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# National greenhouse gas inventory capacity: An assessment of Asian developing countries

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ABSTRACT

The transparency framework of the Paris Agreement (PA) will be elaborated from the existing arrangements under the UN Framework Convention on Climate Change (UNFCCC). Yet, the capacities of developing countries to regularly report national GHG inventories vary, and their needs for capacity building are closely linked with efforts and achievements of previous inventory preparation. The purpose of this study was to analyze the status and changes in the capacity of 37 developing countries in Asia by using a matrix of capacity-indicators. Indicators were composed for four assessment categories: (1) international engagement of a country in the GHG inventory-related process; (2) institutional capacity to produce a GHG inventory; (3) existing technical capacity available to develop a GHG inventory; and (4) actual technical capacity applied to produce a GHG inventory. The paper also analyzed the scale of international support and variations in meeting with capacity building needs. Eleven countries were identified as having low capacity over time, while 9 improved their capacity. Seventeen countries, including 7 countries with established capacity, continuously had relatively high capacity over time. International support was scarce in the majority of Asian developing countries with the most capacity building needs. Improvements in basic technical capacity available for GHG inventory preparation, such as statistics and the scientific expertise, were found to be a key necessity for countries to respond to the PA's enhanced transparency framework. Based on these findings, the study recommended increasing support for improvements in basic technical capacity, especially in countries where existing capacity is low and support is limited. Such capacity building efforts are also beneficial for countries to form and implement nationally determined contributions (NDCs) and other economic and development policies.

## 1. Introduction

At the 21 st session of the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in December 2015, the Paris Agreement (PA) was adopted to strengthen global efforts to mitigate climate change. The core objective of the PA is that all Parties implement their nationally determined contributions (NDCs), which are expected to be progressive each time they are renewed in a five-year cycle. Parties track implementation of their NDCs in accordance with the PA's transparency framework in order to "build mutual trust and confidence and to promote the effective implementation of the PA" (UN, 2015). The PA's transparency framework consists of two information elements: a national inventory report of greenhouse gases (GHGs) and information necessary to track progress in implementing and achieving NDCs by a country. Parties are requested to regularly report on these information elements (UN, 2015).

Almost all Parties to the UNFCCC have reported GHG inventories for nearly 20 years. A national GHG inventory is a compilation of a country's estimated anthropogenic GHG emissions and removals and is prepared following the methods provided in the Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines and the five reporting principles of transparency, accuracy, completeness, comparability and consistency (IPCC, 2006). Under the UNFCCC, developed countries are encouraged to support developing countries to prepare GHG inventories as part of national communications (NCs) and biennial update reports (BURs) (UNFCCC, 2002, 2011).

The PA's transparency framework is yet to be elaborated, but will be built on and enhanced from the existing transparency arrangements (UNFCCC, 2015a,b). Prior to the PA, there are clear distinctions between Annex I (developed) and non-Annex I (developing) countries for the requirements of GHG inventory reporting (UN, 1992). One example of this differentiation is that while Annex I Parties were required to submit GHG inventories annually (UNFCCC, 1999, 2013a), non-Annex I

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**Table 1**
Overview of assessment categories, criteria, indicators and the data sources used for calculating the capacity value.

| Assessment category | Criteria | Indicator (sources) |
|---|---|---|
| International engagement | Timely response | Promptness of application for GEF funding by a country for NC1, NC2 and BUR1, if submitted (UNFCCC, 2003, 2012, 2015b, 2015c, 2015d) |
| Institutional capacity | Coordination capacities | Existence of a single overall coordination body (GHGI[a]) |
| | National formal/legal arrangements | Exitence of national formal/legal arrangements for developing a GHG inventory (GHGI) |
| | Continuous improvements | Existence of a continuous improvement plan (GHGI) |
| | Involvement of stakeholders | Existence of arrangements/systems for Involvement of stakeholders (GHGI) |
| | Domestic financial resources availability | Existence of domestic financial resources available for sustaining a team of experts (GHGI) |
| Technical capacity available | Understanding of IPCC methods | Number of authors/contributors to IPCC guidelines and guidance (IPCC, 1997, 2000, 2003 for NC1; IPCC, 2006, 2013a, 2013b for NC2 and BUR1) |
| | National scientific capacities | Researchers in R & D[b] (per million people) (WB, 2016a) |
| | National statistical capacities | Overall Statistical Capacity Indicator[c] (WB, 2016b) |
| Technical capacity applied | Transparency | Level of information provided for methodologies in each sector (GHGI) |
| | | Existence of QA/QC plan/arrangements (GHGI) |
| | Accuracy | Use of tier 2 or 3 methods in each sector (GHGI) |
| | | Application of uncertainty assessment (GHGI) |
| | Completeness | Comprehensiveness of reporting in each sector (GHGI) |
| | Comparability | Use of appropriate/latest guidelines (GHGI) |
| | | Application of key category analaysis (GHGI) |
| | Consistency | Timeseries inventories (GHGI) |
| | | Timeseries consistency (GHGI) |

