The United Nation's Framework Convention on Climate Change and the Minamata Convention on Mercury: A comparison for the coal combustion sector

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Executive Summary

The UNFCCC is based on a top down approach, giving an overall goal for greenhouse gas reductions but with flexibility on how to achieve these reductions. The UNFCCC can be regarded as the instigator for activities and projects to reduce CO_2 emissions from sources such as coal combustion. Even though many countries are still not parties to the convention, the activities underway are relatively aligned as many countries accept the potential environment consequences of elevated greenhouse gases and take similar approaches to reducing emissions. The solutions to reducing CO_2 emissions from coal combustion appear somewhat simple – burn less coal, burn it more efficiently and apply CCS (carbon capture and storage). However, although the solutions may appear simple, in practice they pose significant challenges. Populations are growing and, with them, the demand for energy increases. Large populations are still waiting for electrification and to control emissions in the face of increased fuel use is not easy. Further, the CCS technologies which are vital to reducing emissions from existing and future plants are still far from commercialisation.

The Minamata Convention is new and in the early stages of implementation. However, many countries had already started to take action to reduce mercury emissions before negotiations had been completed. To date, approaches for mercury control have largely been on a source-specific basis and the majority of the legislation existing and impending are also source-specific approaches, for example the emission limit values in North America and some of Asia.

Although neither the UNFCCC nor the Minamata Convention call specifically for the phasing out of coal, they do set priorities which affect how coal is viewed by the public and how utilities must operate in the future. Both the conventions promote the more efficient use of coal where coal continues to be used.

The UNFCCC is primarily focussed on two options – the reduced or more efficient combustion of coal and the application of CCS, the latter being somewhat away from commercial deployment. The Minamata convention also may promote the reduced use of coal but also relies on currently available flue gas cleaning technologies and even changes in coal supply and demand (for cleaning, switching and blending options). Although Minamata does not directly list combustion efficiency as a requirement, this is certainly an approach that could be considered under BAT/BEP.

The flue-gas control technologies available for CO_2 and mercury control are quite distinct. For the most part, any technology for one will not achieve a reduction in the other. However, detailed consideration must be given to ensure that a control technology for one pollutant does not result in increased emissions of the other. This means considering the final fate of mercury in any CCS system and also considering any negative plant efficiency resulting from the installation of mercury controls.

Acronyms and Abbreviations

2DS	2 degree scenario
ADB	Asian Development Bank
BAT	best available technology
BEP	best environmental practice
CCC	Clean Coal Centre
CCS	carbon capture and storage
CHP	combined heat and power
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
EC	European Commission
EIB	European Investment Bank
ELV	emission limit value
EOR	enhanced oil recovery
ESP	electrostatic precipitator
ETS	emissions trading scheme
EU	European Union
FGD	flue gas desulphurisation
GCF	Green Climate Fund
GDP	gross domestic product
GEF	Global Environment Facility
GHG	greenhouse gas
$GtCO_2e$	giga ton (metric) CO_2 equivalent
GWh	giga watt hour
HELE	high efficiency low emission
IED	Industrial Emissions Directive
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control

JI	Joint Implementation
LCPD	Large Combustion Plant Directive
NAP	national action plan
O&M	operation and maintenance
SC	supercritical
SLCP	short-lived climate polluter
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra-supercritical
WEO	World Energy Outlook

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1 Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) was initiated in 1992 in order to coordinate global action to control the increasing emissions and effects of greenhouse gases (GHG) in the atmosphere. The UNFCCC has evolved through many protocols and amendments. Signatories to the Convention and those committed to its aims have succeeded in initiating many international and national activities.

The Minamata Convention on Mercury (Minamata Convention), with the objective to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds, was opened for signature in Japan in 2013 and there is much work ahead to move the aims of the convention into reality.

Both the UNFCCC and the Minamata Convention have similar aims – to reduce global emissions that are harmful to human health. Both also place a significant onus on emissions from coal combustion. There is therefore potential to learn and benefit from considering potential synergies between the two conventions to coordinate the action taken within the coal combustion sector to maximise the overall benefits.

2 Similarities between the conventions

The UNFCCC is more advanced in terms of development and action than the newer Minamata Convention. To date, however, the UNFCCC has not been ratified by all countries which are heavily reliant on coal. As of April 2015, the Minamata Convention had 10 ratifications. This chapter summarises both conventions in order to highlight areas of overlap and synergy and also areas which may provide opportunities and allow mutual benefit from coordinated action.

2.1 The UNFCCC

The text of the UNFCC was published in 1992 and the convention entered into force in 1994 (UN, 1992). There are now 195 countries that have ratified the convention. The ultimate aim of the convention is to stabilise greenhouse gas (GHG) concentrations "*at a level that would prevent dangerous anthropogenic interference with the climate system*". However, the convention advised that this should be achieved, amongst other things, while "*enabling economic development to proceed in a sustainable manner*".

The nature of the convention was to call upon developed countries to lead the way and to provide financial support for action on climate change in developing countries. This would be achieved under the Global Environment Fund (GEF).

The UNFCCC requires that countries produce inventories of their GHG emissions annually and to introduce national policies and measures to achieve the goal of GHG control. The convention also acknowledged that some change in climate was inevitable and, in response, established an Adaption Committee to work to address adverse effects in vulnerable regions (UN, 2013).

The Kyoto Protocol was the first protocol within the UNFCCC and was adopted in Japan in 1997, but did not enter into force until 2005. The detailed rules for the Kyoto Protocol were adopted in Marrakesh in 2001 and thus became known as the **Marrakesh Accords**. The first commitment period for the accord ran from 2008 until 2012, requiring the 37 signatory countries and the EU to reduce greenhouse gas emissions to an average of 5% below 1990 levels. Market based mechanisms were introduced under the Kyoto Protocol to facilitate cooperation between parties in a cost-effective manner. These were (UN, 2013):

- Emissions trading (where total emissions are defined and assigned volumes may be bought and traded under this total cap);
- The Clean Development Mechanism (CDM) allowing one signatory country to action emission reductions in a 2nd non-signatory country. The CDM has been operating since 2006 based on Certified Emission Reduction (CER) credits. These CER credits can be traded, sold, and used by industrialised countries to meet a part of their emission reduction targets. The CDM is designed to stimulate sustainable development and emission reductions, while giving industrialised countries some flexibility in how they meet their emission reduction targets;
- Joint Implementation (JI: allowing one signatory country to achieve emission reductions in a 2nd signatory country).

The **Bali Road Map** was produced in December 2007 and includes the Bali Action Plan – a move towards establishing cooperative action in the long-term, through 2012 and beyond. It covers five main areas: shared vision, mitigation, adaptation, technology and financing. The shared vision refers to a long-term vision for action on climate change, including a long-term goal for emission reductions.

The **Cancun Agreement**, reached in December 2010, was the first mention of the aim for the UNFCCC to keep the global average temperature rise due to GHG concentrations below 2 Degrees, known as the "2 degrees scenario" (2DS). Again, technology transfer was promoted. The Cancun Agreement also established several new institutions and processes, including the Technology Mechanism, which includes the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN). The Green Climate Fund (GCF) was established to distribute $100 billion/y by 2010 to developing countries to assist in mitigating climate change as well as adapting to its impacts.

In 2011 the **Durban Outcomes** called for a continuation of the current international legal system through a second commitment period of the Kyoto Protocol. This would include revision and update of several articles including those concerning the trading schemes and the IPCC guidelines for GHG inventories (UN, 2012). The **Doha Amendment** outlines new commitments for signatory parties and updates several articles in the original Kyoto Convention, and sets a new target of at least 18% reduction in GHG emissions below 1990 levels. Work under the amendment runs from 2013 until 2020 when a new instrument will enter into effect with associated reduction targets for parties.

The UNFCCC has now been evolving for over two decades. However, despite the changes which continue to appear through the COPs to improve the commitments and achievements under the convention, the aims are still very much the same: signatory countries must maintain inventories on their GHG emissions and must work to reduce them.

There has been controversy associated with the UNFCCC and more particularly with the Kyoto Protocol. Some disagree with the findings of the IPCC whilst others do not agree with the commitments required under the UNFCCC. However, it is clear that many countries that have not signed up to these commitments still agree with the major principles and aims of the protocols. Many regions will strive to achieve similar aims, even if they do so under their own, separate, methodologies. Although the UNFCCC does not specifically target the coal sector, the recommendations and requirements for decarbonisation, energy efficiency improvements and carbon capture and storage (CCS) are having a significant impact on coal use in many regions.

The UNFCCC targets all GHG emissions. Coal production and use is associated with emissions of methane (CH_4) and nitrous oxide (N_2O), in addition to CO_2. Methane can be produced in significant quantities through coal production but is not associated with coal combustion as it is too flammable to escape in combustion gases. Methane will not be discussed further in this report as this report pertains to emissions from coal combustion for power generation. Although elevated nitrous oxide emissions can be associated with certain coal combustion technologies, such as fluidised bed combustion systems, this is a minor consideration compared to CO_2 emissions and therefore will only be mentioned briefly in this report. With respect to the UNFCCC, this report concentrates on only those elements of the convention which relate to CO_2 emissions from the coal combustion sector.

2.2 Minamata Convention on Mercury

The Minamata Convention (UNEP, 2013) was signed in Japan in October 2013 and aims to "*protect human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds*".

With respect to the coal sector, the most relevant section of the Convention is Article 8 on emissions, which calls for parties to *take "measures to control mercury emissions from the point sources falling within the source categories listed in Annex D*". The Article also indicates that Parties with relevant sources "… may *prepare a national plan setting out the measures to be taken to control emissions and its expected targets, goals and outcomes*". A potential plan shall be submitted to the Conference of the Parties (COP) of the Minamata Convention within 4 years of the date of entry into force of the Convention for that Party.

For "new sources"[1], best available technology (BAT) and best environmental practice (BEP) are required as measures to control, and where feasible, reduce emissions.

For existing sources, each Party shall implement one or more of the following measures within 10 years of the convention coming into force:

- Quantified goal for controlling and, where feasible, reducing emissions;
- Emission limit values for controlling and, where feasible, reducing emissions;
- Use of BAT and BEP to control emissions;
- Multi-pollutant strategy that would deliver co-benefits for control of mercury emissions; or
- Alternative measures to reduce emissions from relevant sources.

