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TECHNOLOGY-BASED SECTORAL NAMAs:

A PRELIMINARY CASE STUDY OF CHINA'S CEMENT AND IRON & STEEL SECTORS

Daniel E. Klein
Haibing Ma
Ned Helme
Can Wang

CENTER FOR CLEAN AIR POLICY

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Center for Clean Air Policy

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SUMMARY

Among the various nationally appropriate mitigation actions (NAMAs) under consideration by developing countries, sectoral approaches have emerged as one of the most promising tools to motivate developing countries and industry around the world to deliver greenhouse gas (GHG) emission reductions. These types of mitigation actions have been codified in the Bali Action Plan as "cooperative sectoral approaches and sector-specific activities." Along with other nationally appropriate mitigation actions (NAMAs), developing countries have a variety of opportunities to take action on mitigating climate change.

This paper explores the possible use of a technology-based sectoral NAMA for energy-intensive industries. Whereas other sectoral approaches have focused on energy or GHG intensity as the overarching metric for measuring progress, a technology-based sectoral NAMA is expressed in terms of technology selections (either specific technologies, production processes, or their performance equivalents) and future market penetration goals. Methodologies can be developed to express these technology-based metrics as equivalent progress in reducing GHG emissions and/or improving GHG intensity but achievement of the NAMA would rest on meeting the market penetration goals.

In this way, a technology-based sectoral approach can be a useful NAMA in meeting many of the goals of the Bali Action Plan. Also, recognizing that comprehensive sector data are incomplete, metrics such as technology penetration ratios and units of production may form the basis of a more workable system of monitoring, reporting, and verification. For some developing countries, the practical complexities of GHG emissions reporting could result in significant delays in establishing sectoral programs that require complete and accurate emissions data across the sector. In contrast, a technology-based approach – particularly in the case where individual technologies are being specified – is measured more in terms of technology types, market shares, and units of production, which are used as proxies in estimating GHG reductions. Even where production processes are specified for the NAMA, and direct measurements of energy use and/or emissions are needed to verify emission reductions, the measurement and boundary issues are likely to be much simpler compared to those observed in a broader sector-wide context.

International financing might also be easier for a technology-based sectoral approach. In an intensity-based approach, the overall results are the ultimate measure, and the connections between the financing and specific activities are not always clear before the fact. In contrast, a technology-based approach offers a relatively clear and unambiguous link between the funds and the specific activities to be undertaken. Up-front financing might be directed to specific technologies and processes, with sectoral credits flowing where market penetration levels are exceeded.

While this approach may not incentivize as wide a range of GHG reduction activities as some intensity-based approaches, it appears to be suitable as a "nationally appropriate" action for mitigation, and comparable with international frameworks and support mechanisms.

This approach is illustrated using the cement and the iron and steel sectors in China. Using research conducted by Tsinghua University, specific technologies are identified for both sectors that would improve energy efficiency and reduce GHG emissions. The examples used here are a subset of the broader set of technologies and processes identified in the Tsinghua University research, and are presented here as an illustration of the methodologies, and are not intended to represent the total set of possible mitigation actions within the sector. Relative to a business-as-usual (BAU) rate of market penetration, an accelerated rate of technology adoption provides a quantifiable goal capable of measurement, monitoring, and verification.

In China's cement sector, three mitigation technologies are described here to illustrate the technology approach: (1) installation of waste heat recovery systems, (2) increased use of flyash, slag, and other supplemental cementitious materials to produce low-clinker blended cements, and (3) accelerated replacement of older and less efficient capacity (particularly the vertical shaft kilns). As a unilateral commitment, increased market penetration of the first two technologies could enable CO_2 emissions reductions of about 190 Mt in the year 2020. Waste heat recovery, currently in use on about 30 percent of the production lines, would increase to 80 percent in the year 2020. The amount of cement blending would also increase, reducing the amount of clinker in the final product; from a current clinker-to-cement ratio of 75%, a decrease to 65 percent would be targeted in 2020. Additionally, an accelerated pace for the replacement of the older and less efficient capacity, currently under way in China's cement industrial plan, is estimated to result in another 27 Mt of CO_2 reductions per year as an additional component of a unilateral commitment. In a no-lose target, additional market share for these technologies could achieve total CO_2 emission reductions of about 280 Mt in 2020.