[a] GHG inventory section and annexes of NC1, NC2 and BUR1 submitted by each country.
[b] Representation of years for NC1, NC2 and BUR1 is 2000, 2010 and 2013, respectively.
[c] Representation of years for NC1, NC2 and BUR1 is 2004, 2010 and 2015, respectively.

Parties were required to do so every three to four years as part of NCs and communicate updates on their inventories as part of BURs (UNFCCC, 2002, 2011). Another example is that while Annex I Parties were encouraged to use most recent IPCC guidance and guidelines for inventory compilation, non-Annex I Parties could choose older guidance as references (UNFCCC, 2002, 2013a). In this paper, we refer to Annex I Parties as developed countries and non-Annex I Parties as developing countries.

Differences in reporting requirements between developed and developing countries will likely be smaller under the PA's transparency framework, because it ensures participation by all Parties. However, the existing capacity of developing countries for national reporting is highly variable (Damasa and Elsayed, 2013). Capacity for the purpose of this study refers to the ability of a country to conduct a GHG inventory in response to the international requirements under the UNFCCC. One illustration for varying capacities in developing countries is that, despite agreeing in COP17 that developing countries would submit their first BUR (BUR1) by December 2014, only nine met this deadline (UNFCCC, 2011). To date, only 34 countries have submitted their BUR1 (UNFCCC, 2016a, 2016b, as of September 2016). A challenge for the majority of developing countries is to make reporting on a regular basis, in accordance with the IPCC guidance and guidelines.

Shortage in capacity can be due to a number of factors related to the political, institutional and technical aspects of national systems for preparing GHG inventories (NCSP, 2005; IPCC, 2006; NIES, 2006; Umemiya, 2006; Damasa and Elsayed, 2013; UNFCCC, 2013b; CGE, 2016; US-EPA, 2016). Therefore, capacity building is necessary for countries to prepare and communicate a GHG inventory. Yet, capacity building efforts vary substantially across countries. As we found in this paper, those efforts are closely linked with capacity building efforts and achievements of previous inventory preparation, including support from developed countries. To consider allocation of resources for future capacity building efforts, it is essential to investigate what progress has been made in terms of capacities for making national GHG inventories in developing countries and where and to what extent additional capacity building is needed (Dagnet et al., 2015; Umemiya et al., 2016).

This paper analyzes the change in capacity of developing countries across Asia to develop national GHG inventories by comparing the status of capacity at the time of submitting the first GHG inventory with the status of capacity at the time of submitting subsequent GHG inventories. We performed this assessment of GHG inventory capacities by using a matrix of capacity-indicators. Further, we analyzed the availability and scale of international support and compared it with capacity building needs we identify in each country.

## 2. Data and methodology

### 2.1. Data

This study focuses on 37 of 55 developing countries in Asia (UN, 2014). These countries were selected, because they have submitted their GHG inventories at least as part of NC1 and NC2 (seven also submitted BUR1) and also because their NCs and BURs were available on-line (UNFCCC, 2016a, 2016b). Data were assembled from publicly available sources and integrated into a single database.

The main data source to assess the GHG inventory development capacities was the GHG inventory section and annexes of individual Parties' NC1, NC2 and BUR1. Another primary source was information collected from the questionnaire survey targeting GHG inventory experts. GHG inventory experts are those who have experience with developing a GHG inventory of a developing country in Asia or supported such a process as an expert. As mentioned below, the survey was conducted to identify the importance of indicators, which we refer to as indicator weighting. Results of the questionnaire provided by ten experts, nine from developing countries and one from a developed country, were used in this study. Additional information on understanding of IPCC methods, national scientific capacities and statistical capacities was taken from a variety of publicly available sources (Table 1).

Data sources for measuring the level of international support related to GHG inventory development were the OECD Rio Marker (OECD, 2016) and the UNFCCC Capacity-building Portal (UNFCCC, 2016c). The OECD Rio Marker is the database focusing on bilateral official development assistance (ODA). The Portal summarizes information provided by United Nations agencies and the Global Environment Facility (GEF) on their respective capacity-building activities, including on GHG inventories.

