53%	3,4	8,7%
Total SADC	**964,1**	**368,3**	**38%**	**433,2**	**45%**	**53,4**	**5,5%**
Brazil	845,9	543,9	64%	263,6	31%	66,6	7,9%
China	932,7	163,5	18%	554,9	59%	154,9	16,6%
India	297,3	64,1	22%	180,8	61%	169,7	57,1%
United States	915,9	226,0	25%	409,3	45%	175,5	19,2%

Sources: FAOSTAT 2005; World Resources Institute 2005
Note: (a) Agricultural areas include temporary and permanent pastures, permanent crops, and temporary crops. The figures do not provide any indication of the suitability or availability of the land for particular purposes.
Note: (b) Cultivated areas includes permanent crops and temporary crops

Source: *Johnson and Matsika, 2006,*