The definition of BAT and BEP is given in the Convention text and further guidance on BAT/BEP will be adopted by the first meeting of the COP.

Parties to the convention are also required to establish (within 5 years) and maintain an inventory on mercury emissions from relevant sources.

Article 9, on releases to water and land, and Article 11, on mercury in wastes, are also relevant to coal plants.

The Minamata Convention states that "*multilateral, regional and bilateral sources of financial and technical assistance, as well as capacity building and technology transfer, are encouraged on an urgent basis to enhance and increase their activities on mercury in support of developing country Parties in the implementation of the Convention relating to financial resources, technical assistance and technology transfer*". It also defines a Mechanism for the provision of financial resources including a GEF trust fund and a specific international programme to support capacity-building and guidance. Articles 17, 18 and 19 deal with information exchange, public information, awareness and education, and research, development and monitoring respectively.

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[1] (c) "New source" means any relevant source within a category listed in Annex D, the construction or substantial modification of which is commenced at least one year after the date of:
(i) Entry into force of this Convention for the Party concerned; or
(ii) Entry into force for the Party concerned of an amendment to Annex D where the source becomes subject to the provisions of this Convention only by virtue of that amendment;
(d) "Substantial modification" means modification of a relevant source that results in a significant increase in emissions, excluding any change in emissions resulting from by-product recovery. It shall be a matter for the Party to decide whether a modification is substantial or not;

The Minamata Convention was opened for signature in October 2013 and there is a significant amount of work ahead to provide more details on how best to achieve the aims set out. However, there is much within the UNFCCC that may be of relevance to the Minamata Convention and could be used to leverage potential synergies for mutual benefit.

2.3 Alignment between the conventions

Table 1 summarises the main aims and formats of the conventions. The following sections compare the approaches for each, highlighting potential synergies relevant to emissions from coal combustion.

Table 1 Comparison of UNFCCC and Minamata Convention

	UNFCCC	**Minamata**
Aims of the convention	Stabilise/reduce GHG	Control/reduce mercury
Action plans	Decided nationally	Optional, to be decided nationally
Strategies applicable to the coal sector	Promote low carbon options Increase combustion efficiency CCS installation where/when possible	May include low mercury options, use of co-benefits, range of other technology. No firm targets established.
Will the convention apply to existing/older plants?	Possibly under national plans in the long term	Yes. Existing facilities in the identified source categories must be controlled.
Will the convention apply to new plants?	Some national legislation appearing CCS promoted Promote HELE options	New facilities must use BAT/BEP for control.
Guidelines on inventory production	IPCCC guidelines	To be adopted by the COP. UNEP Toolkit available
Monitoring and reporting	IPCCC guidelines	Reporting required on measures taken in accordance with paragraph 4 to 7
Economics and finance	Established	Categories of activities to receive support to be decided by COP
Communication and outreach	Established	Obligations for information exchange, information and research

2.3.1 Aims

Although the UNFCCC and Minamata Convention target different pollutants, the aims are very similar – to stabilise or control and, where possible, reduce emissions and their subsequent effects in the environment. Although the energy sector, and coal combustion, are included along with a large number of potential sources, it is clear that coal combustion is one of the main sectors to be targeted by action taken under both conventions with the shared objective of reducing emissions.

Putting all the technical details aside, there are only 4 major routes towards reducing emissions from the energy sector:

1 Reduction in energy demand through end use efficiency and lower fuel consumption

2 Avoid electricity generation processes involving the combustion of fuels containing the precursors of these emissions (in this case, carbon based fuels and fuels containing mercury);

3 Burn any fuels containing carbon and mercury more efficiently, to reduce emissions on a g/GWh basis; and

4 Capture emissions produced to avoid release to the atmosphere.

Therefore, by following these major routes, the aims of both the UNFCCC and the Minamata Convention may be satisfied. However, whereas the UNFCCC concentrates mainly on routes 1, 2, and 3 with route 4 being heavily dependent on the development of CCS (carbon capture and storage), the Minamata Convention considers all four routes.

With respect to Route 1, coal combustion can be avoided in some areas by promoting renewable technologies and by switching to alternative non-carbon or lower carbon intensive fuels, such as, for example, natural gas. However, it is clear from the World Energy Outlook (WEO) data that coal is projected to be a major source of energy for decades to come with many emerging economies choosing coal as an option as the move towards electrification and industrialisation. **Figure 1** shows the growth in coal use projected globally by the WEO.

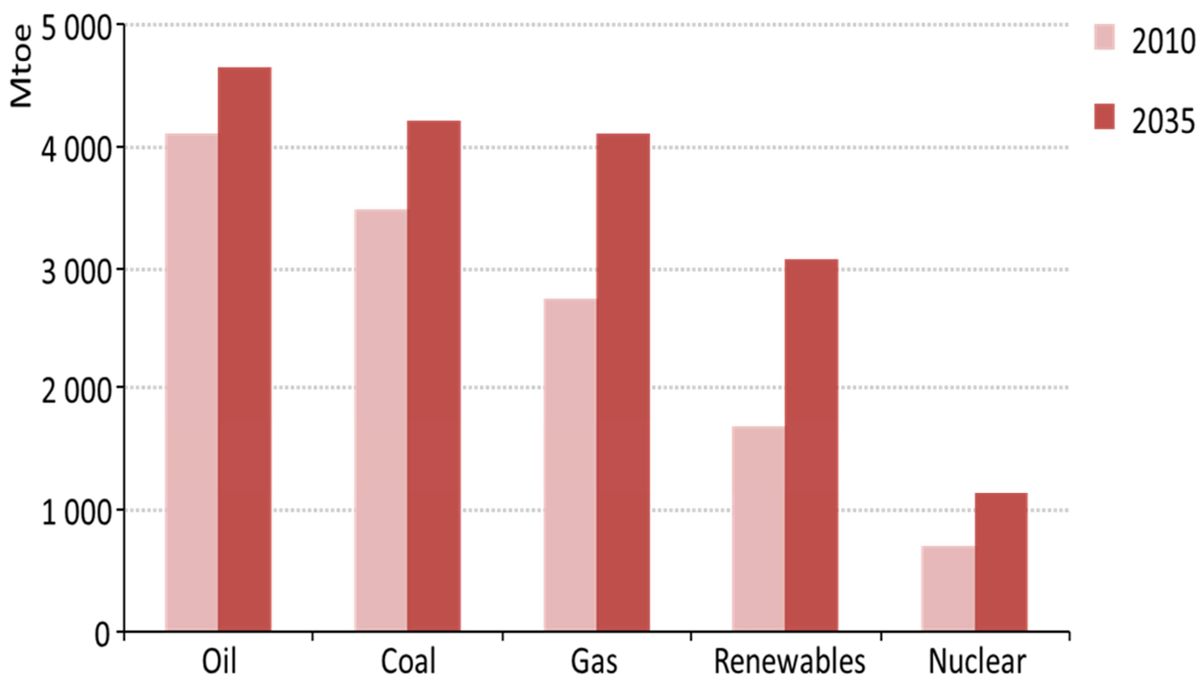


Figure 1 **IEA WEO 2012 – World primary energy demand by fuel**

The latter two of the four routes described above combine to form the basis of HELE – high efficiency low emission – technologies. HELE technologies are those which run at the highest possible efficiency, to produce the maximum amount of power for the least amount of fuel use, and produce the lowest possible emissions of all harmful gases. HELE technologies include state-of the art combustion systems such as supercritical (SC) and ultra-supercritical plants (USC), which run at higher temperatures and pressures than subcritical systems.

Compared to most existing and aging coal plants, which are sub-critical and run at average efficiencies of 35% or below, USC plants can achieve up to 45% (lower heat value or LHV, net) efficiency. This can reduce the CO_2 emissions from over 880 gCO_2/kWh of energy produced to 740 g/kWh and may even reach 670 g/kWh within the next 10-15 years. This represents a 30% improvement in plant performance and means that significantly lower volumes of fuel are needed to produce the same amount of useable electricity. Less fuel equates to lower emissions. The IEA note that around 50% of the new coal-fired units built internationally in 2011 used HELE technologies. Whilst this represents a doubling in HELE technologies in the past decade, it also highlights that 50% of new build plant are still subcritical systems. This locks inefficient coal use into the budget for several decades to come.

This "locking in" of emissions is an important issue. The total emissions over the coming years will be cumulative from current plants which continue to run and all new plants coming on line. Not all plants will run for their projected lifetimes whereas others may run for longer. Achieving a significant increase in emissions of CO_2 will require a significant change in, not only new plant performance, but a decrease in emissions from older plants which continue to run. Whilst mercury emissions can be controlled from all plants at up to 95% or more, in some cases, without CCS, this is not going to be the case for CO_2. Whereas mercury emissions can be somewhat decoupled from both existing and new plants due to increasingly effective control technologies, CO_2 will continue to increase with fuel use until CCS is available.

Figure 2 shows examples of pathways to producing cleaner coal-fired systems. The HELE option combines efficiency with flue gas treatment systems to produce plants which use less fuel and produce lower emissions of all gases. Whilst HELE fits the aims of the Minamata Convention well, the energy efficiency portion is not specifically required under the convention. Rather, energy efficiency could be considered as one of many options under the BAT/BEP approach, depending on specific circumstances in different regions. The Minamata Convention would therefore benefit from embracing the concept of HELE for all new plants. The UNFCCC must also embrace and promote HELE but with the additional consideration of CCS where possible. Since CCS is outside the aims of Minamata, in order for the conventions to align fully, Minamata must consider any beneficial or detrimental effects of CCS on mercury emissions and must work to minimise the latter.

