CECILIA 2050

OPTIMAL EU CLIMATE POLICY

Choosing Efficient Combinations of Policy Instruments for Low-carbon development and Innovation to Achieve Europe's 2050 climate targets

Scenarios for international climate policy instruments

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LIST OF ABBREVIATIONS

CAIT	Climate Analysis Indicators Tool
CDM	Clean Development Mechanism
CERs	Certified Emissions Reductions
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
EU	European Union
ETS	Emission Trading System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GINFORS	Global Interindustry Forecasting System
G-20	Group of Twenty
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICAR	International Carbon Reserve
IEA	International Energy Agency
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
JCM	Joint Crediting Mechanism
LULUCF	Land Use, Land-Use Change and Forestry
MRV	Monitoring Reporting and Verification
Mt	Megatonne
NAMA	Nationally Appropriate Mitigation Action
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PMR	Partnership for Market Readyness
REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
REN21	Reneable Energy Policy Network for the 21st Century
RGGI	Regional Greenhouse Gas Initiative
SRES	Special Report on Emissions Scenarios
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
USA	United States of America

1 Introduction

1.1 About this report

The CECILIA2050 project aims to find an optimal policy mix for the European Union (EU) to achieve its emission reduction goals through 2050, but the 28 member states do not exist in a vacuum. In an increasingly globalized world, it matters whether other countries – particularly the EU's major trading partners and the world's biggest economies – attempt to reduce greenhouse gas (GHG) emissions and how.

Carbon markets are the most obvious example of the globally interconnected nature of emission reduction policies: the degree to which Europe's market, the EU Emission Trading System (ETS), is linked to emission trading programmes of major trading partners can influence the optimality of the EU ETS as an instrument within the EU, as a larger overall carbon market allows emitters in that market to take advantage of a wider range of abatement opportunities. Furthermore, when producers must factor a carbon price into the cost of production, it can change the price of their goods – this has impacts on the EU's economy from a trade perspective, as it affects relative prices of energy-intensive imports and exports.

Beyond emissions trading, measures other countries take to reduce GHG can affect the relative optimality of the EU's measures – changing land management patterns (reducing the amount of tropical rainforest converted to agricultural use, or shifting to less energy-intensive agricultural practices) can affect the cost of agricultural products for which the EU is a buyer or seller. Policies that reduce major economies' fossil fuel use can affect global fuel prices, to which the EU is of course also subject and which often determine EU energy investment decisions as well as the cost effectiveness of measures from fuel switching in electricity generation to public transport system construction.

This task within Work Package 5 therefore considers the direction climate policies might take through 2050 – *globally*, rather than within the EU. By factoring the implications of other countries' policies - as well as transnational measures - into the assessment of the EU's policy mix, the models used in the project are able to reflect a more realistic context in which to seek the optimal EU climate policy mix.

1.2 Deviation from description of work

Originally, this task involved consideration of carbon markets only – based on recent political developments at the national and regional level outside of the EU and on the ongoing effort toward a global climate change mitigation agreement within the United Nations Framework Convention on Climate Change (UNFCCC), it would have laid out three carbon market scenarios of increasing scope, with no additions to the status quo being the least ambitious and a global carbon market in which all major economies participate being the most ambitious. The consortium has agreed that this approach is lacking, for several reasons.

First, a narrow focus on number and size of carbon markets only does not fully take advantage of the abilities of the project's models (such as GINFORS) which are able to include factors beyond carbon price as determined by cap-and-trade systems and/or carbon taxes. The models can incorporate as inputs the results of other policies: renewable energy support systems including feed-in tariffs or quotas, energy efficiency requirements, fuel price effects of eliminating fossil fuel subsidies, and cross-cutting policies like standards for international aviation and maritime transport. All of these factor into global emission reduction but also affect relative energy prices to which the EU is subject – to the extent that such "modelable" policies exist in the countries involved, the scenarios therefore attempt to include them rather than simply positing three different global carbon market sizes by 2030 as in the original description of work.

Beyond the desire to make maximum use of the models' capabilities, a wider approach is warranted because there is no simple correlation between the number of regions covered by carbon markets and the world's collective climate change mitigation "ambition". A more ambitious global emission reduction scenario might be achieved under conditions in which few countries actually implement carbon trading, but instead e.g. use a carbon tax and cut fossil fuel subsidies.

Another reason for the divergence from the approach outlined in the description of work is the decreasing relevance of a 'global agreement' reached under the UNFCCC (the third or 'most ambitious' of the three scenarios posited in the original description of work). An internationally agreed global carbon market scenario resembling a continuation and expansion of the Kyoto Protocol, with corresponding legally binding emission reduction targets and timetables set within the Convention for all countries is not merely unlikely – it is virtually impossible given the current state of the negotiations.[1] UNFCCC observers and participants alike argue that, while implementation of climate change mitigation actions (including creation of and linking among carbon markets) is proceeding and will likely continue to proceed, it is increasingly not doing so in the context of the UNFCCC (IETA/PWC 2013, World Bank 2013).[2]

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[1]Heller (2013) points out that "The world has moved on from the expectations that underlie the ongoing climate negotiations, but the negotiations themselves have not. The 21st Conference of the Parties will be held in Paris in 2015, with the goal of setting a course for a new global agreement. There is very little reason to believe developing countries will be willing to take on targets in some sort of relatively uniform formula, and even less reason to believe very large amounts of money are going to be transferred from the troubled developed economies to the emergent developing nations." See also Behr and Witte (2009).

[2]In their annual survey of over 700 carbon market players, the International Emissions Trading Association and Pricewaterhouse Coopers found that only one percent of respondents expect nations to meet their aim of agreeing in 2015 on legally binding emission targets for all major economies that are ambitious enough to limit global temperature rise to two degrees C. However, respondents considered implementation of planned domestic mitigation policies in key countries more likely: More than two-thirds of those surveyed thought planned emission trading systems in South Korea and China will be up and running in 2015, while just over a third expected similar national markets to emerge before 2020 in Brazil, Japan and Mexico. Ninety-four per cent of respondents expected Australia's carbon market to complete its planned link with the EU ETS before 2020 (International Emissions trading Association/Pricewaterhouse Coopers (2013).

Thus this task does compare various scenarios of different outcomes of negotiations toward a global climate change agreement in 2015, though it does make assumptions about some of the programmes being considered in the UNFCCC negotiations. Also, not only carbon markets constitute indicators of “ambitiousness” of what countries outside of the EU are doing, but also other instruments that influence global emissions pathways, including policies in the energy sector and policies affecting transnational transportation.

2 Scenario creation

Scenarios can either constitute “forecasts”, describing how alternative futures might develop from current conditions and driving forces, or “backcasts,” which start with an image of the future and aim to find plausible development pathways for getting there. Rather than focusing on current trends and conditions, backcasting takes as its starting point a desirable resolution to the problem at hand – in the case of the EU, the desired status in 2050 of having brought average annual emissions at least 80 percent below their 1990 levels.

This task represents a procedural mix of forecasting and backcasting - detailed explanations of current conditions surrounding emission reduction policies outside the EU (Section 3.1) serve as a basis for speculation about how such policies might evolve through 2050. The scenarios described in the remainder of Section 2 embody different ways such an evolution may take place, implying different global emission reduction outcomes.

What conditions the policies applied in these different scenarios produce – factors like carbon or fossil fuel prices in various years through 2050 – will be assessed by the modelling teams and used as inputs to macro-economic simulations done by e.g. the GINFORS model in Task 3.3. GINFORS outputs are then in turn used as inputs for various other modelling components of the project. The set of inputs derived from these scenarios that is used for Task 3.3 will also be relevant to Tasks 4.1 on combinations of instruments and Task 5.3 on the global effects of EU policies on countries outside the EU.

It should be noted that the scenarios in this task deal with *instruments* only. Scenarios are subject to the constraints of the models they work with, and CECILIA2050’s models do not handle weather patterns or predict GHG levels according to policy actions or the GHG reductions those actions might achieve. The narratives (also referred to as ‘storylines’) in the Intergovernmental Panel on Climate Change’s (IPCC) special report on emissions scenarios (SRES) - and the more recent incarnation of those modeling efforts, Shared Socio-Economic Pathways or SSPs - inform the analysis of climate change impacts, adaptation and vulnerabilities as well as integrated assessment of climate response strategies. This incorporates model outputs involving e.g. terrestrial climate impacts, etc, whereas GINFORS and the other models employed in CECILIA2050 measure economic policy instruments. For instance, while policies regarding reduced emissions from deforestation and forest degradation (REDD) are featured in the narratives described in this task, the models used cannot fully incorporate them because they link GHG emissions to economic production but not to forest stock. While the next generation of models espoused by the IPCC depends on scientific advances in e.g. the representation of the terrestrial carbon cycle (Moss et al 2010), the CECILIA2050 project does not aspire to such advancements in modeling per se – models are rather tools than the subject of the study, similar to global oil companies' regularly published energy outlooks (ExxonMobil 2013 and Shell International 2013).

2.1 Countries involved

Since the scenarios for this task will generate inputs to models, they are based mainly on climate policy instruments in the countries those models cover. Of the models used in the CECILIA2050 project, GINFORS is the one using scenarios in this task most directly as the source of model inputs. The GINFORS model handles a group of about 40 countries consisting mainly of EU member states. This leaves 11 countries for which the details of individual *national* climate policy evolution through 2050 are relevant, with all others belonging to the GINFORS category "rest of world."[3]

Box 1: GINFORS countries that are not EU Member States, countries currently considered "industrialised" are in bold

Europe/Asia		Americas				Asia				Oceania
Russia	Turkey	Brazil	**Canada**	Mexico	**USA**	China	India	**Japan**	South Korea	**Australia**

Conveniently, these 11 countries are among the biggest economies and largest emitters whose climate change policies matter most - with the exception of a few, such as South Africa, which is not on the list of GINFORS countries but has higher annual emissions than some that are, including Turkey. Several countries belonging to the 'rest of world' category are pursuing climate policies that could have a bearing on EU trade and global carbon prices because they feature fast-growing economies – these include medium-sized nations in Latin America and Asia like Chile and Thailand. The instruments analysed and explained below therefore include some employed by (or contemplated in) those other nations as well.

2.2 Instruments analysed

In constructing scenarios for 2050, we looked at "modelable" climate policy instruments through 2050. As explained above, these include not only emissions trading systems (carbon markets), but also other policies with emission-reduction effects. Though the focus is on carbon pricing instruments, the scenarios also incorporate effects of other national policies in the countries listed above - these include quotas for renewable power as well as the removal of fossil fuel subsidies. Further, the scenarios consider global measures to reduce

[3] The "rest of world" category includes some very high-emitting countries, particularly in terms of emissions from land use change. Indonesia, for instance, ranks among the world's 5 highest-emitting countries when emissions from deforestation are taken into account. Instruments in countries that are part of the "rest of world" are thus not addressed as a separate category, but the economies and emissions of individual nations like Indonesia are assumed to be part of relevant global instruments such as trading mechanisms for credits from avoided deforestation.

international transport emissions, i.e. emissions from shipping and aviation. The latter are by definition not country-specific, but relevant to the achievement of climate change mitigation targets given the contribution of international transport to global emissions.

2.2.1 Carbon pricing

Policies that create or imply a carbon price fall into this instrument category.

Besides the EU, several countries and regions have or are in the process of creating national **emissions trading programs or regional carbon markets**. These may in the long run become linked to each other, creating a global carbon price that incentivises emission reduction via e.g. moving away from fossil fuels toward renewable energy production. Existing markets outside the EU ETS include ones in New Zealand, the Northeastern US, and California. Several countries have plans for such markets to enter into force, are running regional pilot programs, or are exploring the possibility of using carbon trading as an instrument. These are South Korea, China, and other countries in the World Bank's Partnership for Market Readiness (PMR), respectively.