The submission years of NC1 and NC2 from the countries assessed in this study ranged from 1997 to 2007, and from 2003 to 2016. For BUR1, submissions were between 2014 and 2016. Therefore, for the

purposes of data collection from other sources (Table 1) and the reporting of results, we used three representative years, 2000, 2010 and 2015.

Data on support were collected for the two periods 2002–2011 and 2012–2014. For the purposes of this paper, support included project-based assistance expressed in the amount of finance used.

### 2.2. Methodology

A methodology was developed to attribute a value to the capacity necessary for GHG inventory development at the country level. This approach was derived from the methodology of Romijn et al. (2012). We supplemented this methodology with the inclusion of indicator weighting. The capacity value was calculated by summarizing eighteen indicators representing fourteen criteria for four major assessment categories. The capacity value was calculated at the time of a country's submissions of NC1 and NC2 (and BUR1, if submitted) to the UNFCCC. We then classified these values into different capacity statuses and examined change in country's capacity status over time. In addition, the value of international support provided for GHG inventory development in each developing country was calculated. We then compared the capacity and support values to analyze variations across countries in the availability and scale of support.

#### 2.2.1. The capacity value

A preliminary list of assessment categories, criteria and indicators were developed based on literature review (NCSP, 2005; IPCC, 2006; NIES, 2006; Umemiya, 2006; Damasa and Elsayed, 2013; UNFCCC, 2013b; CGE, 2016; US-EPA, 2016). Four assessment categories were identified: (1) international engagement of a country in the GHG inventory-related process; (2) institutional capacity to produce a GHG inventory; (3) existing technical capacity available to develop a GHG inventory; and (4) actual technical capacity applied to produce a GHG inventory.

The first assessment category addresses the level of engagement of a country in the international UNFCCC processes related to NCs and BURs and the understanding that countries have in responding to the UNFCCC requirements, such as access to funding of GEF. The second category is indicative of the current national institutional capacity for preparing a GHG inventory. This includes coordination capacities, legal arrangements, existence of systems for stakeholder engagement, etc. (NCSP, 2005; Damasa and Elsayed, 2013; UNFCCC, 2013b; CGE, 2016; US-EPA, 2016). The third category presents technical capacity, that is not specific to, but necessary for GHG inventory development. This includes capacity such as general scientific and statistical capacity of a country (NIES, 2006). The fourth category identifies technical capacities that are specific and applied to submitted GHG inventories. These capacities were formed following the IPCC's principle of transparency, accuracy, completeness, comparability and consistency (IPCC, 2006).

Each assessment category was then divided into the criteria that represent the specific elements of the assessment categories. These 14 criteria consisted of one or two indicators used to assign a value to the criteria during a desk review of data sources (Table 1). The indicator score was then weighted, based on expert opinion collected in survey form on the importance of each category (see Indicator weighting methodology below). The sum of the weighted indicator score was used as the capacity value for GHG inventory development in this study.

*2.2.1.1. Indicator score.* During the desk review of data sources, an indicator score in the range of −0.5 and 2 was assigned to each indicator characteristic (Table 2). The higher the score, the higher the capacity of a country was in relation to the criteria concerned. Some of the indicator scores also contained "not applicable (N/A)". This meant that the indicator should not be considered, because COP decisions or IPCC guidelines at the time of reporting by countries did not require that capacity to be taken into account. For example, a key source analysis was encouraged to be undertaken for the first time at COP8 in 2002 (Decision 17/CP.8), so any reports submitted beforehand should not be assessed with a lower score, due to a lack of key source analysis.

*2.2.1.2. Indicator weighting.* Based on the list of assessment categories and criteria, a questionnaire survey was conducted with GHG inventory experts. Survey results (n = 10) were used to identify the importance of the assessment categories and produce an expert generated list of indicator weights (Table 3). With the questionnaire survey, experts were asked to distribute a total score of 100 for each of the four assessment categories, depending on how important they considered the assessment category in the overall GHG inventory capacity of a developing county. The average score of each assessment category was then used to calculate the indicator weighting using the following formula.

$$\text{Indicator weighting in category (1, 2, 3 or 4)} = \text{Average category score/the number of criteria/the number of indicators} \quad (2)$$

The capacity value of a country was determined by adding up the weighted indicator scores across the four assessment categories following the below equation. The highest possible value that could be obtained by a country was 111, the lowest possible score was −11.

$$\text{Overall capacity value} = \Sigma(\text{indicator score} * \text{indicator weighting of category 1, 2, 3 and 4}) \quad (3)$$

We then divided these overall values in an equal distribution into four overarching description of capacity status: Limited, Intermediate, Good and Very good (Table 4). Any change in this capacity status was then assessed for a country over time by comparing the status of NC1, NC2 and BUR1, if applicable.