In China's iron and steel sector, there are numerous potential technologies, only some of which to date have been evaluated in depth. Tsinghua University's research described a number of actions, including both individual technologies as well as more complex production processes. Collectively, these mitigation options could reduce emissions by well over 100 Mt per year, above and beyond the reductions being achieved from the replacement of older and less efficient plants. For our illustration, we have selected a couple of specific technologies that have been more fully examined, recognizing that these account for only a fraction of the sector potential.

For the next 10-15 years, three of the iron and steel CO_2 mitigation technologies are (1) increasing the share of facilities using coke dry quenching (CDQ) technology, (2) using Combined Cycle Power Plant (CCPP) to recover overflowed blast furnace gas (BFG), and (3) accelerated retirement of older and less efficient production facilities. As a unilateral commitment, increased market penetration of the first two technologies could enable CO_2 emissions reduction of about 7 Mt from BAU in the year 2020. For example, CDQ technology, currently in use for about 45 percent of the coke production, would increase to 60 percent in the year 2020. In a no-lose target, additional market share for CDQ (to 65% in 2020) and CCPP technologies could achieve CO_2 emission reductions of over 8 Mt in 2020 from 2008.

Further, the accelerated replacement of the older and less efficient iron and steelmaking capacity, currently under way in China, will result in substantial CO_2 reductions as an additional component of a unilateral commitment. China has been aggressively pursuing closure of older, smaller, and inefficient capacity, where the new replacement capacity is considerably more efficient. In the 11th five-year plan, China plans to shut down 100 Mt of iron production capacity (about 20% of 2007 national production capacity), and about 55 Mt of steel production units (about 10% of 2007 national production capacity). Quantification of these GHG savings is not yet complete but is likely to be well over 40 Mt per year.

The cost-effectiveness of the technologies examined varied from plant to plant. For the market shares represented by the unilateral actions, the costs per ton of CO_2 reduced were generally modest. However, at some of the increased market penetration levels envisioned for the no-lose targets, the higher costs for CO_2 reductions could be contingent on financing and/or other assistance. Financing assistance could also cover other advanced technologies such as carbon capture and storage (CCS).

For both the cement and iron and steel sectors, technology-based NAMAs appear to fit well with China's broader planning process and its Industrial Development Plans for key energy-intensive sectors. Therefore, we find that a technology-based sectoral approach can be a useful NAMA for meeting China's objectives as well as many of the goals of the Bali Action Plan.

In broadening the vision on China's planning system to the international level, China will probably continue pursuing technology transfer as the main mechanism for international assistance. As presented here, technology-based NAMAs could actually achieve the twin goals of gaining both know-how and emission reductions as shown in previous analysis.

Additionally, this approach could bring in up-front finance for technology under the NAMAs framework., technology-based NAMAs may offer a new avenue for developing countries to get the support for technology transfer that has eluded them in the first 17 years of the UNFCCC process, because for the first time technology goals would be linked to mitigation efforts and to financing options. Technology-based NAMAs could be a more workable platform to "move the ball".

Although they have not supported sectoral crediting, the Chinese generally like the idea of technology based conditional NAMAs to enhance cooperation on technology innovation and spur greater penetration of key technologies, which can also produce emission reductions.

1. INTRODUCTION

Paragraph 1(b) of the Bali Action Plan calls for enhancing mitigation action with respect to climate change through consideration of "*[n]ationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner;*" as well as "*[c]ooperative sectoral approaches and sector-specific actions.*"

The forms that these nationally appropriate mitigation actions (NAMAs) can take must still be defined, but discussion is centering around three general classes of NAMAs:

- ***Unilateral NAMAs*** – NAMAs that a country intends to implement completely on its own but for which recognition of this effort is desired.

- ***Conditional NAMAs*** – NAMAs that will only be implemented with the help of international assistance, in the form of financing, technology transfer and/or capacity building. These NAMAs – similar to "no-lose" targets – could go beyond unilateral efforts and represent greater ambition for which assistance is needed for the incremental effort, or it could be completely unrelated to any proposed unilateral NAMAs; in either case, the necessary support would also have to be specified.

- ***Carbon Market NAMAs*** – NAMAs that are eligible for support through full or discounted crediting in the carbon market for activities beyond the baseline or NAMA level..

The process by which a developing country would officially declare its NAMAs has yet to be determined, but it has been proposed that each developing country put forward a climate plan or low-carbon growth strategy[1] that describes the NAMAs that it intends to implement. Sectoral programs could be a part of the developing country's plan or strategy. These types of programs allow a developing country to grow their industries in a more climate-friendly manner without compromising the country's sustainable development.