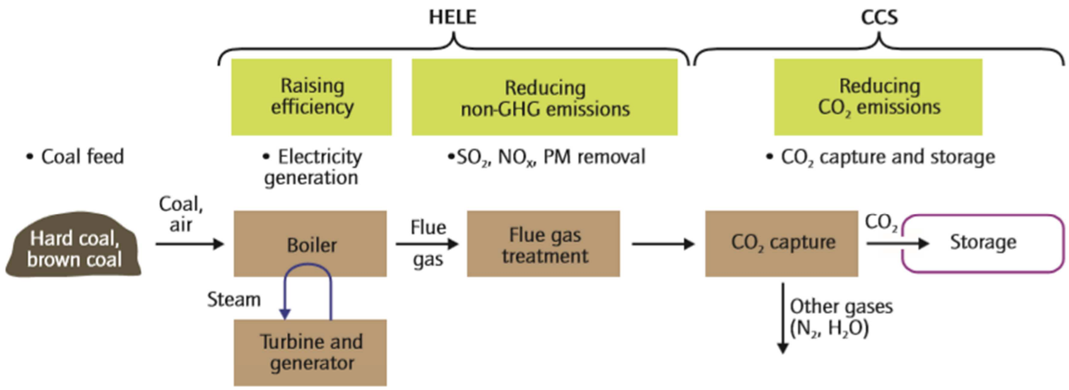


Figure 2 **Examples of pathways for cleaner coal-fired power generation** (IEA, 2012)

The International Energy Agency (IEA) has produced a technology roadmap based on HELE technologies (IEA, 2012). **Figure 3** shows the proposed move from subcritical systems to HELE and ultimately to HELE plus CCS by 2050 as would be required to reach the 2DS (2 Degree Scenario, where the effect on the projected global average temperature increase is kept at or below 2°C). Whilst this is theoretically possibly, the roadmap relies very heavily on CCS becoming commercially viable within the next 10 years.

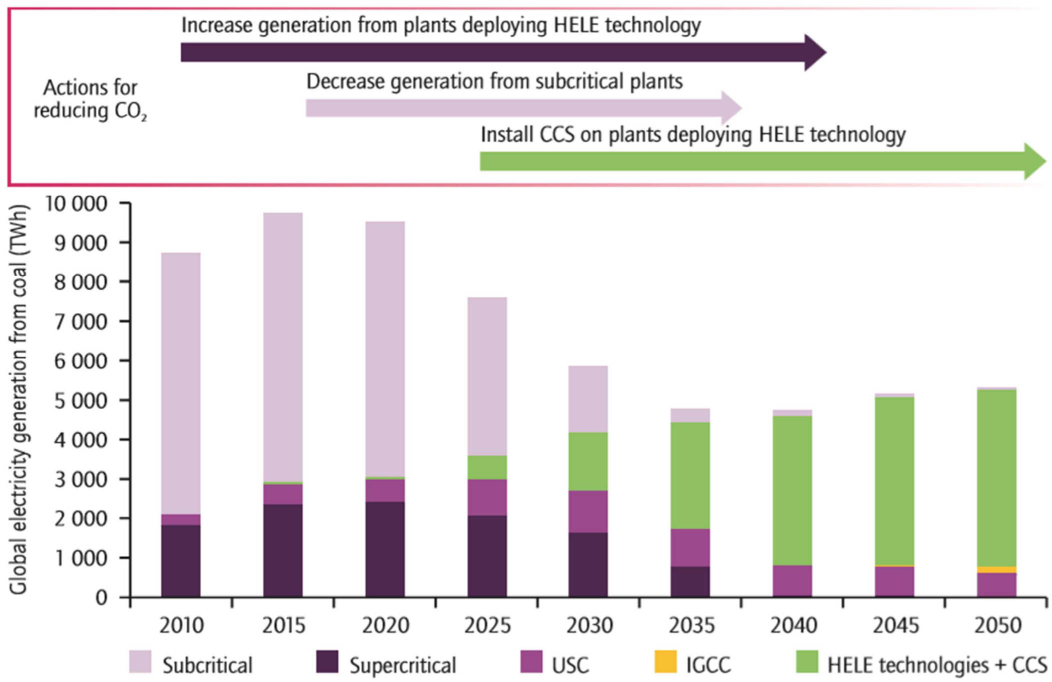
The roadmap defined in Figure 3 would satisfy the requirements of both the UNFCCC and Minamata, assuming that mercury control is fully considered within the low emission technologies – that is, that the final fate of mercury through all air pollution control devices is evaluated and maximised.

Combustion efficiency and emissions control are discussed in more detail in Chapter 4.

2.3.2 Action plans

Article 4 of the UNFCCC calls for the parties to "*promote, implement, publish and regularly update national, and where appropriate, regional programmes containing measures to mitigate climate change …*" Kyoto reiterated the requirement for national and regional programmes including those concerning the energy sector, based on options such as technology and information transfer.

Parties to the UNFCCC have approached the requirement for national plans in very different ways, as would be expected. The European Commission has created targets for member states and established the European Emissions Trading Scheme (ETS). Some individual countries in Europe have taken significant steps towards building GHG reduction into their national energy strategy. However, action plans will vary significantly between developed and non-developed nations.



Note: Carbon capture is integrated with HELE coal-fired units to minimise coal consumption and CO_2 abatement cost.

Figure 3 **Electricity generation from different coal-fired power technologies in the 2 Degree Scenario (2DS)** (IEA, 2012)

The UNFCCC was careful to include some flexibility for those countries undergoing industrialisation and with a heavy dependency on coal for power generation, recognising "*special difficulties for those countries, especially developing countries, whose economies are particularly dependent on fossil fuel production, use and exportation, as a consequence of action taken on limiting greenhouse gas emissions*". The Minamata Convention also makes allowances for "individual flexibility" noting that each party must "*develop and execute an implementation plan, taking into account its personal circumstances for meeting obligations under this Convention*".

It is beyond the scope of this report to look at national action plans in detail. However, for reducing all emissions from coal combustion, parties will be looking at the four options discussed earlier. Many of parties to the UNFCCC and its daughter protocols and even countries which are not party to the convention, have national energy and environment strategies which include energy efficiency and CO_2 reduction. Rather than draft completely new national plans for mercury under Minamata, parties who already have such national strategies would benefit from merging the aims of Minamata into already established strategies and projects. Whilst many of the energy efficiency and CO_2 reduction projects will already include co-benefit effects for mercury, it would be wise for them to be reviewed, taking into account possible counter-effects and to highlight areas where mercury reduction could be enhanced through small modifications to already established guidelines.

Fuel switching and energy efficiency programmes would have a comparable effect on mercury emissions as they do on CO_2 emissions – energy efficiency improvements mean more power from less fuel and, in turn, less fuel means lower emissions of all pollutants. However, the control technologies applied to flue gases for CO_2 and mercury are quite distinct and, although they will be dealt with separately, there is much to be considered with respect to synergies (see Chapter 4).

The original 1992 UNFCCC does not specify control measures in any form. Rather Article 4 on commitments calls for parties to "*adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases* …"

The 1998 Kyoto Protocol was somewhat more specific, requiring development and promotion of new and renewable forms of energy, of carbon dioxide sequestration technologies, and of advanced and innovative environmentally sound technologies.

As discussed in Section 2.2, the Minamata Convention allows for development of action plans but clearly states that measure shall be taken to control and where feasible reduce emissions. For the purpose of the Convention, "control" applies to the establishment of monitoring and managing emissions whereas "reduction" applies to the effect of actually lowering emission totals. In areas of rapid growth and expansion in industry and power generation, control of emissions may not guarantee that reductions will be achieved. Under the Convention, each party shall implement one or more of the following measures:

- Quantified goal for controlling and, where feasible, reducing emissions;
- Emission limit values for controlling and, where feasible, reducing emissions;
- Use of BAT (best available technology) and BEP (best environmental practice) to control emissions;
- Multi-pollutant strategy that would deliver co-benefits for control of mercury emissions; or

Emission reduction goals provide the ultimate in flexibility and they define only the reduction required and do not prescribe the means which must be used to reach this reduction. This allows parties to use the most appropriate methods available to reduce emissions. These will likely include options based on the 3 routes discussed in Section 2.3.1 above. ELVs (emission limit values) would provide an absolute guide on how much emissions should be reduced from specific sources. ELVs have already been applied to reduce mercury emissions in North America and have been introduced in China. ELVs and their efficacy in reducing mercury emissions will be discussed in more detail in Chapter 6. By comparison, although the UNFCCC has not specifically called for ELVs for CO_2, Canada has already set an ELV of 420 g/kWh for new coal-fired plants. Similar ELVs are being discussed in Europe and the USA (see Chapter 6). However, it should be noted that the ELVs being selected for CO_2 for coal can only be achieved with CCS.

BAT for mercury is a complex issue. There are many techniques and technologies which can be applied to coal-fired plants to reduce mercury. However, because of the complex behaviour of mercury in coal combustion systems, there is not one single technique or technology which can be regarded as BAT for mercury control. Rather, BAT must be determined on a plant-by-plant basis. This is due to the complexity of mercury behaviour in combustion systems. Mercury emissions vary with coal type, combustion conditions and many other plant-specific factors. In some cases, BAT may be a multi-pollutant control system – a technique or technology that can reduce emissions of several pollutants simultaneously, most commonly sulphur dioxide (SO_2), halogens and trace elements, including mercury. For developing regions who have not already established emission control requirements for acid gases, multi-pollutant control options offer the most cost-effective way of controlling multiple pollutants.

Technology options for mercury control are discussed in more detail in Chapter 4. The challenge for the Minamata COP will be to develop the guidance on BAT to reflect the definition in the Convention to ensure that each Party can determine for each source the most appropriate method of mercury control (taking physical, geographical and financial constraints into account) whilst still ensuring that the maximum amount of mercury reduction is achieved.

With respect to the UNFCCC, BAT is simply efficiency improvements and CCS. To align BAT for both Minamata and the UNFCCC, the consideration of technologies for coal-fired plants must consider the effect of any control technology on emissions of both pollutants. For example:

- Some flue gas treatment systems for mercury require power to operate (usually <1-2% of output) which will reduce overall plant efficiency and thus increase the overall CO_2 emission rate;
- Some flue gas treatment systems for mercury create new waste streams that must be considered under full life-cycle analysis for their overall effect on GHG emissions; and
- The final fate of mercury in CCS systems needs to be identified – if emissions to the air are reduced then this should not result in an increase in emissions to liquid or solid waste streams, unless these streams are also adequately controlled.

It is therefore important that national and international projects for flue gas cleaning for mercury consider potential effects on GHG emissions and vice versa.

2.3.3 Inventories

Under Article 4 of the UNFCCC, all parties must periodically update, publish and make available national inventories of anthropogenic emissions by all sources. Kyoto went further by requiring a national system for inventory production based on methodologies defined by the conference of the parties. The Intergovernmental Panel on Climate Change (IPCC) has established well defined methodologies for GHG inventory production based on the amount of data available in each region.