#### 2.2.2. The support value

A separate calculation was made for determining the value of international support, both bilateral and multilateral, provided to each developing country with respect to GHG inventory development. The support value was represented by the amount of USD in millions spent on GHG inventory-related capacity building projects in each developing country. For bilateral support, projects in the OECD Rio Marker were chosen as relevant, if a project title or project description contained any of the following key words: "greenhouse gas inventories"; "inventory"; "monitoring"; "reporting"; "MRV"; "emission" and "carbon". The data of Germany; Japan; Norway; UK and the USA as a contributor country were used; because these five countries were the major donors during the first-start finance period (2010–2012) of climate finance under the UNFCCC (Nakhooda et al., 2013). For multilateral support; projects in the UNFCCC database under capacity building activities with priority area listed as GHG inventories was selected. Both bilateral and multilateral support were then combined to estimate the support value for each developing country. We then divided these overall values of support into overarching description of support levels: None; Low; Medium and High (Table 5).

## 3. Results

### 3.1. Status and changes in GHG inventory development capacities

This study highlights variations in the status of Asian developing countries' (n = 37) capacity to develop a GHG inventory and how capacity changed over time. Table 6 presents the changes of capacity status from NC1, NC2 then BUR1, if submitted. Fig. 1 shows the spatial distribution of capacity status for these countries at the time that they submitted NC1 and NC2.

Of the 37 countries assessed in Asia, 20 had limited to intermediate capacity and 17 had good to very good capacity at the time of submitting NC1. About half of the countries in the first group (n = 11)

**Table 2**
Overview of indicator characteristics and score.

| Indicator | Characteristics (score) |
|---|---|
| Promptness of application for GEF funding by a country for NC1, NC2 and BUR1, if submitted* | After a call for application and before the relevant COP decision, or without depending on GEF funding (1.5); Within 2 years after the relevant COP decision (1); Within 2–4 years after the relevant COP decision (0.5); More than 4 years after the relevant COP decision (0) |
| Existence of a single overall coordination body | Existence with clear role (1.5); Existence without clear role (1); Acknowledgement of a lack of existence (0.5); No data (0) |
| Exitence of national formal/legal arrangements for developing a GHG inventory | Existence with clear role (1.5); Existence without clear role (1); Acknowledgement of a lack of existence (0.5); No data (0) |
| Existence of a continuous improvement plan | Existence with clear role (1.5); Existence without clear role (1); Acknowledgement of a lack of existence (0.5); No data (0) |
| Existence of arrangements/systems for Involvement of stakeholders | Existence with clear role (1.5); Existence without clear role (1); Acknowledgement of a lack of existence (0.5); No data (0) |
| Existence of domestic financial resources available for sustaining a team of experts | Existence at the level sufficient to sustain a team of experts (1.5); Existence at the level not sufficient to sustain a team of experts (1); Acknowledgement of no domestic fund available (0.5); No data (0) |
| Number of authors/contributors to IPCC guidelines and guidance | > 10 (1.5); > 2 (1); =1 (0.5); =0 (0) |
| Researchers in R & D (per million people) | > 1500 (1.5); > 1000 (1); > 500 (0.5); > 0 or no data (0) |
| Overall Statistical Capacity Indicator | > 80 (1.5); > 60 (1); > 40 (0.5); > 0 or no data (0) |
| Level of information provided for methodologies in each sector | Methodologies are clearly mentioned for all reported categories (1); Methodologies are clearly mentioned for some of reported categories (0.5); No data (-0.5); N/A (0) |
| Existence of QA/QC plan/arrangements | Existence of a plan/arrangements (1.5); QA/QC mentioned or aknowledgment of lack of a plan/arrangements (1); No data (-0.5); N/A (0) |
| Use of tier 2 or 3 methods in each sector | All reported categories (2); Some of reported categories (1); None (0.5); N/A (0) |
| Application of uncertainty assessment | Application to all or some of reported categories (1.5); Acknowledgement of lack of assessment (1); No data (-0.5); N/A (0) |
| Comprehensiveness of reporting in each sector | All required categories are reported (1); Some of required categories are reported (0.5); No data (-0.5); N/A (0) |
| Use of appropriate/latest guidelines | Use of appropriate/latest guidelines for all sectors (1); Use of appropriate/latest guidelines for some sectors (0.5); No data (-0.5) |
| Application of key category analaysis | Key category analysis conducted quantitatively (1); Key category analysis mentioned or acknowledgement of lack of analysis (0.5); No data (-0.5); N/A (0) |
| Timeseries inventories | Reported (1); Acknowledgement of lack of reporting (0.5); No data (-0.5); N/A (0) |
| Timeseries consistency | Consistent (Recalculated) (1); Acknowledgement of lack of consistency (0.5); No data (-0.5); N/A (0) |