Global policies that correlate with and foster development of carbon markets in that they involve tradable credits for emissions reduction are the so-called "**new market mechanisms**" discussed in the UNFCCC (see e.g. Castro, Duwe, Köhler, and Zelljadt 2012). Current ideas for such new mechanisms involving markets are

- the potential crediting of so-called nationally appropriate mitigation actions (NAMAs), i.e. countries implementing emission reduction measures and getting credit for those on a per-tonne basis
- a potential market for reduced emissions from deforestation and forest degradation (REDD) by which forested nations (particularly those with tropical rainforest) would get credit for each tonne of GHG avoided through forest preservation – i.e. putting a value on standing forest
- the continuation of a global offset system similar to (or constituting a re-design of) the Kyoto Protocol's clean development mechanism (CDM) in which emission reduction projects in developing countries generate tradable credits that can be applied toward targets in industrialised countries

A further carbon pricing instrument is simply a **carbon tax** - a fee or charge on emission of GHG that can be levied at the producer level and has the same effect of disincentivising fossil fuel combustion relative to other energy options in electricity generation and/or transport sectors. Several countries and regions outside the EU have carbon taxes of various types, including the Canadian provinces Quebec and British Columbia. Some, like South Africa, are planning to introduce them (see e.g. Cohen 2013). Even the tax-averse US Congress has seen discussion of carbon tax implementation in recent years as a deficit-reduction measure linked to increased revenue (Carbone, Morgenstern, Williams and Burtraw 2013).

2.2.2 Energy policies at the national level

Several policy instruments do not price carbon, but are relevant to climate change mitigation because they influence the degree to which fossil fuel combustion is used in electricity generation or for transportation.

Many countries employ **feed-in tariffs**, or guaranteed prices for renewably generated electricity, as an incentive for renewable power. Some set **quotas** for the proportion of renewable power sold to consumers, with "green certificates" or certificates of origin representing units of renewably-generated electricity that can be traded among power sellers to meet the quota. Other incentives that favour renewable electricity over construction of fossil fuel burning facilities include loan guarantee programs, tax credits, and expedited permitting for renewable energy facilities. **Energy efficiency policies** can be reflected by incorporating greater or lesser changes in final energy demand over time. Such policies include standards for e.g. electricity use in appliances or fuel use in vehicles. Energy efficiency can also be a market instrument: India, for instance, has a system of tradable credits for energy savings achieved relative to a baseline under which energy-using entities can "trade" units of energy savings to meet prescribed efficiency targets (Krishnan 2013).[4] Various forms of all of these policies either exist already or are being considered in the world's largest economies. As the GINFORS model incorporates renewable energy policies in the form of quotas, the scenarios express the above policies only in that form.

A further type of instrument at the national level that has significant climate change relevance is the **removal of fossil fuel subsidies**, since these distort the relative cost of fossil fuel combustion relative to other energy sources (see e.g. IEA, OPEC, OECD, and World Bank report 2011). Although the actual removal or alteration of an existing fossil fuel subsidy is an act of *national* (domestic) policy, this instrument can also be considered a global one because of the fact that subsidy removal requires *international* coordination as explained above.

2.2.3 Climate measures in global sectors

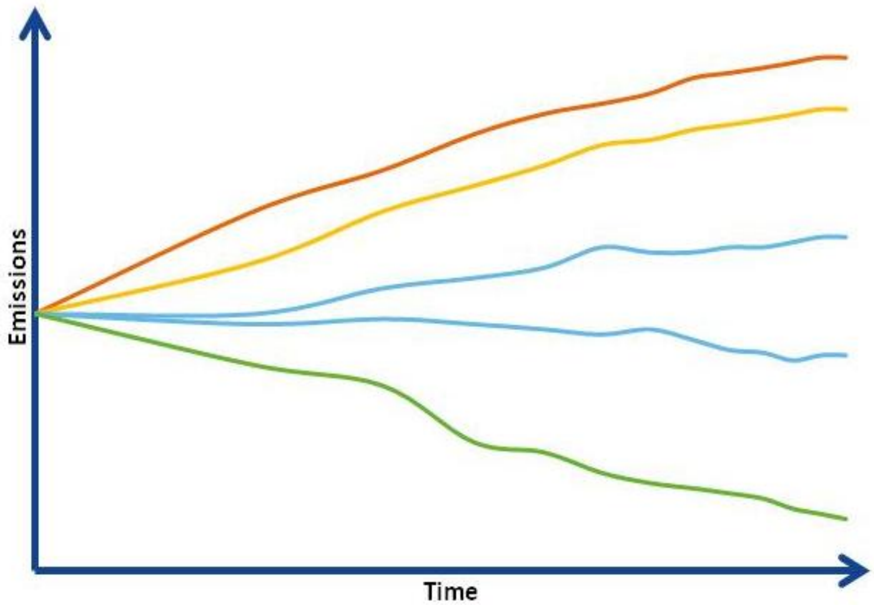
Similar to the international coordination required to lower subsidies, two other large sources of GHG emissions are global in nature and can therefore only be addressed via multilateral agreement of some kind: emissions from international **maritime transport** (shipping) and from **aviation**. These emissions by definition occur outside the boundaries of individual nation-states and therefore require mitigation measures beyond national or regional policies, though individual nations or regions can exercise a degree of unilateral power by setting entry requirements for their ports and harbours.

[4] See also document prepared for World Bank Partnership for Market readiness on India's "Perform, Achieve, and Trade" program, available online at
http://www.thepmr.org/system/files/documents/India_Market_Mechanism_Promote_EE%26Renewables.pdf

2.3 Conceptual methodology

How many of the major emitting countries employ instruments explained above, and how stringent those instruments are, will help determine global emission trajectories. Thus different international combinations of instruments make for different global emissions pathways through 2050. Figure 1 shows several such hypothetical pathways, with the red one representing a scenario in which policies are rolled back or become less stringent than they are now, the orange one showing a trajectory under policies no more stringent than the status quo, the blue lines framing some “middle of the road” policy developments and the green line (in which emissions decrease significantly over time) representing a “successful” combination of instruments from a climate perspective: one that results in the reversal of the current rising global emissions trajectory.

Figure 1 Hypothetical emission trajectories



However, there are endless combinations of instruments, given all the countries and approaches in play. Our scenario-building process thus involves an assessment of possible instrument pathways that can lead to the different emissions trajectories embodied in Figure 1.

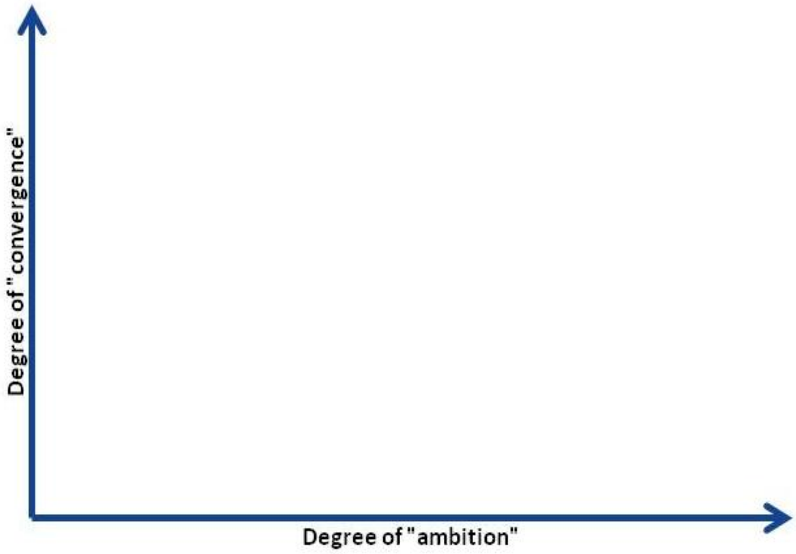
2.3.1 Criteria

We categorized the above-described instrument pathways along two main assessment criteria, each of which can be expressed as a relative measure of ‚degrees‘ along e.g. an axis. The first criterion is the degree of **ambition**, defined both in terms of breadth as well as stringency. Using the instrument of carbon markets as an example, ambition includes in this case the breadth in terms of coverage (how many countries or regions have carbon markets?) as well as stringency (how tight are the caps in those carbon markets?). Ultimately the degree of ambition impacts the GHG abatement potential of an instrument mix – more ambition equals a larger reduction.

The second criterion is a more political one: degree of **convergence** among stakeholders applying the respective policy. This measures homogeneity of the instrument and the extent of harmonisation among regions – using the example of carbon markets, it assesses how similar the various carbon market structures are and how closely these markets are linked.[5] Ultimately the degree of convergence impacts policy efficiency and distributional effects of the instrument mix: if some countries have carbon markets, these may be very stringent (high ambition) but not necessarily similar or harmonised – the latter is important for distributional effects reflected in our models.

Both ambition and convergence can be measured on a continuum as a matter of degrees, i.e. a scenario may have more or less (lower or higher) ambition *and* more or less (lower or higher) convergence. Combining the factors using axes allows scenarios to be more nuanced and multifaceted, while still able to be depicted graphically and conceptually.[6]

Figure 2 Degree of instrument ambition and convergence



The *ambition* of other instruments assesses mitigation action in terms of coverage by evaluating how many countries employ the instrument, e.g. subsidise renewable energy, scrap fossil fuel subsidies, or reduce energy supply. The metric also embodies the relative stringency of the instrument by evaluating e.g. how high the renewable subsidies are, how much the fossil fuel subsidies are reduced, how GHG intensive the economy is.

Measuring convergence in turn assesses similarity of instrument structure, e.g. whether two countries with carbon markets use an intensity-based system or aim to reduce absolute

[5] To be correct in terms of semantics, the term should be "converged-ness" as it measures the extent to which application of the respective climate policy instrument *has converged* among actors, rather than a measure of how fast it is converging.

[6] Our scenario construct thus resembles the approach of the IPCC's first set of scenario constructs or SRES (IPCC 2000, Pages 4-5), which also categorize scenario "families" along two major criteria. The four major scenario families (A1, B1, A2 and B2) essentially constitute quadrants on axes that indicate more or less rapid economic growth (1 or 2, respectively) vs. more or less 'globalization' in terms of homogeneity in global societies (A vs. B, respectively). While our analysis applies a matrix to climate policy *instruments* rather than to the state of global society as a whole, the conceptual application is similar. More recently, the IPCC's working group 3 has explored more scenario creation with stronger socioeconomic focus, see Hallegate et al 2010).

emissions, whether their programs are economy-wide or cover only certain sectors. The metric also embodies the extent of harmonization by evaluating the degree to which instruments are linked – in the case of carbon markets, this pertains to programs recognizing common offset units or declaring their allowances fungible; for renewable energy instruments it pertains to common feed-in tariff levels or whether tradable renewable energy credits are fungible among entities.

To illustrate the results of such a categorization along two axes, we can divide scenario "families" into four broad quadrants. The bottom left hand quadrant (low ambition and low convergence) is embodied by e.g. a scenario in which „race to the bottom" dynamics unfold: countries do not implement ambitious instruments to mitigate climate change, and do not cooperate on instruments either. This scenario of regression in terms of climate change mitigation policy represents a global prisoners' dilemma (see e.g. Axelrod 1984) in which no actor wants to be the first mover. The top left quadrant (low ambition and high convergence) embodies situations in which there is significant cooperation around climate change mitigation instruments, but those instruments are not ambitious. For instance, several major emitters could establish similar carbon trading systems and link them – but the caps or reduction targets of these programs are not stringent. The bottom right hand quadrant (high ambition, low convergence) represents a non-coordinated set of instrument choices, where most of the key players establish strong (stringent) domestic emission reduction policies but do not link them or achieve multilateral agreements. A scenario in which there are a few unilateral or bilateral 'deals' on key climate policies (e.g. between the US and China) could fall into this quadrant because there is no widespread cooperation, but what little cooperation there is pertains to the most important players. Finally, the top right quadrant (high ambition and high convergence) embodies a scenario often referred to as "the global deal" (see e.g. Edenhofer and Flachsland 2009 and Flachsland et al 2011) in which countries succeed in creating a successor to the Kyoto Protocol that constitutes a global carbon market with very ambitious targets, putting the world on a politically negotiated emission reduction path.[7] A version of this not exclusively focused on carbon markets would result from the negotiation of several common instruments like renewable energy quotas or co-ordinated phase-out of fossil fuel subsidies that collectively result in major GHG reductions.