Emissions are commonly estimated as follows:

Emission = emission factor x activity data

Emission factors can be based on either fuel or source specific data whereas activity data is generally based on either amount of fuel used or on energy production. Emissions can be estimated on a top down or bottom up basis.

Top down:

- Use aggregated data (often compiled by government agencies) to provide data on all sources;
- Emissions are calculated based on total activities in grouped sectors, for example total coal burned in a country multiplied by the average mercury content of the fuel.

Bottom up:

- Uses more detailed data on individual facilities;
- Emissions are calculated/estimated/measured on a source by source basis and added together.

The bottom up approach can be more accurate since emission factors can be produced on a more source-specific basis. However it requires a significant amount of specific data and would only be applicable in a country where there were a very small number of sources to be included. The majority of national and international inventories are largely based on a top down process, although these are being made increasingly accurate by the incorporation of more accurate emission factors obtained from bottom-up studies.

The IPCC guidelines for CO_2 emissions require the use of emission factors – actual measurements of CO_2 are discouraged as the cost of the measurement systems is often prohibitive and it is argued that the results they produce are no more accurate than emission factors based on coal data. The IPCC has provided a default emission factor for CO_2 for coal, based on coal type. Parties may choose to use these emission factors or to produce their own national emission factors based on national data. The majority of countries appear to use the IPCCC values (Sloss, 2011). The IPCC guidelines provide advice on estimation methods at three levels of detail, from tier 1 (the default method) to tier 3 (the most detailed method). The guidelines include mathematical specification of the methods, information on emission factors or other parameters to use in generating the estimates, and sources of activity data to estimate the overall level of net emissions (emission by sources minus removals by sinks). All tiers promote the production of estimates with minimal statistical bias, and accuracy and precision should improve from tier 1 to tier 3. The provision of different tiers enables inventory compilers in each country to use methods consistent with their resources and to focus their efforts on those categories of emissions and removals that contribute most significantly to national emission totals and trends.

Under the IPCC methodology, those countries who have access to more accurate emission factors and activity data can use these under Tier 3 but, since the methodologies are all based on the same calculations, the results between parties, even those using different Tier approaches, should still be comparable.

As yet, the Minamata Convention has not decided upon a methodology for inventory production. This will be achieved by the COP. However, it is important to note that the estimation of mercury emissions from coal combustion is significantly more challenging than estimating CO_2 emissions. Whilst the carbon content of different coal types remains generally comparable, mercury emission can vary between coal types and even between coal seams for coals produced at the same mine. Further, combustion conditions and flue gas cleaning systems can affect final mercury emissions causing little or no effect at some plants whilst reducing emissions by over 90% at others. Estimating mercury emissions as accurately as possible therefore requires a significant amount of coal and plant specific data. In the absence of this data, estimates of mercury emissions can only be regarded as best estimates.

Mercury emissions can be monitored on a real-time basis using state of the art measurements systems. However, these systems are expensive and are unlikely to be accepted as a methodology for estimating total emissions in the near future. Rather the data from these systems can be used to produce more accurate emission factors at specified sources. Where continuous monitoring is unavailable, sampling systems such as the US EPA Mercury Monitoring Toolkit can be used very cost-effectively to produce plant-specific emission factors. This has already been demonstrated at plants in Russia and South Africa (UNEP, 2011a; UNEP, 2011b).

In the absence of site specific data, mercury emissions can be estimated based on average mercury concentrations of coals. These data are available from many publications available online. The UNEP

Mercury Inventory Toolkit[2] provides relatively generic emission factors which are recommended for first time inventory production in regions with little experience in these calculations. The emission of mercury can then be calculated based on this emission factor, the mass of coal fired and the retention factor of the plant. The retention factor should take into account as much as possible any mercury capture achieved by flue gas cleaning systems such as electrostatic precipitator (ESP) and bag-houses (fabric filters) for particulate control and, more importantly, scrubbing systems such as flue gas desulphurisation technologies (FGD) for sulphur control. Average retention factors for mercury in these systems can be obtained from widely available publications. The UNEP Mercury Inventory Toolkit provides guidance and a tool for calculating mercury emissions and releases from the coal combustion sector. This Toolkit provides emissions factors.

The IEA CCC (IEA Clean Coal Centre) have produced a report on reporting emissions to international and national emission inventories (Sloss, 2009). The report emphasised the importance of the coordination of inventories to ensure that the results were valid and comparable. Unfortunately, current reporting requirement inconsistences between different legislative formats can lead to significant disagreement between values reported for the same pollutant. It is imperative that this be avoided as much as possible in the Minamata Convention to ensure a valid and fare baseline for all countries to estimate emissions. The Minamata COP could therefore work to produce guidelines for mercury inventories which, like the IPCC guidelines for CO_2, are based on a tier system. This would allow countries which have data available to produce more accurate estimates whilst those who do not have this data to hand can still produce data which can be useful for establishing major sources and for gauging emission reduction potentials.

The emission estimates obtained from these inventory calculations are only as good as the input data. The activity data will come from information on coal use, the accuracy of which will depend upon the amount of data kept by operation plants and report to the agency carrying out the calculations. Since coal use data is already being collated for the CO_2 calculations under IPCCC, it would be optimal if the same coal use data were used for mercury estimation. This will save on duplication of work and also ensure that current inventories and any projections for the future are based on the same data - any projected increase or decrease in fuel use predicted under a party's future energy programme can be used to estimate increases or decreases in both CO_2 and mercury emissions simultaneously.

2.3.4 Economics and finances

The UNFCCC calls for developed parties to provide new and additional financial resources to meet costs incurred by developing country parties, along with the transfer of, or access to, environmentally sound technologies and know-how. This should include full consideration of the specific needs and concerns of, amongst others, "*countries whose economies are highly dependent on income generated from production, processing and export and/or consumption of fossil fuels and associated energy-intensive products*". Kyoto reiterated the need for financial resources to cover the agreed full costs incurred by developing country parties.

[2] Mercury Inventory Toolkit: Toolkit for the identification and quantification of mercury releases (2013) http://www.unep.org/chemicalsandwaste/Mercury/MercuryPublications/GuidanceTrainingMaterialToolkits/MercuryToolkit/tabid/4566/language/en-US/Default.aspx

The Global Environment Facility (GEF) was established to undertake a number of activities, including providing funding for GHG reduction projects in developing countries. Banks such as the Asian Development Bank (ADB) use funding from developed nations to provide finance for new power projects in developing regions, subject to them meeting minimum performance requirements.

Financial mechanisms were established under the Kyoto Protocol which outlined the use of various trading options:

- Emission reduction units (ERUs) are units worth 1t of CO_2 equivalent reduced under a Joint Implementation (JI) project of the Kyoto Protocol. JI projects allow Annex 1 countries to reduce emissions in another Annex 1 country in order to meet their own reduction target.

- Clean Development Mechanism (CDM) has Certified Emission Reduction (CER) units which may be traded in emissions trading schemes

These were means of establishing a monetary value on emissions and emission reduction projects so that a market could be established to promote greenhouse gas reduction strategies and projects. As a result, emissions trading schemes such as the European ETS have been established and operational for several years. Emissions trading schemes allow one source to reach its greenhouse gas reduction targets by funding or facilitating emissions reductions at another source. For example, it may be easier and less expensive to clean up an industrial plant in one country than it would be in another. Although the CDM got off to a slow start, several international projects are now underway. It remains to be seen if and how these financial mechanisms will continue within the forthcoming UNFCCC timeframe.

Each of these mechanisms has advantages and disadvantages. Emissions trading schemes have worked extremely well in the US, reducing sulphur emissions faster and more cost-effectively than initially expected. However, the carbon trading market has had many rough periods and currently the excess of credits means that the price is too low to be an effective impetus to development. The CDM and JI systems can be complex and time consuming, with projects taking many years to set up. By 2010 only one coal project to date had been registered under the CDM (in India) and two further Indian projects were under review.

The next period of the UNFCCC, from 2013 to 2020, will see these finance mechanism mature. The Minamata Convention is still at the stage of establishing financial mechanisms. Article 13 calls for international funding and technical assistance on an "*urgent basis*". The proposed mechanism would include the GEF and also a "*specific international programme to support capacity-building and technical assistance*". Details of the mechanism and the establishment of a hosting institution to run the programme are to be agreed upon at the COP.

Again it is important to build upon the potential synergies that exist between the UNFCCC and the Minamata Convention. Both conventions call for either a move away from coal or the application of HELE technologies for future coal use. It should therefore be possible for the mercury impact of any new project to be considered alongside the GHG issues.

Mercury should not be considered as part of any emissions trading scheme due to its potentially significant localised effects. There will therefore likely be no ETS for mercury. However, for UNFCCC projects under the CDM or JI, mercury could be included as a parameter for consideration within any proposed project. Priority could then be given to projects that will reduce both GHG and mercury. Conversely, any funding setting up for mercury reduction projects under the Minamata Convention should also take GHG emissions into account.

International funding bodies such as the World Bank and the Asian Development Bank are already moving to ensure that coal projects funded in future will have to meet strict environmental criteria, promoting HELE and CCS as much as possible.

2.3.5 Communication and outreach

The UNFCCC (Article 4) required that parties *"promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or present anthropogenic emissions of greenhouse gases … including the energy sector*".

Article 4 of the UNFCCC also includes sub-articles on promotion and cooperation in research, education, training and public awareness whilst Article 5 deals with the promotion of programmes and networks for the exchange of data. Article 6 then calls for the promotion and facilitation of education, training and public outreach. Articles 9 and 10 call for the establishment of subsidiary bodies to provide scientific and technological advice, and to provide assistance on implementation respectively.

Articles 17, 18 and 19 of the Minamata Convention call for very similar activities. Outreach projects such as workshops, brochures, guidance documents, posters and information dissemination systems are already established for the UNFCCC. It would make sense for the COPs of Minamata to look to these projects, and to the institutions and organisations facilitating them, in order to both learn from what has been achieved and to build upon potential expansion of some of these projects to include considerations of mercury as well as of CO_2. Any new outreach programmes established under Minamata could present information on the UNFCCC to highlight potential co-benefit effects of projects and to ensure that any reduction projects initiated consider the outcomes in terms of emissions of all pollutants and not just of mercury alone.

2.4 Discussion

Despite the 21 year differences in age, the UNFCCC and Minamata Convention share very similar goals – the reduction of emissions which are harmful to human health and the environment. In addition, they both include action being taken within the coal combustion sector. There are therefore many similarities between the way these conventions work and this can be used to ensure mutual benefit.