A sectoral program could consist of a single NAMA or a group of associated NAMAs designed to achieve a sectoral goal. This sectoral goal would be made up of a unilateral component – the sectoral goal that the country will adopt independent of any international assistance – and a more ambitious, "no-lose" goal that the country will pursue in return for specific provisions of up-front international assistance. If the country does not reach its no-lose goal, no penalties would accrue; however, if it beats this goal, the excess emission reductions would be eligible for sale in the carbon market.

Previous research by CCAP and others indicates significant differences within industries, across industries, and across countries. These differences relate to industry structure, types of processes, diversity of production technologies, and other factors. A sectoral program that might seem well-suited for a particular industry or country may be a poor fit elsewhere. Clearly, an assumption that "one size fits all" does not hold here, and any identification of a "nationally appropriate" sectoral program needs to be cognizant of industry-specific and country-specific considerations.

2. TECHNOLOGY-BASED NAMAS

As they are often described in concept, sectoral approaches can be measured in terms of changes in greenhouse gas (GHG) intensity, where improvements in intensity can be applied to production levels to determine overall GHG reductions. However, this need not always be the case, and a nationally appropriate sectoral approach can employ different strategies and measures in pursuit of broader GHG reduction goals. In Mexico, for example, CCAP's analysis of the cement sector suggested some actions that would improve the energy efficiency of the kilns, some that would reduce the proportion of clinker in blended cements, and some that would entail building renewable energy projects to displaced grid-supplied electricity. In contrast, Mexico's oil refineries were seen to be better suited for a sectoral

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[1] The latter has been proposed by the European Commission in its "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Towards a comprehensive climate change agreement in Copenhagen," January, 2009 (available at http://ec.europa.eu/environment/climat/future_action.htm).

program based upon a measure of energy intensity, plus construction of cogeneration facilities to displace power purchased from the grid and also supply lower-CO_2 energy to the grid.

In this paper, we explore another approach for establishing and measuring sectoral programs. Here, we consider the case for the cement and the iron and steel industries in China, and specifically examine the feasibility of using specific types of technologies and technology penetration rates as a means for setting sectoral performance goals and measuring progress toward the goals.

Broadly, three types of technology-based program elements can be identified:

- ***Sector-wide technology upgrades.*** In China's context, technology programs often take the form of promoting matured technologies. Our technology-based NAMA acknowledges the fact that some mature technologies with significant GHG reduction technology, like blending in cement production and coke dry quenching (CDQ) in iron and steel processes, have a relatively low penetration in China compared to some countries with a more technologically advanced or less diverse industry. Therefore, we propose accelerating the deployment rate of such technologies (above and beyond a "business as usual" (BAU) deployment rate) as a conditional NAMA. In this way, China could use international assistance to upgrade its sector-wide technology level while simultaneously contributing to significant emission reductions.

  Technology upgrades can take two broad forms. *Individual technologies* such as coke dry quenching or cement kiln waste heat recovery typically refer to discrete equipment installations, either as retrofit or as replacement. But technology upgrades can also refer to *production processes* comprised of multiple technologies plus management improvement. These production processes, such as "advanced blast furnace technology," can often represent substantial GHG emission reduction opportunities. They can be represented as elements of a technology-based NAMA, but since they incorporate varying mixes of many activities, the measurement and verification will tend to require more specific data on energy consumption and/or emissions.

- ***Accelerated Retirements.*** Many older and inefficient facilities are not cost-effective candidates for technology upgrades. But in a rapidly-growing economy, such facilities are often kept operating just to help meet growing demands. For some of these older facilities, energy and GHG progress may take the form of shutting down these facilities and replacing them with new capacity. China has put considerable effort into shutting down outdated production capacity which will also upgrade the sector-wide technology level. In terms of resulting GHG reduction, the retirement actions have no less effect than deploying climate-friendly technologies.

- ***Advanced Step-Change Technologies.*** Technology-based NAMAs could also benefit global cooperation on step-change technologies like Carbon Capture and Storage (CCS). For example, if China sets up a plan to build a certain number of CCS projects, the world would benefit from the maturing of advanced technologies with the experiences and lessons learned in China's exercise while China could benefit from some of the know-how rights, not to mention the huge mitigation potential from the deployment of such technologies.