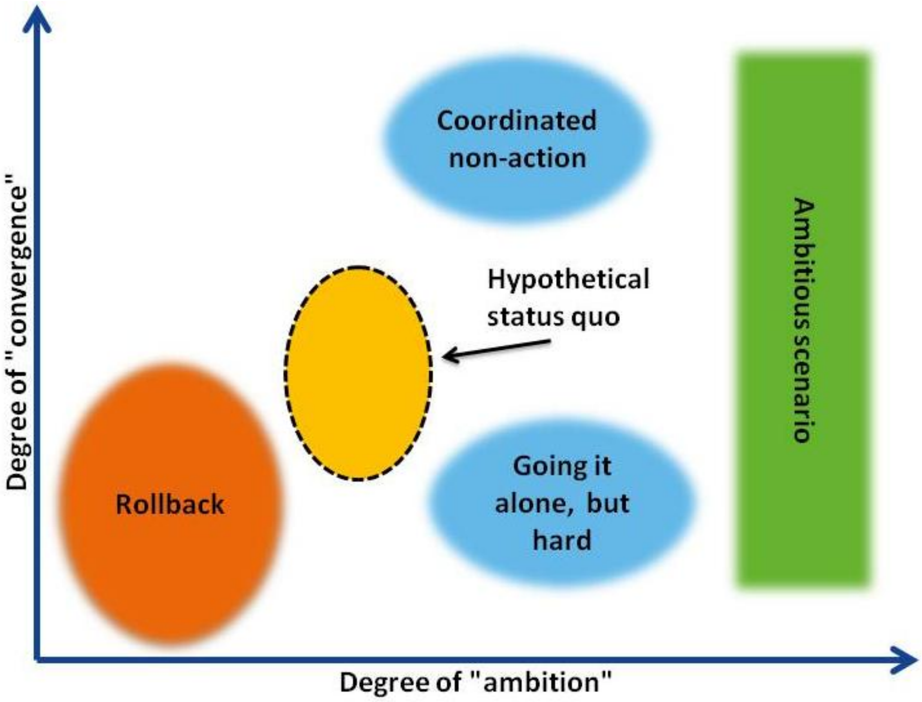
2.3.2 Scenario "landscape"

Applied to this dual axis structure, the possible emission trajectories discussed above and depicted in Figure 1 appear rather as zones or realms of scenarios on the axis. A future in which current policies are rolled back and become less stringent than they are now would clearly fall into the bottom left quadrant, with even less cooperation and ambition than the

[7] Such scenarios model the political process and results envisioned by Nicholas Stern in his book *The Global Deal* (Stern 2009, see especially pages 146-165), which laid out the (at that time) common vision of climate negotiations proceeding toward an internationally agreed set of targets and timetables for GHG mitigation, led by industrialized countries and gradually incorporating developing nations – this plan also assumed expansion and convergence of carbon markets, primarily the (at that time still functional) CDM. Ironically, this book was published shortly before the Conference of the Parties to the UNFCCC in Copenhagen in 2009, at which such a global deal was expected to be decided and then was not.

current status quo. “Middle of the road” scenarios could take any number of forms, leaning for instance toward a higher degree of cooperation or greater ambition. From a climate change mitigation perspective, a “successful” combination of instruments is one in which emissions decrease significantly over time - it occupies the area on the extreme high end of ambition, but could be achieved under differing degrees of policy convergence.

Figure 3 Scenario landscapes



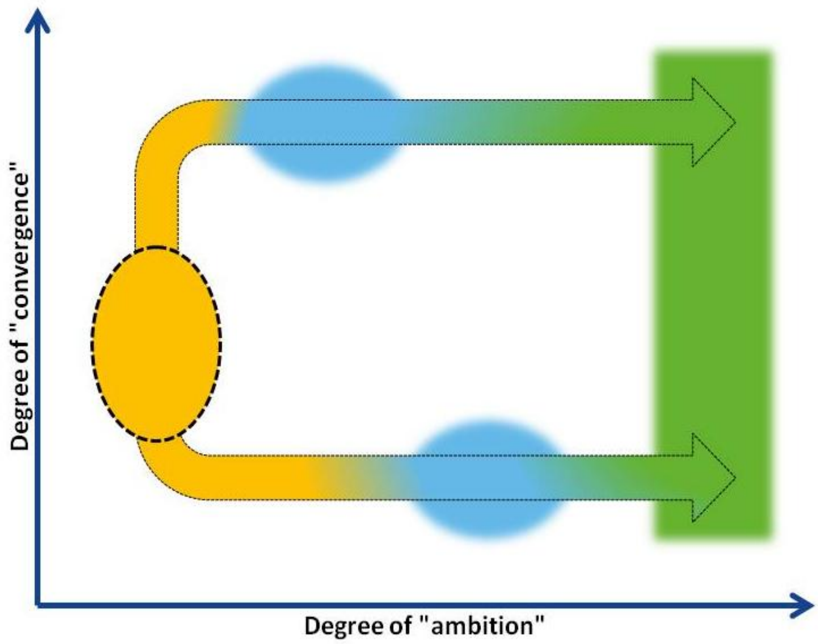
Various factors constitute **“drivers”** of global climate policy toward different regions in this landscape[8] (Schwartz 1996). Success of current effort within the UNFCCC to coordinate emissions monitoring, reporting and verification (MRV) among countries clearly increases the degree of convergence, but does not by itself imply increased ambition. Increased MRV is thus mostly a driver of convergence. Rising fossil fuel prices, on the other hand, usually correlates with greater emissions reductions as emissions-intensive energy sources become more expensive relative to e.g. renewables, but commodity prices are rarely the result of intentional international agreements – except for mutually agreed reduction of fossil fuel subsidies. Fossil fuel prices are thus typically a driver of ambition more than convergence. Carbon finance constitutes a textbook driver of both ambition *and* convergence: the flow of funds from industrialised to developing countries is based on cooperation and agreements, but also allows developing countries in particular to implement stringent climate policies because they do not have to carry the financial burden for those policies alone.

[8] The concept of drivers is based on what scenario expert Peter Schwartz calls “driving forces in the macro-environment” of a scenario that influence the key factors identified earlier - in our case the criteria of convergence and ambition (Schwartz 1996, pg. 242).

The role such drivers play in a global policy mix has an influence on the **path** toward a respective scenario. A set of drivers that facilitates *political consensus* in e.g. the UNFCCC – such as the above-mentioned progress on agreeing common MRV standards, or coordinating an international approach involving targets and timetables for emissions reduction – may actually induce cooperation and thus policy convergence that in turn *leads to* ambitious climate change mitigation instruments collectively. This was the path envisioned for the UNFCCC and embodied by its Kyoto Protocol: forging a global convergence of climate policy instruments via international agreement makes for a more ambitious scenario globally than if countries "go it alone." It is the path archetype of the "global deal" scenario mentioned above.

On the other hand, drivers outside the realm of political negotiation - such as the rapid advancement of non-fossil energy sources – can facilitate an ambitious (though un-coordinated) climate policy path that leads to some instrument convergence through sharing of technologies. Given the lack of participation in the Kyoto Protocol's second commitment period, the increasing aversion to a 'targets and timetables approach' toward global GHG reduction, and lack of progress within the UNFCCC negotiations in recent years,[9] a path that does not involve convergence drivers currently seems the more likely one to achieve an ambitious scenario.

Figure 4 Scenario paths



[9] The head of the UN climate secretariat acknowledged in May 2013 that a future climate 'deal' is unlikely to involve universal targets, but will more likely consist of a 'mosaic of pledges' at the national level (ENDS Europe 2013, May 29). This is corroborated by results of the survey mentioned in Section 2.1.

3 The Scenarios

Given the international goal of curtailing emissions levels to those the IPCC's 4th Assessment Report estimates could keep global average temperature change below 2 degrees Celsius, at least one scenario in this analysis must embody an international policy context in which this is the case. Any such scenario occupies the green "ambitious" area of the landscape depicted in Figure 3, but can take many different paths.

Global deal path

As discussed above, a path with high degrees of convergence has been the one espoused by climate policy analysts and diplomats - characterised as the optimal solution to a global problem, this "global deal path" involving emission reduction targets and timetables for all industrialised (and eventually developing) countries enshrined in a treaty was seen as the path for achieving the 2 degree goal through 2050.

Also discussed above is the fact that this ideal-type scenario involving high degrees of policy convergence no longer looks very likely. Therefore, we lay out the parameters for a "non-global-deal scenario" that is still high in ambition, but involves less convergence. We retain the ideal-type scenario of the global deal path as one of two scenarios achieving the 2 degree future, but do not go into detail about the political developments it would involve and instead mainly use it as a comparison to the more nuanced 2 degree path explained below.

Non-global-deal path

Decreased likelihood of reaching international agreement on global emission reduction targets and timetables throws up the question "how *else* might the world manage to mitigate against catastrophic climate change?" Only some mitigation instruments applied in only a few countries (but ambitiously), could still keep cumulative global emissions through 2050 within levels necessary not to exceed 2 degrees - an internationally agreed uniform approach targeted at achieving a global carbon price is not a prerequisite.[10] By including a non-global-deal scenario to reaching the 2 degree target, we explore this path and the developments it would involve.

Among those developments are serious emission reductions in sectors other than energy. The International Energy Agency (IEA) notes in its explanation of a 2 degree scenario[11] that "although transforming the energy sector is vital, the goal can only be achieved provided that CO_2 and GHG emissions in non-energy sectors are also reduced" (IEA 2013). The scenario thus

[10] Edenhofer et al (2013) point out that "a number of rationales and mechanisms make unilateral initiatives economically rational even in presence of free riding incentives" (pg. 14) and that recognizing "the existence of multiple political actors at different levels" provides a more promising approach to global climate policy analysis than the "standard view of centralized nation states as the key agents of policy making" (pg. 21).

[11] This scenario is broadly consistent with the IEA's World Energy Outlook 450 PPM Scenario through 2035, from which some CECILIA models including GINFORS, derive data on e.g. fuel prices.

involves development of policies in e.g. the agriculture and forest sectors, such as credits for reduced emissions from deforestation and forest degradation known as "REDD". Absent a UNFCCC agreement creating a global carbon market, this path would still involve establishment (and to a certain extent linking) of regional emissions trading systems.

Given that the two scenarios leading to a 2 degree world may be considered quite optimistic under the current global rate of emissions *growth*, we also consider two further scenarios with less climate-friendly outcomes.

Middle-of-the-road scenario

Going back to the scenario landscape discussed above, a high degree of policy convergence can lack ambition: the "co-ordinated non-action" region of the landscape represents a future in which diplomacy prevails and countries agree on joint programs and global mitigation instruments, but in which those programs and instruments are not necessarily ambitious enough. In such a scenario, the degree of convergence may be higher than the non-global-deal path – but it comes at the expense of higher ambition.[12] In Figure 1, such a reduction path represents the emissions trajectory range between the blue lines. Many of the diplomatic "successes" of recent climate summits reflect cooperation that constitutes convergence but does not immediately imply actual GHG reduction, such as agreement on monitoring, reporting and verification or safeguards for indigenous peoples (securing them a say) in the process of crediting emission reduction from avoided deforestation projects.[13] Even for more directly mitigation-related instruments, parties may converge strongly by adopting the same emissions caps, renewable energy quotas, energy efficiency standards or carbon taxes and accountably enforcing them – but this has little effect on the scenario's emission trajectory if the caps, quotas, standards or tax levels are too low or weak to incentivise emission reduction. Other examples include the long sought-after agreement to jointly reduce fossil fuel subsidies for both extraction and consumption, as well as international shipping emissions standards or requirements to offset aviation emissions – convergence on these may be high, but ambition low.