Areas of mutual agreement:

- The reduction of emissions which are detrimental to human health and the environment
- The focus on emissions from human activities, including fossil fuel combustion
- The promotion of BAT/BEP type approaches to reduce emissions
- The establishment of emission inventories

The promotion of HELE technologies will achieve reductions in both emissions of CO_2 and mercury simultaneously. Flue gas cleaning systems for CO_2 and mercury are distinct – those systems which reduce mercury may incur an efficiency penalty which could increase CO_2 emissions. Further, as yet, it is still not clear where mercury will end up in some CCS technologies. Bridge-building between these conventions should include evaluations of these areas of miss-match with a view to minimising any potential detrimental effects.

Also, within both conventions, there are specifications which require that:

- mission inventories must be established
- signatory countries consider how reductions are to be achieved
- assistance, both in terms of financing, technology transfer and information dissemination, could be given to eligible countries

Since the UNFCCC has already required that parties establish CO_2 inventory methodologies, these methodologies could be aligned with those for mercury - the activity data (such as coal use or energy production) provided to both these calculations should be the same. This will insure comparable data for projecting changes in emissions into the future under different scenarios.

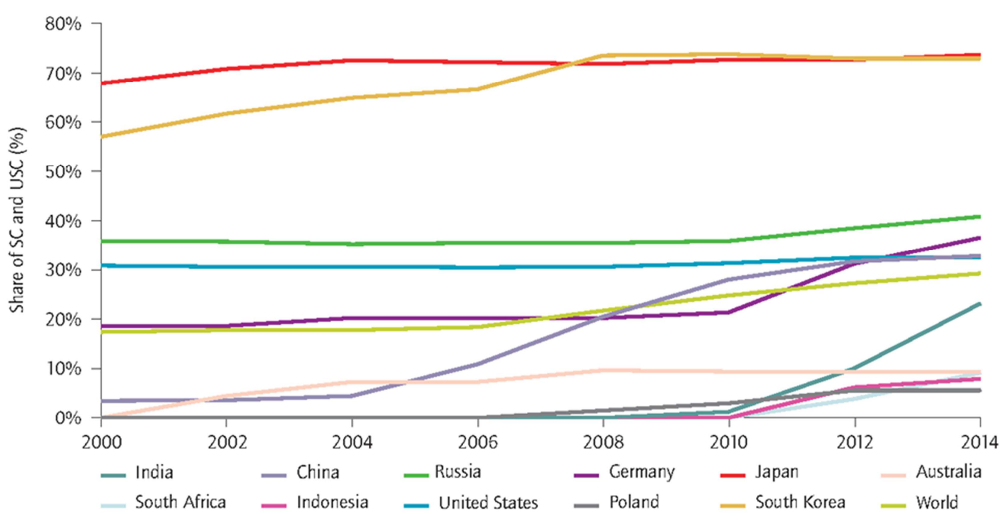
The networks, projects and programmes established under the UNFCCC for coordination of work and dissemination of information could be expanded or at least act as a template for similar projects on mercury control in the same regions.

3 Global Energy Use Trends

The aims of both the UNFCC and Minamata Conventions will be achieved, to some extent, by reductions in emissions from the power generation sector. However, it is clear that energy demand in most regions of the world is growing alongside the population, especially in developing regions. The balance between growing fuel use and decreasing emissions will be determined by the efficiency and relative cleanliness of existing and new power stations if they continue to use coal.

3.1 Current move towards cleaner power

As discussed in Chapter 2, implementation of HELE power generation concept is capable of producing plants which use less fuel and produce lower emissions of pollutants, among them mercury and CO_2, per unit of power generated. As of 2012, the number of HELE plants throughout the world remains low and percentage of SC and USC plants varies significantly from one country to another. As shown in Figure 4, Japan and the Republic of Korea are leading with the extent of HELE plants deployment (about 70% of fleet's capacity), as approximated by the deployment of SC and USC generation. For other countries, the deployment of SC and USC varies between below 10% to about 40%. Two countries with the largest power generation (China and USA) remained at about 30% deployment of SC and USC plants in 2012.



Note: For India, achieving 25% SC and USC by 2014 is an ambition, with perhaps up to 10% likely to be achieved in practice.
Source: Analysis based on data from Platts, 2011.

Figure 4 Extent of SC and USC plant deployment in major power generating countries (IEA, 2012)

Improvements in energy efficiency inherent to SC and USC generation can reduce emissions of long- and short-lived climate polluters (SLCPs), mercury and conventional pollutants such as particulate matter because less coal is burnt for each kilowatt-hour of electricity generated. The vast majority of the existing 1600 MW of coal-fired plants worldwide operates under an older, less energy-efficient subcritical steam generation regime. Even in 2011, half of the newly built power plants used such technologies. More efficient ultra-supercritical technologies are capable of reducing emissions of CO_2 and mercury per unit of electricity produced by about 15%.

More expensive, advanced materials (the so-called super alloys) and assembly techniques (such as welding) are required when building SC and USC plants compared to older subcritical plants since the former operate at higher temperatures and pressures of steam. These requirements result in higher cost of SC/USC plants than older subcritical plants.

The worldwide capacity of coal-fired power generation is predicted to remain at above 1,600 GW with significant share of subcritical generation through 2020's. Countries that in 2010 accounted for over 85% of CO_2 emissions from the production of electricity and heat from coal were, in decreasing order of emission contribution to global emissions: China, US, India, Germany, Russia, Japan, South Africa, Australia, Republic of Korea, and Poland (IEA, 2012a). As older coal-fired plants become less efficient and increasingly difficult to operate reliably, new plants will need to be built to replace them in order to satisfy the energy needs. In many regions, where gas is readily available and affordable, natural gas combined cycle plants are popular. But not all regions have access to gas. In the near term if new plants are to be coal-fired they would need to have their efficiency significantly increased compared to what is practiced today and be "CO_2 capture-ready."

Countries highly reliant on fossil fuels for their power generation may choose to restructure their generation schemes to low-carbon alternatives, including capture and storage of CO_2 (CCS). Under the concept of "CO_2 capture-ready" plant, the operator of such a power plant does not initially deploy CCS, but may do so at some future date. Such "CO_2 capture-ready" plant is designed to minimize the future retrofit cost of CCS. This is done by incorporating a set of design features into the initial plant construction, which consider the future installation of CCS, such as additional space in piping and cabling, access to utilities, or building foundations where future CCS equipment will be installed. In some regions, this may also include a requirement for permitting for CO_2 storage and proof of necessary associated financial and legal instruments.

The majority of new plants projected for near-term deployment will be located in Southeast Asia (SE Asia), China, and India. Electricity demand in SE Asia increased by about a factor of five between 1990 and 2011 (IEA, 2013). This trend is expected to continue due to rapid economic growth of the region. Countries of SE Asia present disparate cultural, political, and economical approaches, including energy production. Notably, Indonesia's National Energy Policy calls for reduction of the share of oil and natural gas in their energy mix in in favour of increasing share of coal (about 30%) and of renewable sources by 2025 (MEMR, 2012). Vietnam plans to reach 5% of renewable generation by 2020 and to save 5-8% of energy consumption over the period 2010 to 2015 by introducing energy efficiency measures, including on coal-fired plants (IEA, 2013). This could include a combination of increasing boiler and fuel efficiency as well as upgrading to reduce consumption of energy in auxiliary processes at the plant. Overall, SE Asia is expected to select coal as a fuel of choice for power generation because it is abundant and relatively inexpensive throughout the region.

The importance and deployment of HELE technologies is expected to increase as the share of renewable energy generation (such as wind or solar) increases, such as planned for in SE Asia. Renewable technologies are considered to be variable generation sources and coal-fired plants of the future will have to operate at an increased flexibility to balance variations in renewable generation. This increased operational flexibility will affect coal-fired plant's capacity factor and thus increase unit electricity generation cost. Therefore, it is of utmost importance that HELE technologies be deployed for any new coal-fired power plants. GHG emission reduction potential in 2030 for power generation sector as a result of HELE technology implementation (including CCS) is estimated at between 2.4 and 4.7 $GtCO_2e$/year (UNEP, 2013b).

One of the major issues affecting the movement of alternative energy technologies (such as wind, tidal and solar) onto the grid in many countries is the intermittency of the electricity generated. Power grids require a consistent base load power source which nuclear and fossil fuel power generation are most suited for. The fluctuating power produced from renewable sources can be difficult to utilise and, in some situations, sources such as coal plants are called upon to operate in less than ideal conditions to ensure consistency of supply. This may mean that these plants have to operate at much lower efficiencies than desired. Mills (2013) provides an excellent resource of information on the best means of combining renewable energy with coal to limit losses in efficiency.

In addition to the increasing demand for coal in SE Asia (as well as China and India), some countries, like recently Japan and Germany, may decide to replace non coal-fired plants with modern fossil fuel-fired ones or with nuclear power. This trend again highlights the importance HELE technology.

3.2 Technology Constraints

There is currently no consensus on the best way forward in terms of coordinating an overall move towards cleaner and more efficient power plants. At present, different countries use different approaches to address the issue of climate change. For example, the EU has committed to reducing GHG emissions by 20% by 2020 and by 80-95% by 2050 compared to 1990 emission levels (EC, 2011). A number of countries (including Norway, Canada, and Australia) and California in the US use carbon price or carbon tax for permitting of facilities or for trading of emission allowances. And so, although the UNFCCC leads the way in defining the aims of global action, there is still currently no coordinated international approach.

The present lack of internationally binding agreements causes lack of economic drivers to deploy the CCS and thus introduces uncertainty to widespread large scale application of CCS. Other uncertainties include unclear storage requirements and public opposition to onshore storage. Installation of CCS brings an energy penalty for operating the CCS process itself-that is, energy is lost in the operation of a CCS system such as running compressors prior to CO_2 injection and temperature and pressure demands to facilitate the capture chemistry. For example, a 500 MW plant operating at 0.65 capacity factor produces about 2,850 GWh of electricity per year without CCS and would produce 2,280 GWh/year with the CCS, assuming approximately 20% energy penalty. Despite present day uncertainties, in consideration of future CCS requirements, the concept of a "CO_2 capture-ready" power plant should be considered for new power plants in terms of defining minimum design requirements.