It is seen that in China's case, these types of technology-based goals can be more nationally appropriate with China's overall economic planning process, and can be readily monitored, verified, and converted into equivalent GHG reductions.

3. Technology-based Sectoral NAMAs: Two Examples for China

We illustrate this approach using the cement and the iron and steel sectors in China. Research conducted by Tsinghua University, working with the Center for Clean Air Policy, has developed baseline forecasts and evaluated the mitigation potential for a variety of actions. For both sectors, we illustrate how specific technologies can be deployed as part of a technology-based sectoral NAMA to improve energy efficiency and reduce GHG emissions.

General Methodology

Broadly, the methodology for a technology-based sectoral NAMA is not too dissimilar to that of an intensity-based sectoral approach. First, BAU baselines are developed, then GHG mitigation measures are identified and evaluated for cost and effectiveness. For a technology-based approach, these steps need to present the anticipated technologies to be put in place, as these become the building blocks for estimating GHG reduction potentials.

For example, if a baseline forecast estimated that 20 percent of facilities would deploy a certain high-efficiency technology, but that under a NAMA this technology could be accelerated to 70 percent market penetration, then the potential additional GHG reductions would stem from the extra 50 percent of capacity now having the higher-efficiency technology. Per unit of production, the higher efficiency is expressed first as fuel savings, then as equivalent GHG reductions. When these per-unit savings are applied to the production from this set of affected facilities, total GHG reductions are computed.

By using technology performance and market shares as proxies for GHG reductions, we are simplifying a more complete measurement approach that would rely on the differences between full emissions inventories, before and after. While this undoubtedly misses some of the GHG emission changes in a complex industrial setting, it often enables a reasonable estimate to be made when comprehensive emissions data are not or cannot be made available.

As noted above, technology upgrades can refer to both individual technologies as well as production processes comprised of multiple technologies plus management improvements. Using technology performance and market shares as proxies for GHG reductions is more applicable when individual technologies are specified. When more complex production processes and operations are the focus for improvement, the measurement of performance will tend to require a more direct measurement of energy consumption and/or GHG emissions.

An additional consideration is not specific to technology-based approaches, but is instead applicable to developing countries such as China that have already initiated GHG-reducing activities. Conceptually, a BAU forecast is a reference marker, and is thought to be a baseline projection that does not incorporate any particular actions for GHG reductions. Contrasted to such a baseline, a set of proposed actions can be evaluated for their additional contribution. This distinction works well in an *ex ante* situation, before a country (or other entity) has begun taking action. However, once mitigation actions have begun, then the distinctions going forward between BAU and the proposed actions become increasingly blurred, eventually becoming one and the same. This is the situation in China, where energy efficiency improvement goals and national industrial planning have already led to early shutdowns of some older facilities, advanced technology retrofitting of others, and other actions reducing GHG emissions that previously would have been considered as additional to BAU. Accordingly, for those climate-related actions that have been planned but not yet implemented, it seems appropriate to include the GHG benefits as part of a set of unilateral actions, rather than including the benefits as part of a BAU forecast. As part of a unilateral NAMA, the effects would be primarily for recognition rather than a conditional action dependent upon international financial assistance and/or crediting.[2]

TWO EXAMPLES FOR CHINA

Researchers at Tsinghua University, working with CCAP, have been evaluating China's cement industry and iron and steel industry. They have developed projections of production, technology mixes, fuel use, and CO_2 emissions. Using these projections, they have identified significant GHG mitigation technologies and have evaluated the costs and potential reductions.

For both sectors, the Tsinghua University researchers identified several potential technologies that could reduce GHG emissions, including both individual technologies and production processes comprised of multiple technologies plus management improvements. Collectively, the GHG reduction potential from these sets of technologies was substantial.

To date, the availability of data on practices and mitigation costs is uneven, and some of the mitigation abatement options are less well-examined than others. For illustration purposes in this paper, we focus upon a subset of the fuller list of options examined, particularly those where China-specific information and costs could be obtained. Below, we briefly summarize each.

Cement

In China's cement sector, a broad range of individual technologies and production processes were examined for their potential energy savings, costs, and CO_2 emission reductions. These activities covered various aspects of raw material preparation, clinker production, finish grinding, and cement blending.

Three cement sector mitigation technologies are described here to illustrate the technology approach: (1) installation of waste heat recovery systems, (2) increased use of flyash, slag, and other supplemental cementitious materials to produce low-clinker blended cements, and (3) accelerated replacement of older and less efficient capacity (particularly the vertical shaft kilns).