The middle-of-the road scenario thus takes into account current plans for emission reduction in key countries, assuming that the trajectory they are on may continue in terms of instruments applied and cooperation envisioned. This includes the above policies for which higher degrees of convergence can be achieved, such as linked emissions trading systems or common energy efficiency standards. The emission trajectory this scenario implies is broadly

[12] This reflects current negotiating realities of informational asymmetries among parties, under which actors perceive not a prisoners' dilemma (in which non-cooperation constitutes the dominant strategy) but rather "a game of coordination, in which there is no incentive for any player to unilaterally deviate from the cooperative outcome" (Edenhofer et al 2013) and thus cooperation itself becomes an attribute of "success" rather than success being defined as achievement of that which is being cooperated upon (in this case, climate change mitigation).

[13] Agreeing that certain groups have a say in a mitigation approach does not necessarily make the mitigation any more likely to happen. Similarly, steps that brought parties closer to globally-agreed methods for monitoring, reporting and verification of emissions (an international standard for measuring GHG output) have been hailed as a negotiating success but do not in and of themselves imply actual *reduction* of GHG output.

consistent with the IEA World Energy Outlook's New Policies Scenario through 2035, projecting a long-term temperature rise of 4°C.[14]

Do-nothing (status quo) scenario

No scenario comparison would be complete without a pessimistic or "doomsday scenario" to which the potential more positive futures can be compared. In the case of climate change mitigation, however, such a negative result is merely the product of continuing the status quo: the IEA's 6°C scenario, in which emissions rise to the extent that the global average temperature is three times the 2 degree increase within which scientists recommend keeping, is "largely an extension of current trends."[15] In terms of mitigation instruments, this path assumes only the continuation of policies and instruments currently being employed but no implementation of additional measures. It is a testament to the severity of the climate change mitigation challenge that this scenario does not even assume the rollback or discontinuation of existing emission reduction efforts – unlike most economic projections, just keeping the status quo (the current "level of effort" in fighting climate change) is itself the doomsday scenario.

3.1 Countries and Instruments: current state of play

Most of the 11 countries modeled by GINFORS consistently make it into any recent ranking of top ten emitters.[16] China and the US alone account for nearly 40 percent of global anthropogenic GHG output. Thus the analysis of the future development path climate change mitigation instruments could take focuses mainly on those instruments currently employed, planned, or contemplated for those countries. The following short profiles of the main emitting nations explains the status quo and potential future mitigation instruments in each, establishing a baseline for the various scenario pathways.

[14] Even though a 4 degree outcome is seen as undesirable from a climate change mitigation perspective, the IEA notes that it is "already an ambitious scenario that requires significant changes in policy and technologies. Moreover, capping the temperature increase at 4°C requires significant additional cuts in emissions in the period after 2050." The group's own description of the 4 degree trajectory notes that it takes into account "recent pledges made by countries to limit emissions and step up efforts to improve energy efficiency" (IEA 2013).

[15] For modelling purposes, the 6 degree path is again broadly consistent with an IEA the World Energy Outlook scenario, namely the "Current Policy Scenario" through 2035, which projects global energy use nearly doubling from 2009 to 2050.

[16] Rankings and the emission levels taken into consideration for rankings vary by year and depending on whether the estimate includes emissions from land use change and forestry (the "LULUCF" category under the UNFCCC). Typically, the inclusion on LULUCF emissions does not change the ranking for most countries in this list compared to their energy-related emissions except for Brazil, from which emissions levels including LULUCF are nearly double those without in 2010 due e.g. to deforestation. Rankings for 2010 with and without LULUCF data were obtained via the World Resources Institute's Climate Analysis Indicators Tool (cait) available at www.2cait.wri.org

Table 1: Overview of GINFORS country climate policy status quo

Country	A Emissions background* B Announced target(s)	Sampling of existing and planned policies
Australia	Emits >700 $MtCO_2e$ per year counting LULUCF emissions, <600 Mt excluding LULUCF. Highest per capita emissions worldwide (>33 tonnes) if counting LULUCF emissions in 2010 Reduce emissions 5% below 2000 levels unconditionally by 2020, and possibly further to 15 or 25 per cent below those levels depending on "the extent of international action" (what other countries do)	Climate change instruments are in flux, as new government elected in the second half of 2013 is changing/abandoning many of them
Brazil	Accounts for ~7% global emissions at >2 billion tonnes per year. Per capita emissions are >10 tonnes CO_2e with LULUCF emissions included, ~6 tonnes excluding LULUCF Reduce emissions growth by 36 to 39 percent below business-as-usual levels by 2020.	Forest law (entered into force 2012) Subsidies for biofuels (ethanol)
Canada	Annual emissions are >725 $MtCO_2e$, per capita emissions >21 tonnes Emissions targets are pegged to those of the US: 17% reduction from 2005 levels by 2020 Individual provinces have own climate targets	Various provinces have individual instruments (carbon tax in British Columbia, ETS in Quebec, coal phase-out in Ontario, GHG intensity regulation in Alberta)
China	Currently the largest emitter, accounts for more than one-fifth of global anthropogenic GHG emissions at >10 billion tonnes CO_2e per year. Per capita emissions: >7 tonnes CO_2e Reduce national carbon dioxide emissions per unit GDP 40-45% by 2020 (from a 2005 baseline) Increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020 Increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 (from 2005 levels)	Pilot ETS in 7 provinces, national ETS planned for 2015 National capacity targets for wind, solar, biomass and other technologies by 2020. Feed-in tariffs for wind, solar and biomass
India	Accounts for nearly 5% of global emissions (>2 billion tonnes CO_2e). Per capita emissions very low at ~1.9 tonnes CO_2e Reduce the emissions intensity of GDP 20-25% by 2020 (from 2005 levels). The target does not include emissions from agriculture.	Energy efficiency trading scheme Renewable energy subsidies
Japan	Annual emissions of >1.2 billion $MtCO_2e$, per capita emissions >10 tonnes Bring 2020 emissions to 3.8 percent below their 2005 levels	Bilateral offset mechanisms
South Korea	Total annual emissions ~650 $MtCO_2e$, per capita emissions are 13.7 tonnes Bring emissions 30 percent below projected 2020 business-as-usual emissions	South Korean Emissions Trading System (to start operating in 2015) covers ~60% of South Korea's total emissions.

Mexico	Emitted >700 $MtCO_2e$ per year in 2010, 6 tonnes per capita reduce greenhouse gas emissions by 30 percent below 2000 levels by 2020, and by 50 percent by 2050 30 percent compared to business-as-usual levels by 2020 and 50 percent by 2050, provided international support	General Law of Climate Change (2012) commits Mexico to the 30% target and creates several relevant institutions. Legal reforms to old Environmental Law and Sustainable Forest Development Law facilitate implementation of a REDD+ mechanism
Russia	Emits >2 billion tonnes per year, ~16 tonnes CO_2e per capita Russia will keep its greenhouse gas emissions at least 25 percent under 1990 levels by 2020[17] – they are currently already more than 30% below 1990 levels	
USA	Annual emissions are 6.7 billion tonnes, per capita emissions ~22 tonnes CO_2e 17 percent below 2005 levels by 2020, with additional soft targets of 42 percent below 2005 levels by 2030, and 83 percent below 2005 levels by 2050	Standards for fossil fuel fired power plants incentivise emission reduction from electricity generation

*Data is from World Resources Institute CAIT database for the most recent year available (2010). Unless otherwise specified, emissions include those from LULUCF.[18]

3.1.1 Carbon pricing state of play

For instruments that put a price on carbon, i.e. internalize the negative externalities of GHG emissions, there are significant opportunities for convergence but also few incentives for ambition. Linking emissions trading systems creates larger carbon markets, allowing participants to take advantage of a wider range of abatement costs. However, making the caps on those trading systems tight enough to evoke significant GHG reduction (incentivised by correspondingly high allowance prices) is usually politically unpopular. The same is true for carbon taxes – to the extent that in some countries containing the word “tax” immediately renders a policy suggestion dead in the water (Hardisty, Johnson and Weber 2009). New market mechanisms similarly price environmental externalities by creating carbon offset mechanisms at the global scale, e.g. at a sectoral level (Castro et al, 2012). Again, while there may be political convergence as to how to go about this - as has been the case recently with

[17] This target is now national law, having been signed as a presidential decree by Vladimir Putin on 20 September (Decree [Указ] number 752, 2013)

[18] Note: estimates of both absolute and per capita emissions for 2010 vary extremely widely, with compilations often not specifying whether only energy-related emissions are counted or whether data includes total national GHG output. Per capita figures and world rankings are equally inconsistent, national reports being at odds with those of analytical institutions. E.g. Mexico’s per capita emissions are listed here at 6 tonnes per year and at 4 tonnes in Mexican national reports. CAIT data was used for consistency, but should be assumed to contain a large accuracy spread and used mainly as a point of reference to compare orders of magnitude.

progress toward a global mechanism of tradable credits for avoided deforestation (Mollins and Verchot, 2013) - the level of agreement or consensus about the mechanism is irrelevant in climate terms if the prices that mechanism involves are not high enough to stimulate ambitious reductions.

Carbon markets

Seeral of the key countries in Table 1 are either actively establishing emissions trading programmes or are home to regional carbon markets that operate at the sub-national level (see Kossoy et al, 2013). China's seven pilot carbon markets in provinces[19] make it the "country to watch" in this respect simply because of its enormous share of global emissions: the seven programmes would cover thousands of companies collectively emitting 700-800 $MtCO_2e$ per year, meaning the combined size of the pilot markets is around a third of the EU ETS (Reklev 2013). The areas covered by the market account for nearly one-third of China's gross domestic product. Analysis involving a survey by Jotzo, de Boer and Kater (2013) concludes that Chinese CO_2 prices will exceed those of the EU in 10 to 15 years.

The stated goal of these pilot programmes is to gain experience necessary to implement a Chinese national emissions trading scheme, the espoused start date for which is 2015. In March 2013, China was awarded $8 million in funding from the World Bank's Partnership for Market Readiness to research and begin the designs of a national system - various institutions and departments are currently considering the optimal structure of key carbon market design elements, such as cap setting, allocation, price containment mechanisms like offsets, oversight and a legal framework. In terms of ambition, the cap stringency will determine the extent to which a market-based carbon price evokes emissions reduction. The proposal submitted to the World Bank offers three methods for setting the cap: a top-down method in which the cap is set by the central government, a bottom-up method calculated by compiling allocations to installations at each local level and adding them up, or a coordination method involving initial cap-setting at the local level subject to standards and review by the national government. Swartz et al (2013) argue that China will most likely go for the coordination method, given the wide variety of industrial sectors and number of entities to be covered, as the central government would be unlikely to manage keeping tabs on these in a functional manner.

Meanwhile, the US state of California (together with the Canadian province of Quebec) also employs a carbon market to achieve its statewide target of bringing GHG emissions to 1990 levels by the year 2020. Currently emitting roughly half a billion tonnes CO_2e per year, California's ability to incentivize reductions via a market instrument is influential – particularly as that state's environmental policies often end up being taken up at the US

[19] These are the cities of Beijing and Shanghai (November 2013), the highly industrialised and populous province of Guangdong (December 2013), the city of Shenzen within Guangdong (June 2013), as well as Hubei province and the cities of Tianjin, Chongqing and Hangzhou in 2014 - see Han, Olsson, Hallding and Lunsford (2012) as well as Chen and Reklev (2013), Stanway (2013) and Swartz et al (2013) for details.

federal level.[20] The Canadian province of Alberta – a significant extractor of fossil fuels and the country's highest emitting province – employs a baseline-and-credit emissions trading programme aimed not at reducing absolute GHG emissions, but at offsetting them and at improving facilities' emissions intensity over time. Officials cite compliance data as suggesting that existence of the programme since 2007 has prevented a total of 40 MtCO_2e from being emitted that otherwise would have.[21]

Until September 2013, Australia's carbon pricing system (a "fixed price" program or tax of $24 per tonne CO_2e emitted, scheduled to evolve into a "flexible price" allowance market in 2015) covered a significant portion of the country's energy-related emissions and would have linked to the EU ETS in 2015. With the Abbott government dismantling various national programs to address climate change at the time of writing, it remains uncertain to what extent Australia might make use of carbon pricing instruments going forward.[22]

South Korea is finalizing rules of an emissions trading system set to enter into force in 2015. The programme would cover emitting entities (mainly stationary sources) accounting for about 60 percent of the country's GHG output, which is currently roughly comparable to Australia's though per capita emissions in South Korea are only half as high. The programme is aimed at helping achieve South Korea's national GHG reduction pledge of 30 percent below 2020 busines-as-usual emissions in 2020, but projections of what the business-as-usual level will be in that year vary widely – thus the degree of stringency of the South Korean programme (and therefore the efficacy of the carbon price in incentivizing emission reduction) remains uncertain (see e.g. Chatterton et al, 2013).