It is generally agreed that improved power plant efficiency and CCS could go a long way to helping countries reach the aims of the UNFCCC, the technologies involved are still arguably new or developmental, especially CCS, and the cost risk is relatively high. Further investment is required to move through this development stage to make CCS practicable and affordable. Once this is achieved, countries will be able to make a "technology leap" and move quickly to reduce potential emissions from their new fleet. However, for older plants which have been built without CCS considerations, the challenge will be as to whether these plants can be retrofitting or whether closure and/or replacement is the only means to control CO_2 emissions. It is clear from the lack of full-scale CCS plants to date, that there is a significant amount of work to be done.

Conversely, mercury control technologies are widely available and most are proven at full-scale. Although the efficacy and cost-efficiency varies on a case-by-case basis, it can be argued that mercury control is proven as practical. The challenge for the Minamata Convention will be how to provide information on how to select the most appropriate control options in each situation. This will form the basis of the BAT/BEP guidance document to be developed by the Conference of the Parties (COP) of the Minamata Convention.

Although the technologies for CO_2 and mercury are quite distinct, there should be consideration given to co-benefit or negative effects. For example – where will the mercury end up in CCS systems? How much CO_2 will be produced additionally as a result of any energy requirement of a mercury control system applied on a coal plant?

3.3 Comments

There is a general move in many countries towards more efficient and cleaner energy production. However, the approaches taken in each region are distinct and vary with the local situations. The general nature of the goals of the UNFCCC allow this flexibility in approach. Whilst this flexibility is beneficial in many regions, it means that there is no legal or financial impetus, as such, for countries to invest in the development of advanced GHG control such as CCS. CCS is challenging and, to date, there are few demonstrations at full-scale on coal-fired plants and so the technology is not regarded as ready for deployment. Significant time and investment will be required before CCS is ready to be considered an affordable solution. Conversely, mercury control technologies are relatively developed and are commercially available. However, their efficacy and affordability is very site and case specific. The Minamata Convention will produce a BAT/BEP guidance document which will help Parties to determine the most appropriate methodology.

To ensure synergy between the conventions, the application and further development of control technologies and methodologies for both CO_2 and mercury should take into account the effects of the reduction of one pollutant with potential effects upon the other. For CCS this will means considering the final capture location for mercury in the CO_2 capture process. For mercury controls, any potential negative effects on plant efficiency, and thus a potential increase in CO_2 emissions, should be considered.

4 Mutual aims

Both Minamata and UNFCCC aim to reduce emissions of harmful pollutants and both also target the energy sector for much of this reduction. This raises the question of how to decouple emissions of mercury and climate forcers from coal-based electricity generation. For example, electricity and heat generation accounted for 61% of global CO_2 emissions in 2010, while global annual mercury emissions from coal combustion constitute 24% of total anthropogenic emissions of the element that is so damaging to human health. Coal combustion also produces black carbon and tropospheric ozone precursors such as carbon monoxide, volatile organic compounds, and nitrogen oxides. Coal combustion for power generation does not produce significant amounts of black carbon, however inefficient use of coal in domestic cooking and heating is a major source of black carbon in developing Asia. CO_2 and nitrous oxide are potent greenhouse gases while both black carbon and tropospheric ozone are SLCPs. For many countries, coal will for many years be the main source of energy production. It will be a large challenge to control emissions of these pollutants from this continuing use of coal for cooking and heating.

This Chapter looks at the moves being made to reduce emissions at both ends of the energy process – at the power plant, though technological aims, and at the site of use by the customer, through social aims

4.1 Mutual technological aims

Two approaches, fuel blending with biomass and increase of energy efficiency at power plants, provide a potential means of simultaneous reduction of emissions of CO_2 and mercury. Reduction of emissions may also be achieved by other measures, such as pre-treatment of coal and installation of air pollution control equipment. Each of these options is discussed in the sections below.

4.1.1 Fuel blending and cleaning

Both CO_2 and mercury emissions arise from coal combustion because mercury and carbon are present in the coal. It is therefore clear that reducing the amount of either these elements in the coal, or the amount of coal fired, could reduce emissions.

Biogenic emissions of CO_2, such as emissions from biomass combustion for power generation, are considered to be carbon neutral. This is because the carbon contained in these fuels is new carbon – carbon that is in the current budget, as opposed to fossil carbon which is being unearthed and added to the current budget. However, life cycle emissions must be considered and, for biomass, there may be fossil emissions associated with production, transport and preparation of biomass. In general, biomass co-firing with coal (fuel blending) can limit CO_2 and, because less coal is used to produce the same amount of electricity, it also reduces mercury emissions. Biomass typically contains lower concentrations of mercury than coal and also contains many chemical species which may help trap the mercury released from the coal in the solid ash waste. Biomass is more physically and chemically variable than coal and therefore may pose new challenges with respect to maintaining the efficiency of combustion and operation of existing coal-fired plants (Sloss, 2010).

Typically, plants considering the retrofit of fuel blending must consider and implement changes to fuel preparation, handling, and preparation as well as burners and air. Depending on the type of biomass used for fuel blending and its handling properties, the fraction of biomass replacing coal may vary from 2 to about 30%. CO_2 emission reduction is proportional to fraction of biomass used. Mercury emission reduction may exceed the amount directly attributable to the reduction of the amount of coal burned. This is because biomass may contain significantly higher amounts of chlorine than coal. Chlorine may react with mercury in vapour state promoting the extent of mercury oxidation and thus making mercury easier to remove in downstream air pollution control equipment such as fabric filter or FGD.

Even if co-firing with biomass is not an option, blending different coal types can often lead to higher combustion efficiencies (lower CO_2) and higher capture of mercury in the ash (due to the presence of oxidising species in many types of biomass). Coal blending could therefore be considered as an option for reducing emissions of both CO_2 and mercury, although the extent to which this would be possible would be case specific (Sloss, 2014).

Coal washing has the potential to reduce ash from coal which provides greater combustion efficiency, thus reducing CO_2 emissions, although this can be quite minimal. Coal cleaning and sorting can reduce wasted transport and processing of incombustible materials which could have a significant effect on CO_2 emissions from the coal production sector in countries such as India. Coal cleaning can also achieve anywhere from 0 to over 50% mercury removal, depending on the method used and the coal involved. Again, the effectiveness of this approach would be case specific but could prove to be an economic option at some plants.

4.1.2 Energy efficiency at power plants

An efficient power plant uses less fuel to produce the same amount of power as a less efficient plant. Efficiency is therefore a potential means of reducing fuel use and lowering emissions of all pollutants simultaneously.

Aside from replacing subcritical plants with SC or USC plants, there is a number of relatively lower-cost and technically less demanding improvements that can be made to improve energy efficiency of existing, often older plants, including subcritical ones (EPA, 2010).

For older units, there is a range of options to increase energy efficiency: from operation and maintenance procedures to high capital cost repowering and combined heat and power (CHP) options. A well-operated and well-maintained plant will experience less rapid deterioration of heat rate and associated increase in CO_2 and mercury emissions per unit of electricity generated. CHP offers significant efficiency gains compared to electricity generation alone, mainly because the waste heat from electricity production is captured and used for heating.

Operation and maintenance (O&M) practices have a significant impact on boiler performance, including its efficiency, reliability and operating costs. Each of these parameters change over the life of the boiler, as deterioration of plant equipment is unavoidable. However, the rate at which this deterioration occurs depends significantly on O&M practices. Thus, O&M practices themselves influence emissions and impact their rate of increase. Rapid deterioration results in higher heat rate, higher emissions, and higher operating costs. After a period of time, the point may be reached where significant investment is required to rehabilitate the plant and bring it as close as possible to the “design” performance. Such rehabilitation programs are capital intensive and fall outside what is considered the “normal” maintenance that should be covered in the annual O&M budget of the plant.

Replacing burners with more efficient ones will provide efficiency gains by improving one or more of the inefficient parameters such as incomplete combustion, excess air, or cycling duty. Older, wrongly-sized or mechanically-deteriorated burners are typically inefficient. This inefficiency results in incomplete combustion and the need for high excess air. In the past, burners were mostly designed to achieve complete combustion.

Most fossil fuel-fired heating equipment wastes a significant amount of the heat in the flue gas. Energy efficiency can be increased by using waste heat gas recovery systems to capture and use some of the energy in the flue gas. The most commonly used waste heat recovery methods are preheating combustion air, steam generation, and water heating. Heat recovery equipment includes various types of heat exchangers (economizers and air heaters), typically located after the gases have passed through the super-heater and steam generating sections of the boiler.

There are a number of options that can be applied to improve the combustion process and the overall performance of the plant. They may be separated into the following groups: combustion system tuning, combustion and plant performance optimization, and instrumentation and controls.

Boiler heat transfer surfaces are exposed to high temperature gases and products of combustion. Formation of soot, ash products, and incomplete combustion of carbon all contribute to the potential for surface deposits. These deposits are related to operational issues ranging from malfunctioning burners to the condition of the heat transfer surfaces. To minimize deposition problems, it is important to operate the boiler within the parameters for which it was designed.

4.1.3 Gas cleaning

The current options for CO_2 control at coal-fired power plants are either those which relate to the combustion process, such as oxy-fuel combustion, or those which relate to cleaning of the flue gas.

Oxy-fuel combustion is an emerging technology where fuel is combusted in pure oxygen instead of air. The product of oxy-combustion is a stream of concentrated CO_2 in flue gas, which is almost ready for storage or transport. Oxy-combustion is more difficult to retrofit on existing power plant than post-combustion technology because it requires different boiler material and a dedicated air separation unit for production of oxygen. An overview of oxyfuel combustion is given in the free CCC report by Lockwood (2014).

The pre-combustion process, Integrated Gasification Combined Cycle (IGCC), is the most energy efficient of the available CO_2 capture possibilities but cannot be retrofitted on existing plants and is the most expensive. In IGCC, coal is gasified into a mixture of hydrogen and CO_2. Hydrogen may be used in the power plant to generate electricity or to produce synthetic fuels. CO_2 is separated and transported for storage.

Post-combustion CCS at power plants involves three steps: capture, transport, and storage. There are some sectors of CCS development which may be considered mature technologies, such as some approaches to gas storage or transfer. However, complete large-scale CCS schemes operating at a power plant are only now appearing in early demonstration phase.