* Countries, which did not use the GEF funding but used own resources, were scored at 1.5 (UNFCCC, 2015c and UNFCCC, 2015d).

**Table 3**
The average score of each assessment category (1, 2, 3 and 4) used for calculating the indicator weighting.

| Assessment category | Score |
|---|---|
| 1. International engagement | 12.0 |
| 2. Institutional capacity | 36.5 |
| 3. Technical capacity available | 26.1 |
| 4. Technical capacity applied | 25.4 |

**Table 4**
The overarching description of capacity status based on the capacity value.

| Capacity status | Capacity value |
|---|---|
| Limited | > 0 |
| Intermediate | > 20 |
| Good | > 40 |
| Very good | > 60 |

**Table 5**
The overarching description of support levels based on the support value.

| Support level | Support value (Million USD) |
|---|---|
| None | 0 |
| Low | > 0 |
| Medium | > 5 |
| High | > 10 |

**Table 6**
Number of countries at different capacity status comparing at the time of NC1 and NC2 and NC2 and BUR1.

| | | Capacity status (NC2) | | | | |
|---|---|---|---|---|---|---|
| | | Limited | Intermediate | Good | Very good | Sum |
| Capacity status (NC1) | Limited | 2 | 3 | 2 | 0 | 7 |
| | Intermediate | 1 | 5 | 5 | 2 | 13 |
| | Good | 0 | 0 | 5 | 5 | 10 |
| | Very good | 0 | 0 | 1 | 6 | 7 |
| | Sum | 3 | 8 | 13 | 13 | 37 |

| | | Capacity status (BUR1) | | | | |
|---|---|---|---|---|---|---|
| | | Limited | Intermediate | Good | Very good | Sum |
| Capacity status (NC2) | Limited | 0 | 0 | 0 | 0 | 0 |
| | Intermediate | 0 | 0 | 0 | 0 | 0 |
| | Good | 0 | 0 | 1 | 0 | 1 |
| | Very good | 0 | 0 | 0 | 6 | 6 |
| | Sum | 0 | 0 | 1 | 6 | 7 |

continued to have low capacity levels when they submitted NC2, indicating they had little capacity development between the two GHG inventory submission years. For the purpose of our discussion here, we call this group of countries the “low improvement group”. In contrast, the other half (n = 9) showed increases in capacity, referenced here as the “improvement growth group”. In Fig. 2, the capacity values of these different country groups are presented with respect to each of the four assessment categories. In contrast to the low improvement group, the capacity development of the improvement growth group was largely due to increases in institutional capacity (category 2) and actual technical capacity applied to GHG inventories (category 4). Changes in the other two categories, international engagement (category 1) and technical capacities available in a country (category 3), were not found to be significant in any change to the overall GHG inventory development capacity.