Carbon taxes

In addition to market-based carbon pricing, China is considering a carbon tax effective starting in 2015. On May 23, 2013, China's Ministry of Finance issued a draft carbon tax law for comment to the country's most carbon-intensive industries and business associations. The draft proposes a tax of at least ¥10 per tonne (roughly €1.20) to be levied starting with the next five-year plan from 2016 onward.

Though Canada has no carbon tax at the national level, the provinces of British Columbia and Quebec currently have one, though the latter applies mainly to transportation fuel and the former is combined with a provincial offset system. The current Canadian government is not considering adopting a carbon tax at the national level, although a major opposition party

[20] The US Clean Air Act, now the main vehicle through which the Obama administration is attempting to curtail carbon emissions from the US electricity sector, was adopted after (and strongly influenced by) California's Clean Air Act, which predates it by several years. Stavins (2011) argues that "we may find that Sacramento, California comes to take the place of Washington as the center of [US] national climate policy."

[21] See the Alberta provincial climate change website with results of the programme through 2012: http://environment.alberta.ca/04220.html

[22] The Abbott government provides ongoing updates about the status of changes to previous government's climate change laws on the website of the Australian Department of Environment. At the time of writing, the site (http://www.climatechange.gov.au/) announced that Australia's carbon tax would be repealed on 1 July, 2014. A set of carbon tax repeal bills were introduced into Parliament on 13 November, 2013.

(the NDP) favours that idea and the main current opposition party (the Liberals) made it part of its party platform in the past.

In the US, the mere idea of a carbon tax has been considered politically implausible for the country in which market-based measures originated[23] – however, recently discussion of the benefits of a carbon tax has increased significantly in the academic, business and political arena in the context of the US deficit as a revenue generating measure.[24] Proponents argue that the internalisation of negative externalities a carbon tax provides would be augmented by significant (arguably direly needed) additional federal revenue (see Carbone et al, 2013) - the effect of political "framing" of a carbon tax in revenue terms on public acceptance is illustrated by Hardisty, Johnson and Weber, 2009. For an indicator of carbon price levels the US government is considering, the US Environmental Protection Agency and other agencies continuously update a carbon "shadow price" used in required cost-benefit analyses of federal rulemakings. This price, called the "social cost of carbon," was revised in June 2013 and represents the value of damages avoided through GHG emission reduction in five-year increments. It is specific to the emissions-year, starting with a 2015 level ranging from $12 to $117 per tonne CO_2e in 2011 dollars (depending on the discount rate used) and rising to a $28 - $236 range in 2050.[25]

India and Japan both employ pricing instruments that, while not a "true" carbon tax, are intended to encourage the use of low-carbon alternatives – particularly fuels. India introduced a tax specific to coal July 2010, which levies a charge of INR 50 (~€0.60) per ton of coal produced or imported into India. The revenue raised is earmarked for research into clean energy technologies and environmental remediation. Japan enforces a CO_2-emissions-based charge on petroleum and coal in addition to the "regular" taxes on those fuels – as part of the country's Carbon Dioxide Tax of Global Warming Countermeasure in its 2012 tax reform, the measure aims to further dis-incentivise energy-related CO_2 output.

At the time of writing, Mexico's legislature was in the process of approving a new tax on CO_2 emissions from fossil fuel use that incorporates a market-based instrument by exempting firms from the tax obligation to the extent they instead purchase carbon offsets for the equivalent amount of emissions. The law allows companies to buy and surrender certified emissions reductions (CERs), the offset credits used for compliance to Kyoto Protocol targets, in lieu of paying a charge of roughly US$5 per tonne of CO_2 emitted. Only CERs from Mexican

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[23] The US Environmental Protection Agency's acid rain program, which instituted the first large-scale cap-and-trade system for emissions of a pollutant (sulphur dioxide) became the model for GHG emissions trading programmes in force all over the world today (see e.g. Sandor, 2012).

[24] Evidence of the increased interest in a US carbon tax as a policy instrument is the flurry of meetings and symposia held around this issue at policy-related institutions since the deficit became a top political issue in 2011. See e.g. the event "Fiscal Reform and Climate Protection: Considering a U.S. Carbon Tax" hosted by Washington DC-based think tank Resources for the Future on 18 October 2011, featuring several academic papers on the subject as well as presentations by representatives from industry and the legislative branch – description and presentations available for download at http://www.rff.org/Events/Pages/Fiscal-Reform-and-Climate-Protection-Considering-a-US-Carbon-Tax.aspx

[25] The comprehensive estimate of climate change damages includes e.g. decreases in human health, property damages from increased flood risk, and changes in net agricultural productivity. The four discount rates considered are 5, 3, and 2.5 percent average and one 3 percent discount rate at the 95th percentile (see US Environmental Protection Agency website http://www.epa.gov/climatechange/EPAactivities/economics/scc.html)

offset projects are eligible. The law aims to increase the currently almost non-existent demand for CERs and indirectly supports Mexican projects that generate them (Twidale, 2013). Emissions from extraction of e.g. crude oil and natural gas are exempted, but the tax applies to producers of byproducts including gasoline, diesel, propane, butane and coal (Teixeira, 2013).

New market mechanisms

In contrast to indicators of how carbon pricing instruments might develop through 2050 – consisting mainly of the key measures employed in key countries – the main indicators of the role international market-based mechanisms might play through 2050 come from parties' stances in the international climate negotiations. With the world's current primary market instrument (the CDM) fast becoming meaningless in terms of incentivizing emission reduction due to oversupply of credits and corresponding credit price collapse (see e.g. Twidale, 2013), parties are weighing in on other ideas for a global emission reduction instrument involving trading and offsetting of emissions.

The EU's preferred plan in this regard is a so-called sectoral programme (see European Commission 2012 and de Sépibus, Sterk, and Tuerk 2013). It involves creating a market incentive for at least one "broad segment of an economy" (for example the entire electricity generation sector, metals production, pulp and paper manufacturing, etc.) in a developing country to become less carbon-intensive relative to some pre-agreed baseline or benchmark – that benchmark could be set in terms of emissions intensity or absolute emissions. Either countries set the benchmark very high and are rewarded ex-post with credits if they exceed it (the crediting approach also known as "no lose"), or they set the benchmark rather like a target that earns emission units if exceeded, but requires countries to buy such units if emissions end up above the agreed level (the "trading" approach). China has essentially rejected this idea, saying it will not accept anything but an approach that credits reduction efforts on a project-by-project basis. Besides the EU, parties are not pushing for this approach.

Instead the concept of crediting avoided deforestation has garnered more momentum, with various parties, non-governmental organizations, coalitions and side negotiations devoted to *reducing emissions from deforestation and forest degradation* (REDD). The unlikely combination of business looking for offset projects to support and nature protection groups looking for ways to save the rainforest has made progress toward structuring a framework under which actors (at the national or sub-national level) may be rewarded for *not* cutting down forests (see e.g. Mollins and Verchot, 2013). After years of discussion and evolution, the concept now pertains to protection of wetlands, peatlands, boreal forests and other carbon-rich ecosystems (REDD+).[26] Although the theoretical basis for a global REDD programme enjoys political support (it is difficult to be *against* saving the world's forests),

[26] UN documents now refer to REDD+ as "Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries."

implementation of a REDD market mechanism is uncertain: many countries favor an approach of direct payments to tropical forest nations on the basis of emissions avoided rather than a market model involving tradable credits whose price is subject to supply and demand-induced fluctuation. Brazil, one of the biggest stakeholders in this issue, has traditionally favored direct payments but in recent years has shown itself open to home to a market approach – the governments of individual states in the country are in fact pursuing market-based arrangements. The state of Acre and the US state of California have signed a Memorandum of Understanding, along with Mexico's Chiapas,[27] that REDD credits from avoided deforestation in Acre and Chiapas may eventually be counted as offset credits available to California GHG emitters as compliance units in the US state's regional cap-and-trade programme.

In essence, a global REDD programme involving tradable credits (like the Acre-California arrangement but on an international level with countries, rather than local governments, as the participating entities) could constitute a sectoral crediting or trading programme as outlined by the EU – only the sector in question would be land use rather than e.g. power generation or industrial production.

3.1.2 Domestic energy policies state of play

While they do not price carbon directly, individual countries' energy policies can strongly influence carbon prices by affecting the relative costs of fuels, of electricity generated by those fuels, or of extracting those fuels. Energy efficiency policies affect the demand for (and therefore cost of) electricity and can therefore influence carbon prices. Thus both the stringency of, and degree of convergence among, these policies through 2050 is an important determinant of the global policy framework within which the EU will be trying to achieve its climate targets in the coming decades. Whereas the "stringency" of carbon pricing instruments can be measured fairly directly by how high a carbon price they create, the stringency of related energy policies must be assessed in terms of the degree to which they indirectly lower emissions – to the extent that renewable energy quotas or feed-in tariffs, for instance, imply a greater percentage renewables in a country's energy mix, carbon emissions from that country's power sector can decrease. In the same way, removing subsidies for fossil fuels (and their extraction, as extraction itself is a carbon-intensive process) affects the amount of fossil fuel combusted (depending of course on demand elasticity for fuels) and thus GHG emissions from energy.

Renewable energy quotas

The key countries have various policies to promote renewable energy and energy efficiency: individual subsidies and tax credits for renewable infrastructure, feed-in tariffs for renewably

[27] Full text of this document, signed in 2010 by the then-governors of the three jurisdictions is accessible online at the website of the NGO Tropical Forest Group: http://tropicalforestgroup.blogspot.com/2010/11/text-of-ca-chiapas-acre-mou-on-redd.html

generated electricity, energy efficiency policies involving markets for power not generated,[28] initiatives to encourage building insulation and thus lower energy demand for heating and cooling, efficiency standards for appliances, etc. Due to modeling constraints, all such policies will be represented by one instrument for the purposes of this report: a renewable energy target expressed as a quota, i.e. percentage of total national electricity production coming from renewable sources by a certain target year. Only a few countries have such a target in national percentage terms, but many have targets for absolute amount of generation (in gigawatt hours) and or capacity (in megawatts) by a certain year – some have these only at the subnational level. The following chart, derived from the REN21 Renewables global status report, shows all key countries' current targets in this regard, which form the basis of the four scenarios described in Section 4.2.2.