The BAT for post-combustion removal of CO_2 involves absorption with tailored sorbents that can be economically regenerated yielding a concentrated stream of CO_2 ready for transport to storage site. Other post-combustion technologies such as membranes, dry sorbents, flue gas recirculation, cryogenic capture, or chemical looping are at varying stages of early development. Post-combustion processes produce CO_2 separated from flue gas after combustion and, given space, can be retrofitted on existing power plants.

Once the separated CO_2 in any of processes described above has been purified and compressed at a power plant, it is ready for transport to its storage site. At the storage site, CO_2 is liquefied or compressed to supercritical levels and may be injected underground for geological storage. An alternative to geological storage is injection into a petroleum reservoir for the so-called Enhanced Oil Recovery (EOR).

Options for control of mercury in flue gas mercury at coal-fired power plants, as outlined in the UNEP Process Optimisation Guidance (POG) document (UNEP, 2010), can be summarised as follows:

- co-benefit effects – taking advantage of pre-existing control systems for other pollutants such as bag-houses for particulates and flue gas desulphurisation (FGD) for sulphur control;
- sorbents – the addition of material to the flue gas to which the mercury will adhere to facilitate capture in a particulate control system;
- oxidants – the addition of oxidising materials to enhance the conversion of mercury to the oxidised form which is soluble and "sticky", thus making it easier to capture in existing control systems
- advanced systems – such as electronic or plasma based systems specifically for mercury control.

As mentioned before, the effectiveness of each of these control options varies from plant to plant with coal characteristics and plant specifications. Determining which method is most appropriate in each situation requires expert knowledge. However, the Minamata Convention BAT/BEP guidance document should go a long way to improving the understanding of the decision making process.

Consideration must be given to the potential negative effect of cleaning technologies on emissions. For example, cleaning systems which can lower mercury emissions (such as FGD) may require energy to run, thus reducing the output and net efficiency of the plant by a few percentage. Whilst this effect is not hugely significant, as discussed earlier, reducing efficiency means more emissions of all pollutants, including CO_2. CCS systems for CO2 capture may also have an effect on mercury emissions. However, since CCS systems are largely still under development, it is not fully understood where mercury will end up. A free report from the CCC (Adams, 2010) gives an overview of flue gas treatment for CCS systems which suggest that the majority of technologies under development consider the movement and behaviour of other pollutants including mercury and some collect and separate the mercury for ultimate disposal.

4.2 Mutual societal aims

Once electricity has been generated, transmitted, and distributed, consumers play an important role and can contribute to lowering coal's influence by implementing energy efficiency measures. Two of the biggest uses of electricity are in industry and in buildings. This chapter briefly discusses efficiency of electricity end-use by major consuming sectors: industry and buildings. When higher energy efficiency is attained by consumers in these major sectors, demand is more easily satisfied, less fuel is used and resultant emission of pollutants is lower. Recently, increased demand pressures are being introduced by lifestyle changes in developing countries, for example by increased need for refrigeration.

In succinct form – the more efficient the end user is with the energy provided, the less energy must be produced and, as discussed earlier, the less energy produced, the lower the emissions. Western societies are already moving to more efficient lifestyles with energy efficient building designs, more fuel-efficient cars, improved heating systems and so on. This is as much a change in behaviour and lifestyle as it is a change in technologies. Technology leaps to developing regions and emerging economies must be promoted to ensure that those currently being introduced to electrification and moving onto the grid are encouraged to use this new power effectively and efficiently.

4.2.1 End-use efficiency

For the industrial sector, there are many energy efficiency measures that could be implemented to reduce emissions. Many of these measures are industry-specific but generally, as discussed before for combustion processes, include the deployment of CHP (combined heat and power – where excess heat which cannot be used for steam generation is used for heating process water or local heating systems), equipment retrofit or modernization, and process improvement. Greenhouse gas emission reduction potential in 2030 for manufacturing industry sector is estimated at between 2.5 and 5.5 $GtCO_2e$/year (UNEP, 2013b).

For buildings, improvements in energy efficiency come, for example, from better insulation, improved appliances, efficient lighting, and sustainable architectural design to decrease heating/cooling needs. These improvements aim to lower energy use and therefore to reduce CO_2 and other emissions resulting from electricity generation.

Better insulation of buildings may be accomplished by more demanding building codes that set standards for energy performance levels. Building codes may be applied to both new buildings and retrofits of existing buildings.

GHG emission reduction potential in 2030 for buildings is estimated at between 5.4 and 6.7 $GtCO_2e$/year (Gigatonnes, CO_2-equivalent; UNEP, 2013b).

4.2.3 Education and outreach

Although many of the goals of the UNFCCC will be achieved through changes by utilities and industry, the public can contribute significantly to greenhouse gas reduction. The less energy required by the public, the less energy that needs to be produced and the less fuel that needs to be burned.

The UNFCCC has had significant publicity and outreach which websites, literature, educational videos and other materials all being readily available on the internet. Many governments, organisations and other bodies have embraced the concept of energy efficiency as an area of contribution to the UNFCCC aims which can be achieved by all. For example, many public buildings have campaigns to encourage the reduction of unnecessary lighting and heating. Energy efficient light bulbs are becoming standard in many regions. Domestic appliances come ranked in terms of their energy efficiency so that the user can make a choice based on both cost and contribution to lowering energy use.

Minamata should follow the example of UNFCCC and make information widely available on how the public can engage themselves in working towards lower mercury emissions. This is likely to require outreach in many distinct sectors since mercury can arise from gold mining, industry and other sources, not just the energy sector. However, with respect to emissions from the coal combustion sector, the exact same measures being promoted under UNFCCC to reduce emissions through energy efficiency will also result in reduced mercury emissions, due to the reduction in wasted fuel. Combined UNFCCC and Minamata outreach to the public could therefore highlight the co-benefit effect of energy efficiency – reduced emissions of all pollutants, not just CO_2.

4.3 Comments

Improving plant combustion efficiency is the simplest way to reduce the rate of fuel use and therefore reduce emissions of all pollutants simultaneously. Although efficiency upgrades will only be effective at less efficient plants, an overall move to increase general plant efficiency could achieve significant emission reductions worldwide. Advanced combustion technologies such as oxy-fuel combustion and IGCC could prove, in future, an effective means of improving combustion efficiency and, at the same time, simplifying the CO_2 capture process.

There are specific technologies for the capture of emissions from flue gases. For CO_2, these CCS technologies are relatively new and mostly still in the development phase. For mercury, the market is more mature and there are numerous control options to select from. However, the selection process is complex and will require expert guidance.

Although the technologies for CO_2 and mercury are distinct, there are still important considerations with respect to potential negative outcomes - when installing a control technology for one pollutant, the potential effect on the control of the other, positive or negative, should be included in the decision process. The end-use energy efficiency programs have potential to yield significant energy savings and, at the same time, reduce emissions of pollutants from the electric power sector. For example, if not for energy efficiency gains since the 1970s, the United States would need to produce about 50% more energy to support country’s current gross domestic product (GDP) (ACEEE, 2013).

Moving to the other end of the energy chain, by decreasing the demand for energy by industry and the public, less power will have to be produced and, as a result, emissions of all pollutants will decline.

5 Legal and economic impetus

This chapter looks at both the legal and economic impetus behind the actions currently being taken globally to reduce CO_2 and mercury emissions from coal combustion.

5.1 Legal Impetus

Although there are many financial mechanisms which can have a significant effect on how the coal sector operates, this chapter concentrates only on actual legislation on emissions from coal-fired power plants.

5.1.1 Existing CO_2 legislation

As yet, there is very minimal legislation specifically controlling CO_2 emissions from coal-fired plants. Pushes towards HELE technologies and CCS are coming through financial mechanisms and selective international funding. However, there has recently been a move towards setting actual ELVs for CO_2 for new build plant. The first country to set strict limits is Canada with a limit of 420 gCO_2/kWh (Maclean, 2013). Although no other countries have legislated limits, there are several maximum levels in discussion:

Table 2 Proposed CO_2 emission limits (*US EPA, 2013; ~Yale, 2013)

Agency/Country	**Proposed maximum, gCO_2/kWh**
US Environmental Protection Agency (US EPA)	500 (1,100 lbs CO_2/MWh)*
European Parliament	450 or 500
European Investment Bank	550~

These limits are still just proposals and would only apply to new build plants. For comparison, the average coal-fired power plant (subcritical) has CO_2 emissions at >880 g/kWh and so these limits are effectively stopping any new build without CCS.

There are no emission limits for CO_2 on existing plants and, without CCS reaching the commercial scale where it is affordable for retrofit, there is no indication of any impending CO_2 limits on existing plants.

The new limits being adopted and proposed for new plants can be seen as a strong move under UNFCCC commitments to avoid introducing new sources of CO_2 to the global budget. Any new power plant built today could be expected to last 30-60 years and so new plants are seen as "locking" new CO_2 emissions into future inventories. By promoting, or even legally requiring, HELE and CCS technologies, countries can be sure that these new locked in emissions are as low as possible. Whilst this approach makes sense, it requires a significant financial commitment and, unless funding is controlled, there could be a move towards funding of cheaper and more polluting technologies in countries which cannot afford HELE with or without CCS.

5.1.2 Existing mercury legislation

Legislation on mercury emissions has been evolving internationally since its first mention under the Long Range Trans-boundary Air Pollution (LRTAP) Heavy Metals Protocol in 1998. Since then, a number of regional programmes and action plans have evolved and several countries have set national legislation which is applicable to emissions from coal-fired utilities.

Canada was the first country to set emission reduction targets for mercury from coal-fired plants. The Canada Wide Standard (CWS) set caps for mercury emissions from coal plants on a province specific basis, leaving each region to achieve the required reduction in the most appropriate manner. Whilst some plants have opted for mercury-specific control technologies, others have opted for fuel switching to gas or biomass.

The USA took many years to agree on mercury control and finally included mercury as a target pollutant, along with other gases, under the Mercury and Air Toxics (MATS) rule, completed in 2013. The MATS promotes the use of multi-pollutant control options to reduce emissions of sulphur, particulates, halogens and trace elements simultaneously. Since the US spent many years trading sulphur and nitrogen, the installation rate of FGD is significantly lower than that in the EU, running at around 50% by 2010. This relatively low rate of FGD installation meant that the co-benefit mercury control was lower in the US than in the EU and therefore mercury remained more of an issue. However, the MATs sets emission limits which are extremely challenging for many plants, requiring 90% or greater mercury control. Whilst some plants may be able to achieve this with a combination of cleaner fuel, oxidation techniques and FGD, some plants are having to invest in mercury-specific technologies such as activated carbons.