[2] Conversely, if recognition of such efforts was denied simply due to a country's proactive steps, it would have a chilling effect upon other unilateral efforts being taken prior to a full international framework being in place.

As a unilateral commitment, increased market penetration of the first two technologies could enable CO_2 emissions reductions of about 190 Mt in the year 2020.[3] Waste heat recovery, currently in use on about 30 percent of the production lines, would increase to 80 percent in the year 2020. The amount of cement blending would also increase, reducing the amount of clinker in the final product; from a current clinker-to-cement ratio of 75%, a decrease to 65 percent would be targeted in 2020.

Additionally, the accelerated replacement of the older and less efficient capacity with modern technology – currently under way in China's cement industrial plan – is estimated to result in another 27 Mt of CO_2 reductions per year as an additional component of a unilateral commitment. As noted earlier, when a country has already initiated GHG-reducing activities, the distinctions going forward between BAU and the proposed actions become increasingly blurred. For a country that had not yet initiated these types of activities, the GHG reductions would be considered additional to a BAU forecast either as a unilateral action or as part of a no-lose commitment. For these illustrative examples, we are including them as part of a unilateral action by China.

In a no-lose target, additional market share for these technologies could achieve CO_2 emission reductions of about 280 Mt in 2020. The market penetration for waste heat recovery would increase further to 95% by the year 2020, while the clinker-to-cement ratio would decrease further to 60 percent.

Iron and Steel

In China's iron and steel sector, there are numerous potential technologies, only some of which have been evaluated to date. Tsinghua University's research described a number of actions, including both individual technologies as well as more complex production processes. Collectively, these mitigation options could reduce emissions by well over 100 Mt per year, above and beyond the reductions being achieved from the replacement of older and less efficient plants. For our illustration, we have selected a couple of specific technologies that have been more fully examined, recognizing that these account for only a fraction of the total sector potential identified.

For the next 10-15 years, three of the iron and steel CO_2 mitigation technologies are (1) increasing the share of facilities using coke dry quenching (CDQ) technology, (2) using Combined Cycle Power Plant (CCPP) to recover overflowed blast furnace gas (BFG), and (3) accelerated retirement of older and less efficient production facilities.

As a unilateral commitment, increased market penetration of the first two technologies could enable CO_2 emissions reduction of about 7 Mt from BAU in the year 2020. For example, CDQ technology, currently in use for about 45 percent of the coke production, would increase to 60 percent in the year 2020. In a no-lose target, additional market share for CDQ (to 65% in 2020) and CCPP technologies could achieve CO_2 emission reductions of over 8 Mt in 2020 from 2008.

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[3] As seen in the attached Tsinghua University description, the analysis was actually extended to 2025 in which the correspondent reduction potentials are 290 Mt and 385 Mt from 2008 baseline for unilateral and no-lose targets respectively

Further, the accelerated replacement of the older and less efficient iron and steelmaking capacity, currently under way in China, will result in substantial CO_2 reductions as an additional component of a unilateral commitment. China has been aggressively pursuing closure of older, smaller, and inefficient capacity, where the new replacement capacity is considerably more efficient. In the 11th five-year plan, China plans to shut down 100 Mt of iron production capacity (about 20% of 2007 national production capacity), and about 55 Mt of steel production units (about 10% of 2007 national production capacity). Quantification of these savings is not yet complete but is likely to be well over 40 Mt per year.[4]

Carbon capture and storage (CCS) is a key advanced technology, and conceptually could fit well into a technology-based NAMA. However, it is not evaluated as part of these examples because there is not yet adequate cost and performance data on its applicability to the cement and iron and steel sectors.

4. Compatibility with Domestic and International Climate Framework

How might Technology-Based NAMAs fit into China's broader planning process?

As is well known, China has been conducting GHG mitigation actions on its own in recent years and will continue its unilateral actions in the future. In a centrally commanded economy like in China, the central government and those governmental agencies that regulate the industry sectors normally play significant roles in designing both general and specific mitigation plans.

Technology-based NAMAs would appear to fit well with China's broader planning process. The NDRC and other governmental agencies usually release so-called Industrial Development Plans for key sectors like cement, iron and steel, pulp and paper, etc. These plans serve as short/medium-term guidance for industrial development and normally have much more detailed requirements/standards than those economy-wide regulations. For instance, the state council recently (March 20th, 2009) published the *Planning on Adjusting and Boosting Iron and Steel Industry* which details the direction and focus of steel industry's development in the period of 2009 – 2011. Similar plans for other key sectors are expected to be released in the next couple of months too. It's reported that there will be such plans for up to ten sectors.