Table 2: Overview of GINFORS non-EU country renewable goals

Country	Share of electricity production from renewables in 2011	National target	Subnational targets
Russia	0.3%	4.5% by 2020	
Turkey	25.3%[29]	30% by 2023	
Brazil	89%	Wind: 15.6 GW by 2021; Small-scale hydro: 7.8 GW by 2021; Bioenergy: 19.3 GW by 2021	
Canada	63%		New Brunswick: 40% by 2020; Nova Scotia: 25% by 2015; Saskatchewan: 33.3% by 2030; Prince Edward Island: 30 MW increase in wind by 2030 relative to 2011; Ontario: 10,700 MW by 2022
Mexico	16%	35% by 2026	
USA	13%		29 States, the District of Columbia, and 2 territories have renewable portfolio standards requiring certain percentages of renewable power by a certain year. All are slightly different in terms of what "counts" as renewable energy and who the target applies to

[28] such as India's market-based "Perform, Achieve, and Trade (PAT) program" for industrial energy efficiency, under which credits for energy savings can be traded in a market similar to emissions permits – see e.g. Krishnan, 2013.
[29] Includes additional individual capacity and generation targets by technology not listed here

			(all retail electricity sales or municipal utilities excluded, etc.)[30]
China	18%	Wind: 200 GW by 2020; Solar PV: 20 GW by 2015; Concentrated Solar Power: 1 GW by 2015; Hydro: 290 GW by 2015; Bioenergy: 13 GW by 2015; Solar thermal 280 GW th by 2015	
India	11%	53 GW renewable capacity by 2017	
Japan	10.5%	Wind: 5 GW by 2020; Solar PV: 8 GW by 2020; Hydro: 49 GW by 2020; Geothermal: 3.88 GW by 2030; Bioenergy: 6 GW by 2030; Wave and tidal: 1,500 MW new capacity by 2030	
South Korea	3%	39,517 GWh (7.7%) by 2030	
Australia	11%	20% by 2020	

Source: REN21

Fossil fuel subsidies

There is currently significant momentum to engage in an internationally agreed phaseout of fossil fuel subsidies worldwide, both for extraction and consumption.[31] At the most recent G-20 meeting in St. Petersburg in September 2013, all leaders emphasised building on the commitment they made at the Pittsburgh G-20 Summit in 2009 to phase out fossil fuel subsides (Environment News Service 2013). Since countries are reluctant to drop such subsidies unilaterally, they most recently agreed on the methodology for a new subsidy peer-review process (Gerasimchuk, 2013). However, fossil fuel subsidies are actually increasing worldwide, with the total having risen to $544 billion in 2012 according to IEA estimates (IEA 2013).

[30] For a complete list with detailed explanations, see the US Dept. Of Energy co-sponsored website http://www.dsireusa.org/documents/summarymaps/RPS_map.pdf

[31] The former type of subsidy is used widely in industrialised countries, whereas the latter is prevalent in developing nations whose governments try to make vehicle and cooking fuel affordable to their poorest citizens. A "partial phase out" of fossil fuel consumption subsidies alone could reduce the gap between the 2012 global emissions trajectory and the trajectory necessary to keep global average temperature rise within 2 degrees Celcius by 0.4 billion tonnes by 2020 (UNEP 2012). The IMF has found that removing all post- and pre-tax subsidies for fossil fuels could avoid up to 13 billion tonnes CO2 annually (Cottarelli, Sayeh, Ahmed, eds. 2013, see "Lessons and Implications")

3.1.3 GHGs from global transport state of play

Emissions from shipping and aviation are notoriously difficult to incorporate into a global agreement in the UNFCCC context, as both modes of transport have their own UN-affiliated global oversight and regulatory agencies.[32] The International Maritime Organization (IMO) is responsible for the security of shipping and the prevention of marine pollution by ships, while the International Civil Aviation Organization (ICAO) sets standards and regulations necessary for aviation safety as well as environmental protection. Both these organizations serve as the forum for cooperation in their respective transport sector, but do not have climate change mitigation as their primary concern. The UNFCCC defers to these groups on any matters concerning emissions from international transport, but neither has laid out caps or global emission reduction targets and instruments in the 15 years since the Kyoto Protocol was adopted in 1997.[33]

Since shipping is currently the most energy-efficient means of goods transport, the lack of action on the part of ICAO is of particular concern given the growth of aviation and thus its emissions.[34] For this reason, the EU began taking matters into its own hands by including emissions from international flights (to and from EU airports) in its emissions trading scheme, essentially putting a price on those emissions in an effort to incentivise reductions in the aviation sector. This prompted an international backlash, causing the EU to "stop the clock" on the inclusion of aviation emissions in its ETS until ICAO addressed the issue. The most recent ICAO meeting took place in October 2013, and resulted in a document committing members to develop a global market-based mechanism for cutting aviation emissions for which the modalities must be agreed by 2016 and implementation must occur in 2020 (ICAO 2013). It remains to be seen how ambitious the cuts evoked by this proposed market mechanism turn out to be: the agreement asserts that ICAO member states collectively aspire to keep global net carbon emissions from international aviation at 2020 levels ("carbon neutral growth") after 2020 (ICAO 2013, point 7) – largely via offset purchases. Which offset credits will be allowed to neutralize aviation emissions at that time – and even which offset types may exist by then – is yet to be determined. Another aspirational goal stated in the agreement is that the aviation industry reduce its carbon emissions 50 per cent by 2050 compared to 2005 levels.

[32] Emissions from air or marine vessels engaged in international transport are known as bunker fuels and receive special consideration in GHG accounting: emissions from such fuels are calculated as part of the national GHG inventories of UNFCCC Parties, but are excluded from national totals and reported separately. They are not subject to the limitation and reduction commitments of industrialized countries (UNFCCC 2006)

[33] Article 2.2 of the Kyoto Protocol states that Annex I Parties are to pursue limitation or reduction of GHG emissions from aviation and marine bunker fuels, working through the ICAO and the IMO, respectively.

[34] Whereas shipping currently makes up 1.5-3 percent of global emissions and is expected to account for over five percent by 2050, aviation currently makes up 2-3.5 percent of global emissions but is expected to make up 15 percent of global emissions by 2050.

3.2 Evolution through 2050 by instrument type for each scenario

3.2.1 Carbon pricing

Carbon pricing Status quo

As the name implies, the status quo scenario foresees no *new* carbon pricing mechanisms in the key countries, but only that those instruments already in existence or set to launch as of 2013 will continue through their currently-foreseen lifetimes. In the case of emissions trading systems, this pertains to all those outside Europe (including Kazakhstan and New Zealand) although the ones that matter most in terms of influencing the global emissions trajectory as shown by GINFORS model results are in non-European GINFORS countries: the US and China. California's emissions trading programme thus continues through the final year of its current cap (2020) and no further, while the Regional Greenhouse Gas Initiative (RGGI) on the US east coast remains in effect through 2019 but is then also not renewed, and the two do not link to each other. Alberta's provincial baseline-and-credit system for carbon trading based on emissions intensity continues through 2050, but continues the existing intensity target during that period and therefore does not reduce emissions in absolute terms. The pilot programmes already started in China in 2013 (Shenzen, Guangdong, Beijing and Shanghai) continue through 2015. Though the Chinese government envisions a national ETS taking over from that year based on experiences from the various pilot programs (see among others Swartz et al 2013), the status quo scenario assumes this *does not* happen.[35]

The current state of new market mechanisms is that none exist, though plenty of structures have been suggested in the context of the UNFCCC and evaluated as explained in Section 3.2.1. The status quo scenario thus assumes there are no international market mechanisms involving global trading of offset credits or other emission reduction units.[36]

The status quo scenario further assumes that carbon taxes around the world remain at their current levels in countries that have them, but are not introduced in any further countries. This means such taxes are absent in North America, with the exception of the provincial carbon taxes in British Columbia and Quebec: the US does not implement carbon taxes and Mexico's proposed legislation to do so does not enter into force. The tax-like policies in Japan and India remain, but do not change in scale or scope.

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[35] Such an assumption is in line with the views of analysts who contend a national scheme will not be ready by 2015, especially since the pilot programmes on which that scheme is to be based entered into force in 2013 and later. Shawn He, lawyer and carbon specialist at the Hualian legal practice in Beijing, points to the absence of national legislation giving legal recognition to the concept of carbon trading in China as well as lack of standardisation of emission measurement (see He quoted in Stanway, 2013).

[36] The results of the November 2013 climate summit in Warsaw indicate that this assumption is not unrealistic: despite a massive amount of literature on structuring new market mechanisms in the form of submissions on this issue ahead of the talks (available at http://unfccc.int/bodies/awg-lca/items/4578.php), including ways to develop new carbon markets and link them together through common accounting and transparency standards, negotiations on such mechanisms were entirely postponed in the first week of the conference. Developing nations refused to continue discussing the issue without greater emission reduction commitments on the part of rich nations. Negotiations over new market mechanisms may instead be taken up at intersessional meetings in June 2014 (see Sterk et al, 2013 as well as Szabo and Reklev, 2013).

Carbon pricing global deal path

In contrast to the current state of international negotiations, the global deal path assumes both development of, and strong convergence among, carbon pricing instruments worldwide. This ideal-type scenario sees parties adopting a new treaty in Paris 2015 that features strict, binding targets for *all* countries (including developing ones) and that includes an accounting system with universally-fungible units (like the Kyoto Protocol's Assigned Amount Units) and penalties more severe than those of the Kyoto Protocol.[37]

Such a treaty would include internationally agreed new market mechanisms. Given the high level of convergence and fungible emission reduction units, the sectoral trading mechanism would apply: since all countries would have measureable and comparable targets (though these would have different degrees of ambition depending on the country's respective wealth, responsibility for climate change, and other factors) a trading of emission allowances on a sectoral basis across countries would be feasible. Since the sectors included would be emission sources (electricity generation, metals production, etc.) those eligible to generate offsets for such a global system are the ones not covered by the sectoral caps, such as land use change. The global deal scenario would thus include credits for avoided deforestation as tradable offset units in an inherently global, treaty-based carbon market. The existing clean development mechanism (CDM) would cease to exist because all countries would be subject to binding GHG cuts. The existence of offset project opportunities in the forest sector would influence the emission trajectory of the countries belonging to the GINFORS "rest of world" category in terms of land use emissions. The burgeoning industrial sectors of small developing countries would also be affected, as they would be subject to caps (however weak) under the sectoral trading mechanism.

A global carbon market brought about by this universal treaty scenario renders carbon taxes an optional policy tool that is merely a means to an end: countries could adopt them to the extent that they help them meet the targets to which they are subject under the treaty – their level would depend on the individual parties' absolute emission reduction target and the respective governments' estimates of what carbon price would evoke a national emission reduction to that target. The global carbon price, however, would de facto be set by the relative stringency of parties' targets under the international treaty.

[37] The compliance mechanism under the Kyoto Protocol stipulates that if a party (having been given a chance to purchase offsets and additional allowances from other countries) still exceeds its assigned amount of emissions allowed several years after the compliance period ends, its "punishment" is to take on a tighter cap (fewer assigned amount units) in the next commitment period. The way this penalisation structure has played out at the global level is that one country in danger of exceeding its assigned amount units (Canada) simply withdrew from the treaty, and most other parties outside Europe never adopted a second commitment period of the treaty to which the penalty of a tighter cap could apply. Those who conclude that these facts render the Kyoto Protocol's compliance method ineffective might look to other ways of penalizing non-compliant parties, such as trade measures including subsidies and border tax adjustments aimed at 'leveling the playing field' with regard to e.g. imports from countries that have not taken on comparable climate mitigation targets or measures (see e.g. Werksman, 2012).

Carbon pricing middle-of-the-road

Under the lesser degree of convergence and ambition that characterises the middle-of-the road scenario compared to a global deal, there is no worldwide carbon market using fungible tradable units brought about via treaty agreement – however, existing regional emission trading systems continue and, unlike the status quo scenario, extend past their currently foreseen lifetimes. The national programs in South Korea and China enter into force as planned in 2015 and continue through 2050 with increasingly stringent caps,[38] while those in North America also continue past 2020 – in California's case, the carbon market continues to represent an instrument employed to achieve the state's long-term emission target of 80 per cent below 1990 levels by 2050.[39] These disparate national and subnational programmes eventually also link to a certain degree via shared offsets – some credits eligible for offsetting emissions in one trading programme are also allowed to do so in another, which makes for an intermediate or indirect form of linking carbon markets.[40] Japan, for instance, funds mitigation projects in developing countries[41] that generate emission reduction credits the Japanese government will count toward meeting its targets – these are as yet not recognised as internationally fungible, but could be accepted as a legitimate offset standard by individual other national programmes and thus link Japan's efforts to those of other countries in terms of net emission reduction. Thus the middle-of-the road scenario features some convergence among instruments, but given the lesser ambition of these instruments (i.e. not very stringent caps) the pathway does not achieve significant reductions.