The European Commission (EC) has taken a different route to mercury control from that in the USA. Unlike the USA, the EU did not engage in emissions trading of sulphur, rather it established ELVs and minimum sulphur capture requirements under the Large Combustion Plant Directive (LCPD) and required BAT under the Integrated Pollution Prevention and Control Directive (IPPC) which, in most cases, could only be achieved with flue gas desulphurisation (FGD) technologies. The LCPD and IPPC have been replaced with the Industrial Emissions Directive (IED) which, if anything, promotes the requirement for flue gas scrubbing even more. As a result, the EU has an FGD installation rate above 80%. Due to the co-benefit effects of FGD and other control systems, mercury emissions have come down by 70% in Europe since the 1970s (Sloss, 2012). Whilst this represents an overall reduction from all sectors, the reduction in the power sector has been significant.

And so, to date, the EC has seen significant mercury reduction without mercury specific legislation. However, it recognises that this trend may change and that emissions may be reduced further with a more mercury-specific approach. The new IED does not set limits for mercury but does require annual mercury monitoring. The EC is also currently finalising BAT reference documents for mercury control at coal-fired plants which would indicate that there may be a move in future towards ensuring mercury control is adequate at all plants. Whether this will mean a move towards ELVs for mercury is unclear at this stage.

There are mercury control measures in place in other countries. Japan has emission limits but these tend to be on a plant-by-plant basis. China has recently set an emission limit for mercury of 30 $\mu g/m^3$, and although this is not particularly challenging, it indicates a move towards tightening pollution control in the future.

Currently, mercury emission legislation is a mixed bag of ELVs, BAT requirements, caps on emissions and reliance on co-benefit effects from other legislation. This reflects the range of options available for existing plants, and provides examples of such options for Parties who are in the process of developing national controls. The information exchange provisions within the Convention provide the opportunity to share information on the most successful approaches which will assist in the selection of the best option for the national circumstances.

5.1.3 Trends and forecasts

Emission legislation continues to tighten for coal-fired power plants, especially in regions such as the EU, North America and, more recently, China. Although it seems unlikely that CO_2 emissions will be legislated at existing plants in the foreseeable future, the indication is that new plants will have to meet HELE and possibly HELE+CCS requirements to receive funding and approval in some regions.

Mercury legislation has evolved in a disjointed manner with some regions moving towards stringent ELVs while others have achieved success through co-benefit effects from legislation for other pollutants. Countries such as the USA and Canada are somewhat ahead as they have set tight emission limits and caps which already require mercury-specific control at plants with the greatest emissions. The EU has achieved reductions in mercury emissions as a co-benefit but is now looking to determine whether more could or should be done.

Lessons can be learned from the different approaches. The co-benefit reduction achieved in the EU emphasises how much can be achieved through a multi-pollutant strategy. By promoting technologies such as FGD which help reduce emissions of sulphur, halogens and trace elements simultaneously, countries which do not yet have emission legislation for sulphur can achieve both sulphur and mercury reduction at the same time and in a cost-effective manner. The push towards mercury control in North America will mean that technologies being developed and moved into commercialisation now will become more affordable by the time they are required in developing regions – allowing a technology leap for these areas to far more cost-effective options.

The requirements for mercury control required by parties to the Minamata Convention will vary under the national plan for each country which has developed one. The definition of BAT in the Convention allows the flexibility for each country to select the most appropriate approach for mercury reduction in each region. However, selection of the BAT for mercury is not simple and can vary on a plant-by-plant and coal-by-coal basis. It is therefore likely that many parties to the Minamata Convention will have to call upon international expertise to provide advice as to the most appropriate BAT in each situation.

5.2 Economic impetus

The UNFCCC and its daughter protocols have not addressed security of supply issues specifically. Security of supply is the concern over ensuring a steady and reliable source of fuel to a country based on country-specific challenges, such as distance from coal sources and international transport options. Countries are required to work towards a less carbon intensive future, taking into account any specific national challenges. Kessels and Bakker (2005) suggest that security of supply interests be integrated into post-2012 climate policy strategies.

Developing countries and countries with economies in transition may require international funding to build new power plants. Conventions such as the UNFCCC and Minamata put pressure on countries to look to alternatives to coal for energy and, where coal is the most appropriate fuel (for example when gas and oil and nuclear power are not available), to build HELE technologies. However, these technologies are currently significantly more expensive than cheaper and dirtier subcritical coal systems. And so without some form of investment criteria, many countries would simply opt for the lower cost option.

International funding bodies such as the GEF and the Asian Development Bank (ADB) have strict criteria for investing in new power plants in developing regions. The ADB, for example will only fund plants that are supercritical or above in efficiency, that improve energy security in the host country and that form part of an "ongoing policy dialogue" with the host government. This includes plants in China, India, and Vietnam. The ADB has also established a CCS specific fund using AUD21.5 million from the Australian Government and £35 million from the UK government. This fund will be used to accelerate CCS development and lower barriers to new plant deployment.

However, there is also a move away from international funding in general. In November 2013 the UK government announced it would no longer invest in coal-fired power plants abroad unless it met minimum criteria (CB, 2013). The UK will only lend to projects:

- in world's poorest countries, where gross national income per head is below $1,945;
- that have a "compelling" impact on poverty reduction;
- where full consideration has been given to low-carbon alternatives;
- which are part of a credible low-carbon development pathway, and meet environmental and social standards;
- where a risk assessment of long-term financial viability has been undertaken;
- where the best available technology is used;
- where an assessment has been carried out of the technical, economic and financial feasibility of attaching carbon capture and storage technology to clean up the plant's emissions.

Similarly tightening requirements for funding are also being seen in the USA and Nordic countries. These countries commonly fund projects through multilateral development banks such as the ADB and the European Investment Bank (EIB). The EIB itself has effectively stopped financing all coal-fired plants, having set an emission limit of 500 gCO_2/GWh for new projects, a level that could only be achieved with CCS (Yale, 2013).

Whilst this is good news in that all internationally funded coal-fired plants built in future will be HELE and carbon capture ready, there is always the risk that countries will require more plants than those to be funded internationally and will turn to alternative banks and lenders, with less stringent funding criteria, to fund significantly cheaper subcritical plants to fill the gaps in their domestic energy requirements. Without stringent national legislation to control what plants are built, these countries will opt for the cheapest available power source. The IEA has predicted that as much as 50% of the energy required to lift developing nations out of fuel poverty will come from coal. Unless sufficient international funding is available to ensure that all these plants are HELE technologies and CCS ready, there is a risk that new but inefficient plants will be built instead, locking in decades of higher emissions of both GHG and mercury.

5.3 Comments

Emission legislation for CO_2 and mercury from coal combustion has been developing, and continues to do so, in a disjointed and uncoordinated manner. Individual countries and regions have taken the lead to set their own targets for reduction and, in some cases, their own emission legislation. Some of these approaches have been more effective than others but all make the right move towards lowering emissions. Whilst neither the UNFCCC nor Minamata Conventions aims to set such stringent targets or controls unilaterally, those looking to implement these conventions would learn much from the successes of the measures already in place around the world. By making this information readily available to signatory countries, this will allow them to benefit from the experience of others and to select and perhaps copy the moves taken in regions which are most relevant.

The major challenge with implementation of both the UNFCCC and Minamata Conventions could be cost. The control technologies required to reduce emissions from coal combustion can be expensive. There has to be a balance achieved between keeping energy available and affordable to the population whilst covering the costs required to reduce emissions. There is a risk that the recent move by international investment banks to limit funding for new build in developing regions only to those plants which meet strict and, in some cases, virtually impossible, emission limits will result in countries funding cheaper and dirtier plants through alternative funding sources. This could lock in less efficient, higher-polluting plants for several decades.

6 Conclusions

The UNFCCC and Minamata have similar aims – to control emissions of pollutants that are detrimental to the environment. The format and requirements of these conventions, however, are quite distinct. Despite this, there are conclusions which can be drawn with respect to the mutual benefits of the convention and the potential for similarities between them

Prediction of mutual benefits:

- **Cleaner energy:** The promotion of the move to renewables and low-carbon economies, and towards energy efficiency under the UNFCCC will promote less dependency on coal. This will result in reduced CO_2 and mercury emissions.
- **Improved reporting:** Concerted efforts to collate data on current and projected fuel use for reporting emissions under both the UNFCCC and Minamata Conventions will create accurate emission inventories and provide information on the trends in emissions into the future
- **Technology advancement**: the promotion of HELE technologies under many of the UNFCCC implementation strategies will result in a concomitant reduction of both CO_2 and mercury emissions.

Potential for bridge building:

- **Action plans**: when countries are preparing national action plants for the control of one pollutant, the effect upon the other pollutant should be considered to ensure that negative effects are avoided and synergies are maximised.
- **Reporting**: the process used to produce emission inventories under both conventions could be aligned. Both inventories should be produced from the same fuel use data, meaning that changes in fuel use data under current and future scenarios will provide comparative information on the projected change in emissions of both pollutants simultaneously. This will streamline and simplify the data collection and reporting process under both conventions. Scenarios which consider the potential reduction of one pollutant will provide information on how this may affect emissions of the other – for example, information on increased biomass co-firing for CO_2 reduction could be used to predict the resulting effect on mercury emissions.
- **BAT/BEP:** The application of control technologies should require consideration of the effects of the technology on emissions of both technologies in order to avoid, where possible, negative effects. CO_2 control technologies should be aware of where mercury will end up in the process and mercury control technologies should be as energy efficient as possible.
- **Funding:** funding for projects under one convention could be priorities towards those projects which consider the reduction potential for both CO_2 and mercury simultaneously.

Remaining challenges:

- Whilst mercury emissions from both existing and new plants can be controlled by over 90%, in some cases, and the technologies for control are commercially available, this is not the case for CO_2. Until CCS becomes commercially available, there is no way to decouple CO_2 emissions from fossil fuel use.

- Since CCS systems are still under development, the fate of mercury in such systems has yet to be defined.
- In order to be successful, the aims of both the UNFCCC and Minamata must be accepted and applied within the major coal producing and using nations globally.

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