Technology-based NAMAs could naturally fit into such sectoral development plans. A focus on sector-wide technology improvement is at the heart of each industry development plan.. The plan especially calls for development and deployment of technologies related to energy saving and emission reduction. In general, China hopes to achieve two technological goals through the industry development plan: 1) to significantly upgrade the sector-wide

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4 Assuming that emissions are roughly 2 tons CO_2 per ton of iron, and that the new replacement capacity is at least 20% more efficient than the old capacity being shut down, then savings would be at least 0.4 tons CO_2 per ton of steel, or 40 Mt for the 100 Mt of ironmaking capacity being phased out. Additional savings would also result from the steelmaking capacity being replaced.

technology level; and 2) to push Chinese industry to move forward on step-change technology development. The technology based NAMAs can contribute to both.

Other than matching China's industry development plan system, technology-based NAMAs also have a great implementation advantage in China in terms of policy making and internal MRV. Since the target is set in the format of a technology penetration ratio which is a macro index, it could effortlessly fit into China's command and plan policy making framework. Moreover, technology penetration ratios which ultimately transform into existing technical indexes are much easier to MRV than emission reduction or intensity target. Given the fact that China is still facing huge data gaps in climate change area, the more feasible technology-based NAMAs should be more appealing to the Chinese government.

Looking ahead, China may be extending its economy-wide energy intensity goal in the next national 5-year plan. Normally, the 5-year plan doesn't include such specifically quantified targets. If China succeeded in achieving the 20% goal by the end of current 5-year plan as is predicted, there might be a chance that more quantified targets would be included in the next 5-year plan. Technology based sector-wide targets are among the strongest candidates of all potential options.

ARE TECHNOLOGY-BASED NAMAS COMPATIBLE IN AN INTERNATIONAL FRAMEWORK?

To date, much of the research on sectoral approaches has focused on energy intensity or GHG intensity as the overarching metric for measuring progress toward GHG reductions. In contrast, a technology-based sectoral NAMA is expressed in terms of technology selections (either specific technologies, production processes, or their performance equivalents) and future market penetration goals. Methodologies can be developed to express these technology-based metrics as equivalent progress in reducing GHG emissions and/or improving GHG intensity, but achievement of the NAMA would rest on meeting the market penetration goals.

In evaluating "proof of concept" of various sectoral approaches, it can broadly be said that, considering the range of conditions across countries, industries, technologies, and data, a "one size fits all" sectoral approach design cannot be found. Because of this, concepts for sectoral approaches need to be adaptable to the real-world conditions that are encountered in each developing country. This is very much in keeping with the "Nationally Appropriate" language expressed in the Bali Action Plan.

Whether a technology-based sectoral NAMA is "better" or "worse" than an intensity-based approach cannot be judged in abstract, any more than "nationally appropriate" can have a single best implementation. In China's case, the technology-based approach appears to fit in well with the country's economic development planning process. Our discussions with Chinese researchers suggest familiarity and comfort with this type of approach, and confidence that once agreed to, goals could be met.

It also appears that technology-based sectoral NAMAs may have some advantages with respect to monitoring, reporting, and verification (MRV) when comprehensive sector data are incomplete. Emissions reporting has often been seen as a complex task for many industries, especially when there is significant variation in industry structure and boundaries. This has often been problematic even in developed countries with experience in GHG reporting. For some developing countries, the practical complexities of GHG emissions reporting could result in significant delays in establishing sectoral programs that require complete and accurate emissions data across the sector. In contrast, a technology-based approach – particularly in the case where individual technologies are being specified – is measured more in terms of technology types, market shares, and units of production, which are used as proxies in estimating GHG reductions. Even where production processes are specified for the NAMA, and direct measurements of energy use and/or emissions are needed to verify emission reductions, the measurement and boundary issues are likely to be much simpler compared to those observed in a broader sector-wide context.

ARE TECHNOLOGY-BASED NAMAS SUITABLE FOR INTERNATIONAL FINANCIAL SUPPORT MECHANISMS?

In the Bali Action Plan, paragraph 1.(b)(2) states that NAMA undertaken by developing countries be "supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner." Would technology-based sectoral NAMAs fit within the financing approaches currently under consideration?