New market mechanisms are similarly disparate under a middle-of-the-road scenario. In the absence of a sectoral trading programme that would require a high degree of convergence (a binding negotiated agreement involving targets for each nation or at least certain sectors within nations' economies), key countries nevertheless have an interest in an international mechanism – e.g. for trading offset credits as explained above, ensuring that these are "global" offsets recognised among a higher number of players. Trading of REDD credits is currently the type of new market mechanism closest to moving from theory to practice, with the 2013 annual climate summit having reached decisions on a REDD mechanism framework[42] and pilot REDD trading programmes already enacted around various projects or

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[38] Contrary to the arguments supporting the status quo path's assumption that China does *not* adopt a national ETS in 2015, recent research on China points to significant benefits of a national scheme over regional programmes. A study by Zhang et al (2013) finds that a national target allowing trading of emission permits across provinces results in the lower-cost reductions than an approach involving provincial targets. The study finds that the national target results in about 20 percent less overall welfare loss in China relative to the provincial targets approach.

[39] This goal exists in legal form only as an executive order issued in 2005 by then-governor Arnold Schwarzenegger, but is the basis of statewide economic modeling on GHG reduction pathways and has not been explicitly retracted by the following administration of Jerry Brown (see Executive order S-3-05 2005).

[40] as compared to the direct linking of mutually recognised allowances (see Mehling and Haites 2009)

[41] Japan has developed a so-called Joint Crediting Mechanism (JCM) that produces offsets through mitigation activities outside Japan, the credits from which it counts as offsets toward reaching its own emissions targets. Japan has official agreements with the governments of Mongolia, Bangladesh, Ethiopia, Kenya, Maldives, Viet Nam, Laos and Indonesia to fund implementation of mitigation actions in their countries. See Japan's government-supported JCM website for information: http://www.mmechanisms.org/e/initiatives/index.html

[42] The agreement on REDD was heralded as one of the few areas in which the 2013 climate summit in Warsaw actually made progress (McGrath 2013). Sterk et al (2013) note that "conditions under which developing countries can access results-based

government initiatives.[43] The middle-of-the-road scenario thus assumes the establishment of a REDD market and therefore a global price on emission reduction credits from avoided deforestation (and related land-use activities) through 2050. Countries whose GHG trajectories are impacted most by this instrument include Brazil as well as several nations in the GINFORS "rest of world" category such as Indonesia and the Democratic Republic of Congo.

The pricing instrument of carbon taxes is assumed to be used by those countries that have already expressed the intention to do so under the middle-of-the-road scenario. These include South Africa (Cohen, 2013), which falls into GINFORS "rest of world" category and has deemed taxation a more efficient way to address GHG emissions than tradable credits, given the nature of its highly emissions-intensive energy sector.[44] The scenario assumes such carbon taxes continue through 2050.

Carbon pricing non-global-deal path

Similar to middle-of-road path in terms of convergence, i.e. lacking an internationally agreed binding set of enforceable targets for each country, the non-global-deal path assumes that domestic and regional emissions trading programmes continue in the absence of a global carbon market. However, due to faster proliferation of low-carbon technologies, their caps are more stringent because policymakers are able to set more ambitious emission reduction goals with more climate-friendly infrastructure available to industry and other interest groups that would otherwise oppose such goals. The scenario thus assumes further development of regional carbon pricing schemes – including taxes – only with "tighter" caps (and thus higher carbon prices) in the medium and long term (2020 and beyond) resulting from rapid commercialisation of non-fossil-based energy technology.

New market mechanisms also exist in this scenario, though they are not standardised via UNFCCC agreement. As this scenario assumes little convergence in the UN climate negotiations process, REDD standards and tradable units are not universalised in this forum such that active trading of REDD credits does not ensue. Individual countries, however, continue to pay for rainforest protection in tropical nations on a government-to-government basis and through multilateral institutions.[45] Some private sector carbon trading goes on via the (voluntary) retail offset market – the scenario assumes that annual levels of retail carbon

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payments for emission reductions achieved in the forestry sector have been established." The decision itself is available in a format still labelled "draft" at the time of writing on the UNFCCC website, see UNFCCC (2013).

[43] The Environmental Defense Fund 's 2010 map shows a sampling of REDD projects intended to generate tradable credits: http://www.edf.org/sites/default/files/10892_REDDmap_EDF_0.pdf

[44] "In order to work effectively, an emissions trading system needs a sufficient number of entities participating in the scheme, as well as adequate trading volumes to generate an appropriate carbon price. In South Africa, the oligopolistic nature of the energy sector may fail to meet these requirements" (Republic of South Africa, 2013).

[45] Norway, for instance, is a front-runner in this regard – the Norwegian government allocated $135 million to the World Bank's BioCarbon Fund initiative and another $40 million to the UN REDD programme in November 2013 (see e.g. World Bank 2013 and UN-REDD Programme 2013). The UK and the US are also contributors. Rules for this results-based approach, by which money is distributed from governments via the UN's Green Climate Fund, passed as a decision at the November 2013 UN climate summit and represents a shift away from the market-based approach envisioned in earlier talks but leave the door open for other forms of REDD funding (UNFCCC 2013).

offset trading continue through 2050 hold steady at the approximately 100 million tonnes contracted in 2012 (Peters-Stanley and Yin, 2013).

Outside of markets, the non-global-deal path sees several countries implementing carbon taxes – not only as a non-market alternative to carbon pricing, but to raise revenue. As explained in Section 3.1.1, carbon taxes have been suggested in several key countries – the non-global-deal scenario assumes they are adopted, meaning several major economies start pricing carbon in the near term and carry on doing so through the coming decades. In contrast to the middle-of-the-road scenario, where only countries with concrete plans to tax carbon are assumed to do so, the non-global-deal path includes North America: Mexico's proposed carbon tax legislation is assumed to pass and, in a move critical to the global economy, the US also takes on a carbon tax as a revenue-raising measure.[46] The widespread adoption of carbon pricing results in several countries that have carbon taxes (including the US) assessing and possibly applying border tax adjustments to reduce competitive disadvantage in trade.[47] The mere act of cross-comparing carbon price policies to determine the extent of potential additional charges levied on GHG intensive goods by countries that tax carbon leads to a de facto "universalisation" of carbon prices through 2050, as the negative externalities of GHG emissions are internalised in globally-traded goods.

3.2.2 Domestic policies

Domestic policies status quo

Under the status quo scenario, national renewable energy targets (discussed in Section 3.1.2 and Table 2) would continue their current trajectory through 2050. Since most of the targets are for the near to medium term (2020 or 2030), this involves extrapolating the path of meeting those quotas in the target years linearly through 2050. That is, the growth in renewables from 2011 to the target year listed in the table is simply projected forward in a linear fashion through 2050. For several countries, this may be quite ambitious, given that it assumes the current (near term) targets are met and continued: some countries are not on track to meeting the current quotas they have set for themselves.

In terms of subsidies, the status quo scenario assumes continued lack of agreement on jointly reducing fossil fuel subsidies worldwide.

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[46] As explained in 4.1.1, the likelihood of this has risen in recent years as both US political parties seek measures to reduce the growing US national deficit. A November 2013 report by the of the US federal government assessed 35 deficit reduction measures and their effects on revenue – imposing a tax on emissions of GHGes resulted in higher revenue gain ($1.06 trillion over the first decade of the tax) than the other measures in question. The report's models assumed a fee of $25 per metric ton on energy-related emissions of CO_2, increasing at an annual real (inflation-adjusted) rate of 2 percent (see United States Congressional Budget Office, 2013 pgs. 176-177).

[47] The term "border tax adjustments" refers to efforts by countries that have a price on carbon to equalise or "level the playing field" with those that do not price carbon and thus have lower production costs for energy-intensive goods they export. Prices of goods would be "adjusted at the border" (through e.g. import duties) to reflect the higher product cost a carbon price in the producing country would have created. The extent to which such border adjustments constitute protectionism and hinder free trade as guaranteed by the World Trade Organisation is the subject of much debate - for a discussion of border taxes and their legality, see WTO and UNEP (2009) pages 90-100.

Domestic policies global deal

Since the global deal scenario foresees global coordination based primarily on universally agreed *climate* targets (rather than renewable energy goals), domestic renewable energy quotas are enacted mainly with the purpose of achieving national GHG reduction targets under the legally binding global treaty. The ambition of the renewable energy quota depends on each country's treaty target, and on the role renewable energy plays in emission reduction for that nation. Countries in which the renewable electricity percentage is already relatively high (Canada or Brazil, for instance) may not adopt renewable quotas at all because emission reduction opportunities lie in industry, transport and land use.

The treaty foreseen under an ideal-type global deal does not include agreement on a phase-out of fossil fuel subsidies specifically, though it may mention the need for countries to cut such subsidies in order to reach the agreed climate targets. Thus the scenario loosely assumes that some countries might individually lower fossil fuel subsidies - as means to reaching targets to which they are bound under the treaty.

Domestic policies middle-of-the-road

Going beyond the status quo scenario of projecting current renewable energy quotas forward linearly through 2050, the middle-of-the road scenario assumes these targets to be more ambitious: 80 percent of power generation in all major countries is from renewable sources.

In a middle-of-the-road result of negotiations on reducing fossil fuel subsidies jointly, countries come to agreement on this issue – but rather later than sooner. The reduction in subsidies does not commence until 2030, as deliberations continue to be unsuccessful for another two decades. Furthermore, the reductions actually agreed are rather weak and thus do not raise the relative prices of fuels very much, which in turn makes for little incentive to switch to alternative fuels or non-fossil-fueled economies.

Domestic policies non-global-deal

In contrast to the middle-of-the road scenario, the non-global-deal scenario assumes more successful efforts to cut fossil fuel subsidies – this is done in non-UNFCCC fora such as the G-20, where there is already an effort underway as discussed in Section 3.1.2.[48] Countries manage to agree on such a phase-out by 2020 and implement the changes (i.e. remove the subsidies) more quickly than in the middle-of-the-road scenario.

The resulting higher overall cost of fossil fuels encourages more rapid innovation in renewable energy and energy efficiency technology development, which in turn leads to

[48] The main distinction between the global deal and the non-global-deal futures in terms of scenario paths described in Section 3.3.1 is degree of convergence, i.e. the degree to which countries are able to agree on joint coordinated mitigation action – this pertains mainly to the UNFCCC process because it is the international process aimed at achieving global GHG mitigation. However, there are other international negotiations requiring convergence among countries' policies, such as those over an international phase-out of fossil fuels. Jointly lowering subsidies for fossil fuel extraction and consumption can be characterised as a trade issue with environmental implications rather than an environmental issue with trade implications. Thus assuming a high degree of convergence in the otherwise "low-convergence" non-global-deal scenario is justified, as convergence pertains to *climate* instruments.

economies that are 100 percent renewable-powered by 2050. In this scenario, the extent to which fossil fuels are used for electricity generation by mid-century is so tiny that it is not reflected in global energy data – though there is still a market for oil and gas as transportation fuel (although biofuel and electricity will have replaced a significant amount of demand in this sector) and in the form of feedstocks for e.g. pharmaceutical products, polymers and plastics. This applies to all GINFORS countries and the "rest of world" category.

Influential to these developments are the multilateral lending institutions World Bank and IMF, which in 2013 embarked on a path toward limiting lending to coal fired power plants in developing countries (World Bank 2013b, Yukhananov 2013) along with the governments of the US[49] and UK[50] – this scenario assumes that trend is continued to the extent that by 2020 none of the lending from multilateral institutions goes toward fossil fueled electricity infrastructure and neither does bilateral lending from industrialised countries' export-import banks.