In general, the types of financial support envisioned for intensity-based sectoral targets could be applied to a technology-driven NAMA as well. As developed in this paper, the various technologies, market shares, and efficiencies are used as proxies for a broader sector-wide change in energy or GHG intensity.

We showed how technology shares could be used to formulate a baseline projection, unilateral commitments, and no-lose targets. Different forms of assistance would be expected at different levels:

- The ***Unilateral NAMAs*** are those that the country intends to implement on its own. Presumably, international financing is not a condition for these efforts, although capacity building and other assistance could play a valuable role.

- ***Conditional NAMAs*** **–** similar to "no-lose targets" – would be implemented with the help of international assistance, in the form of financing, technology transfer and/or capacity building. As developed in these examples, this could go beyond unilateral actions to represent a more ambitious effort for which some assistance is needed for the incremental effort and/or increased technology market share. Tsinghua University's research found that the cost-effectiveness of the technologies examined varied from plant to plant. For the market shares represented by the unilateral actions, the costs per ton of CO_2 reduced were generally modest. However, at some of the increased market penetration levels envisioned for the no-lose targets, the higher costs for CO_2 reductions could be contingent on financing and/or other assistance. Financing assistance could also cover a share of the cost of other advanced technologies such as carbon capture and storage (CCS).

- ***Carbon Market NAMAs*** **–** Full or discounted crediting in the carbon market offers another channel for financial support for activities exceeding the NAMA goal or no-lose target. Crediting would be an incentive for GHG reductions beyond a no-lose target.

In some ways, international financing might be easier for a technology-based sectoral approach. In an intensity-based approach, the overall results are the ultimate measure, and the connections between the financing and specific activities are not always clear before the fact. In contrast, a technology-based approach offers a relatively clear and unambiguous link between the funds and the specific activities to be undertaken. Up-front financing might be directed to specific technologies and processes, with sectoral credits flowing where market penetration levels are exceeded.

In broadening the vision on China's planning system to the international level, China will probably continue pursuing technology transfer as the main mechanism for international assistance. As presented here, technology-based NAMAs could actually achieve the twin goals of gaining both know-how and emission reductions as shown in previous analysis.

Additionally, this approach could bring in up-front finance for technology under the NAMAs framework. Technology-based NAMAs may offer a new avenue for developing countries to receive the support for technology transfer that has eluded them in the first 17 years of the UNFCCC process, because for the first time technology goals would be linked to mitigation efforts and to financing options. Technology-based NAMAs could be a more workable platform to "move the ball".

5. CONCLUSION

Technology-based sectoral NAMAs offer potential advantages and disadvantages for energy-intensive industries in developing countries. The various advantages include fitting in well with China's policy structure of 5-year plans and industrial sectoral development plans, along with overcoming current problems with data gaps in developing countries. In addition, the technology-based sectoral NAMAs make achieving MRV easier, as they smoothly measure technology implementation, rather than emissions and costs. Another advantage is that they have potential to achieve twin goals of increasing technology capacity/sustainable development in developing countries, while achieving significant emissions reductions – that are not offsets – in those countries. For the first time, these sectoral NAMAs link the technology goals of the UNFCCC with emission reduction goals, which increases the likelihood of achieving each goal. Finally, this mitigation option is much clearer in explaining how up-front financing would be used, as well as offering a quicker interim path to emission reductions that can act as building blocks for more full-fledged emission reduction efforts in the future.

At the same time, compared to other approaches, there are also some relative disadvantages to the technology-based sectoral NAMA. This sectoral NAMA does not send a carbon price signal to the developing country market, and emission reductions are less certain since operation and maintenance of technology can significantly affect the level of emission reductions achieved. Furthermore, this approach does not create incentive for switching to lower carbon fuels, nor does it create as much incentive for improving emissions data collection and monitoring. It could lock in existing technologies, and may not create sufficient incentives for developing additional advanced technologies.

Overall, CCAP concludes that a technology-based sectoral approach, where nationally appropriate, can be the basis for effective mitigation action now. This approach is also consistent with a future path for additional reduction actions, both within the sectors and multi-sectors. While it is not a theoretically optimal approach, a technology-based sectoral approach appears reasonably practical in a variety of applications.

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Center for Clean Air Policy

750 First Street, NE • Suite 940

Washington, DC 20002

Tel: 202.408.9260 • Fax: 202.408.8896