3.2.3 Global sectors

Global sectors status quo

Under the status quo scenario, the current reduction measures for emissions from international shipping and aviation continue. For shipping, this means continued application of GHG emission reduction standards for new ships adopted in July 2011 (IMO 2011), which entered into force in 2013 (IMO 2013a). Under these rules, ship builders must adhere to an energy efficiency design index requiring a minimum efficiency level per capacity mile by ship type, and the level is strengthened incrementally every five years. The CO_2 reduction level (grams of CO_2 per tonne mile) requires new ships to be 10 percent more efficient beginning in 2015, 20 percent more efficient by 2020 and 30 percent more efficient from 2025, all from a baseline representing the average efficiency for ships built between 2000 and 2010. However, the effects of this first GHG regulation covering an entire sector are dampened by the fact that it applies only to new vessels while commercial ships typically have a 30-year lifetime. More importantly, a waiver applies to ships registered in developing nations – such ships do not have to comply with the efficiency index requirements until 2019, and analysts contend that developed country vessels can simply register under the flag of a developing nation in order to be exempted from the rules (Hemmings, 2011).[51]

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[49] President Obama's 2013 Climate Action Plan calls for "an end to US government support for public financing of new coal plants overseas" through the US Export-Import Bank and declares that the administration "will work actively to secure the agreement of other countries and the multilateral development banks to adopt similar policies as soon as possible" (Executive Office of the President of the United States, 2013, page 20).

[50] UK Energy and Climate Change Secretary Edward Davey announced on 20 November 2013 that his country would join the US in ending support for public financing of new coal-fired power plants overseas. (UK Department of Energy & Climate Change, 2013).

[51] Countries have long wrangled over the responsibility for emissions reductions from shipping within the IMO, as that body adheres to principles of equal treatment for all vessels while the UNFCCC's concept of "common but differentiated responsibilities" places the initial reduction responsibility on industrialised (Annex 1) countries. Resolutions at the IMO's 65th Marine Environment Protection Committee meeting in May 2013 on ways to share shipping energy efficiency

On the aviation side, this scenario assumes that the international resolution of ICAO's 38th triennial assembly in October 2013 to discuss designing global market-based aviation emission reduction measures by 2016 that would enter into force as of 2020 (ICAO 2013) results in the proposals *not* being adopted at the 39th session in 2016 - thus no international emissions-cutting measures are taken. Europe's efforts to make at least some parts of flights subject to carbon prices by including them in its ETS through 2016 also fail.[52]

Global sectors global deal scenario

The international treaty agreed in the global deal scenario includes strict emissions standards for international maritime transport, to be enforced worldwide by the IMO. The treaty also includes a call from all UNFCCC parties for ICAO to create and enforced an emissions trading system for GHG from international aviation, to which all countries' airlines are subject: since all ICAO members are parties to the UNFCCC, those actions are then taken in ICAO. This in turn strongly incentivises innovation in shipping and aviation, which in turn leads to significant GHG reductions from those sectors through 2050.

Global sectors middle-of-the-road

Going a step further than the status quo, the middle-of-the-road scenario sees some shipping and aviation GHG instruments implemented. Countries adhere to the GHG standards for new ships adopted in 2011 and developed country ships do not register under developing country flags in order to waive the standards – however, the amount of ships affected is small, as firms seek to extend the lifetimes of existing vessels in order not to comply with the energy efficiency requirements. An increasing share of global goods transport is carried out via airplane rather than marine vessel, further increasing overall emissions from international transport per tonne.

On the aviation side, the plan for a global market-based mechanism laid out in the aforementioned ICAO assembly of October 2013 is, in contrast to the status quo scenario, actually adopted in 2016 – but the resulting aviation emissions "market" incentivises only few reductions, as its caps are too weak. The proposal laid out by the International Air Transport Association (IATA) at its 69th Annual General Meeting in June 2013 suggests a market-based approach to "carbon neutral growth" as of 2020 (IATA, 2013) that was brought before the October 2013 ICAO assembly – in this scenario, that plan becomes the one ICAO adopts. It foresees no binding required mitigation action until 2020, after which emission reduction to meet GHG standards (set on a carrier-by-carrier basis) would consist largely of offset purchases to keep net carbon emissions from international aviation at the 2020 level.

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technology (IMO 2013) take both principles into account, potentially paving the way for technology transfer that allows for faster emission reduction.

[52] The EU has proposed the intermediary step of holding all airlines accountable for emissions in EU airspace only, by including those as emissions for which allowances must be surrendered in its emissions trading scheme through 2016 (European Commission, 2013). However, recent opposition to even this option (see e.g. Lewis 2013), which is already a "watering down" of the plan to require allowances for all parts of any air travel taking off or landing at EU airports, means only intra-EU flights will be included in the EU ETS through at least 2016 and that thus no international measures are taken under this scenario.

Global sectors non-global-deal

Advances in shipping and aviation technology, spurred to a large extent by the early and intense increase in fossil fuel prices brought about by the non-global-deal's more rapid subsidy removal explained in Section 3.2.2.4), enable ships to comply easily with the energy index requirements of the IMO's 2011 resolution and also enable the aviation sector (through advances in biofuels and low-weight planes) to achieve the ICAO goal of cutting aviation emissions 50 percent from 2005 levels by 2050 (ICAO 2013).

Table 3: Summary of scenarios by instrument category

	Status quo	Middle-of-the-road	Non-global-deal	Global deal
Carbon pricing	Existing emissions trading systems continue, but end after their currently foreseen "lifetimes" (e.g. 2020). Existing carbon taxes continue, no new ones added. No new market mechanisms.	Existing ETS continue, planned ones (e.g. China, South South Korea) enter into force in 2015, North American carbon markets (California+Quebec, RGGI) extend through 2050, Japan's offset programme continues. Disparate new market mechanisms develop (especially REDD) but are not globally fungible. Existing carbon taxes continue, planned ones (e.g. South Africa) enter into force.	Same as middle-of-the-road path, but with more stringent ETS targets and carbon tax levels. New market mechanism established for REDD, but consists of direct payments rather than tradable emission reduction units aside from the voluntary market. Existing carbon taxes continue and more are introduced in major economies, including the US.	International binding treaty with national emission reduction targets, universally recognized allowance and offset units that are fungible among countries and used to meet targets.
Domestic-policies	Renewable energy quotas continue their current trajectory through 2050, i.e. growth in renewables from 2011 to a country's current target year is linearly extrapolated through 2050. No joint reduction in fossil fuel subsidies.	Eighty per cent of power generation in all major countries is from renewable sources by 2050. Countries agree to jointly reduce fossil fuel subsidies, but not until 2030 and at a lenient rate with many exceptions.	All major economies have 100 per cent renewable power generation in 2050. Countries agree to international fossil fuel subsidy phase-out by 2020. International lending institutions stop funding fossil fuel projects.	Renewable energy quotas are applied "as needed" to reach agreed emission reduction targets countries have taken on under binding climate treaty. Fossil fuel subsidy removal also a means to reaching target – countries do it to the extent necessary to evoke required emission cuts.
Global sectors	IMO's 2011 energy efficiency design index for ships is upheld, but loopholes used to the extent that it applies to very few ships through 2050. Aviation emission reduction proposal for market-based mechanism in 2020 *not* adopted.	Countries adhere to current IMO shipping standards and these apply to more vessels than status quo scenario, but aviation's share of global transport emissions rises. ICAO countries adopt market-based emission reduction proposal in 2016 and offset *growth* in GHG emissions as of 2020.	Strong advances in shipping and aviation technology, spurred by higher fossil fuel costs from subsidy removal, reduce both transport sectors' GHG intensity. Aviation sector achieves goal of cutting emissions to 50 percent of 2005 levels by 2050.	International treaty includes strict emission standards for ships, enforced by IMO. Strict global emission strading system developed for global aviation sector, enforced by ICAO via UNFCCC decision.

4 Conclusion: changing the definition of "ambitious"?

These scenarios, while merely hypothetical, provide policy contexts for European climate change measures through 2050 - a more ambitious *global* carbon mitigation scenario likely makes for relatively cheaper achievement of Europe's 2050 target: with other major countries (particularly the largest economies and Europe's trading partners) moving toward faster and more ambitious reductions of GHG, Europe's efforts are buoyed by economies of scale. A rather lackluster global emission reduction effort makes for a European scenario of 'going it alone', which is more expensive given the many (and increasing) economic interdependencies between Europe and the rest of the world. Application of these scenarios using GINFORS and other models will reveal their influence on e.g. price of achieving the EU's 2050 targets.

The juxtaposition of two very different "ambitious" scenarios among the four outlined in this discussion aims to reflect the changing reality of the global climate change negotiations. Developments in the UNFCCC during the 1990s and early 2000's pointed toward a path of ever-increasing policy convergence, with a treaty (the Kyoto Protocol) that would result in emission reduction if carried forward for several further commitment periods of increasing stringency and applicability. Much previous scenario modeling has been based on the assumption that this global deal path would carry forward, such that the differences among scenarios consist of various distributions of effort among parties under the overall auspices of a treaty or agreement construct. However, at least the last five annual UNFCCC summits have proven otherwise: negotiations are not proceeding along a path of policy convergence with a binding treaty containing mutually agreed targets. Rather, various individual policies are being pursued by individual countries or regions – often not in the form of restrictions or curtailment directed at climate change but rather as promotions or incentives directed at e.g. renewable energy or efficiency that happen to have emission reducing "side effects."

As stated in Section 3, a non-global-deal scenario is the more likely of the two "ambitious" scenarios offered here - especially given current political developments in the UNFCCC (or lack thereof). Several organisations and analysts share this view, and have thus laid out new constructs for the role of the entire Framework Convention: the World Wildlife Fund posits reframing the UNFCCC as more of a renewable energy enhancement body than a climate targets negotiating forum (World Wildlife Fund Global Climate & Energy Initiative, 2013), which would make for less convergence and more ambition – a "convergence through ambition" path as shown in Figure 4. Similarly, Diringer (2013) argues that although UNFCCC negotiations may not collapse altogether and may indeed result in an agreement, that agreement will constitute a collection of transparently peer-reviewed domestic actions rather than binding negotiated emission reduction targets and timetables.

Efforts are underway to connect these disparate programs *without* the unifying oversight of a treaty, i.e. to provide some venues for convergence that may positively impact ambition – this is particularly true for carbon pricing instruments, where convergence most directly facilitates ambition. The World Bank, for instance, is devoting considerable resources to a so-called International Carbon Reserve (ICAR) that individual regional GHG emissions trading programmes could opt into. The ICAR would involve independent rating agencies and surveillance for all participating markets, supporting an “international” carbon price by providing transparent translation of relative allowance values among participating programmes (see Jones, Purvis and Springer, 2013 as well as Hughes, 2013). Despite the absence of internationally agreed climate targets associated with commonly recognized allowances, such an institution would create a de facto global carbon market. The result of these efforts is that a “bottom up” carbon price universalisation process is underway among multinational companies – particularly those selling the most GHG intensive products traded in the most liquid global markets (fossil fuels): several multinational corporations, including the five major oil companies, currently assume a carbon price in their long-term financial and investment planning (Davenport, 2013).

Finally, even without the many non-UNFCCC sources of convergence, technological advances in low-carbon technology may render convergence less necessary for ambition. Sterk et al (2013) point out that although UNFCCC negotiations increasingly consist of “posturing,” the “realities on the ground” (including rapidly declining equipment costs of renewable energy technologies and the correlating rapid scale-up in increasing numbers of countries) render pre-agreed emission reduction targets and timetables less important to achieving a low-carbon future.[53] Thus, of the two ambitious international future emissions paths, the non-global-deal scenario is the context EU climate change policy instruments will more likely find themselves subject to.

[53] The authors point out that equipment costs of solar photovoltaics have fallen by roughly 80 per cent in the last five years, while wind turbine costs fell by one-third in the same timeframe. They cite Citigroup projections that both wind and solar will be fully competitive with other energy sources in most parts of the world by 2020.

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