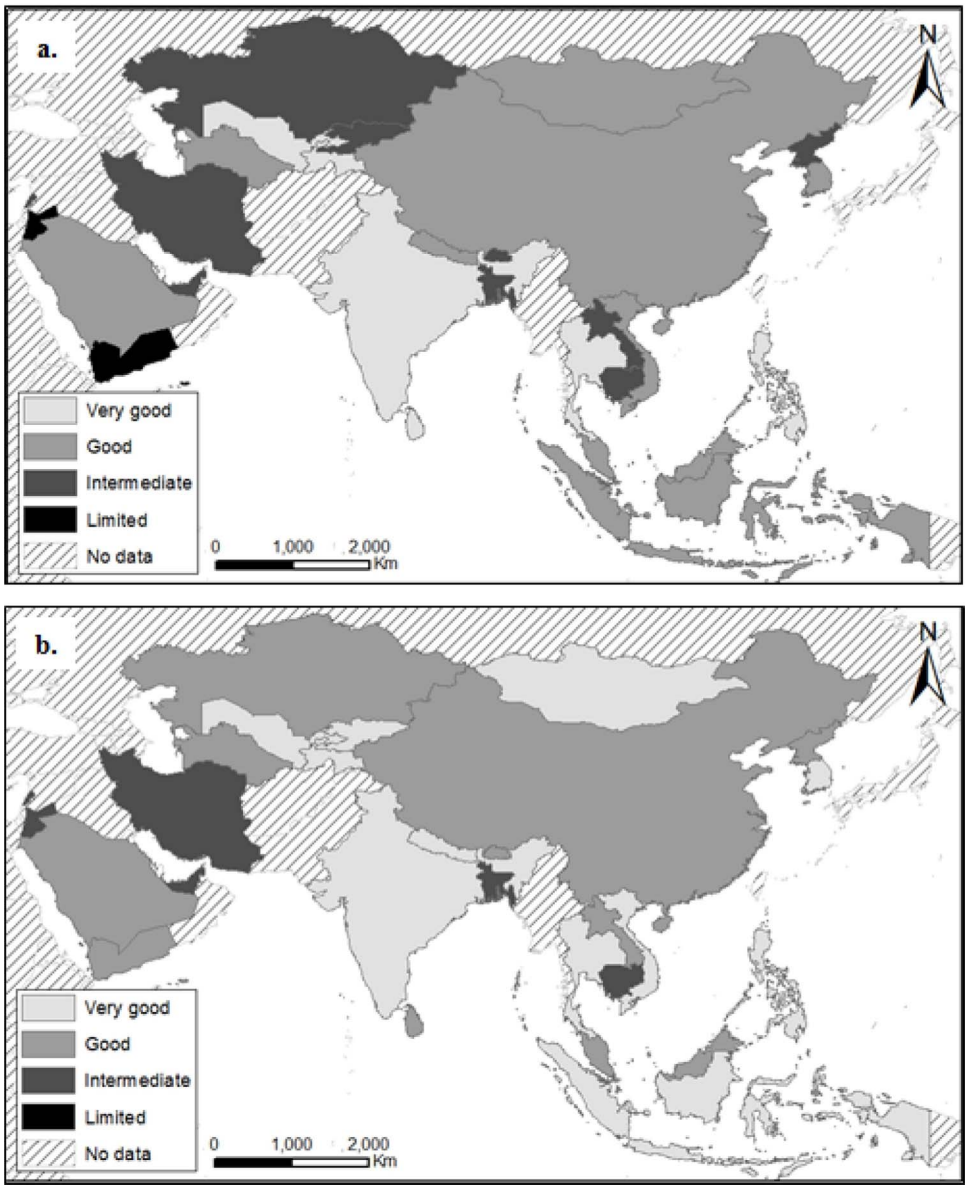


**Fig. 1.** Spatial distribution of capacity status for 37 Asian developing countries at the time of NC1 (a) and NC2 (b).

All 17 countries which had good to very good capacity for NC1 were observed to then have high capacity for NC2. We divide them into two groups: the "top runner" group and the "high stability group". The top runner group included all of the seven countries which submitted BUR1, and of these, six had very good capacity at the time of submitting BUR1. These countries can be perceived as top runners in the region with established capacities. The "high stability group" (n = 10) also consistently had good to very good capacity across GHG inventories. Half of them were at the stage of very good capacity at the time of submitting NC2. However, none of them submitted a BUR1 (as of September 2016). The countries in both of the top runners and the high stability group showed high capacity with respect to all categories (Fig. 2). The top runners especially demonstrated high technical capacities available in a country compared to other groups.

### 3.2. Availability and scale of support

Comparison between changes in capacity status by country groups and support levels are presented in Table 7. Around half of the countries covered in this study did not receive support in the first (2002–2011, n = 15) and second (2012–2014, n = 16) periods. The other half had support at different levels. Eight and ten out of the eleven countries in the low improvement group received no to little support for the first and second periods, respectively, despite their lack of capacity. Only two of them did receive high support for the first period. The improvement growth group (n = 9) did not receive much support in these years, except for a few which had medium support. The majority of countries in the high stability group (n = 10) received no to little support, although two were highly supported in the second period. The top runners received higher levels of support compared to other groups. Four out of seven top runner countries had high support in the first period, and three received medium to high support in the second period.

## 4. Discussion

### 4.1. Varying capacity status and changes

Our analysis found varying capacity for producing a GHG inventory in 37 Asian developing countries and variations in changes of that capacity. Seven countries, including India, Indonesia, the Republic of Korea and Singapore, were found to be equipped with established

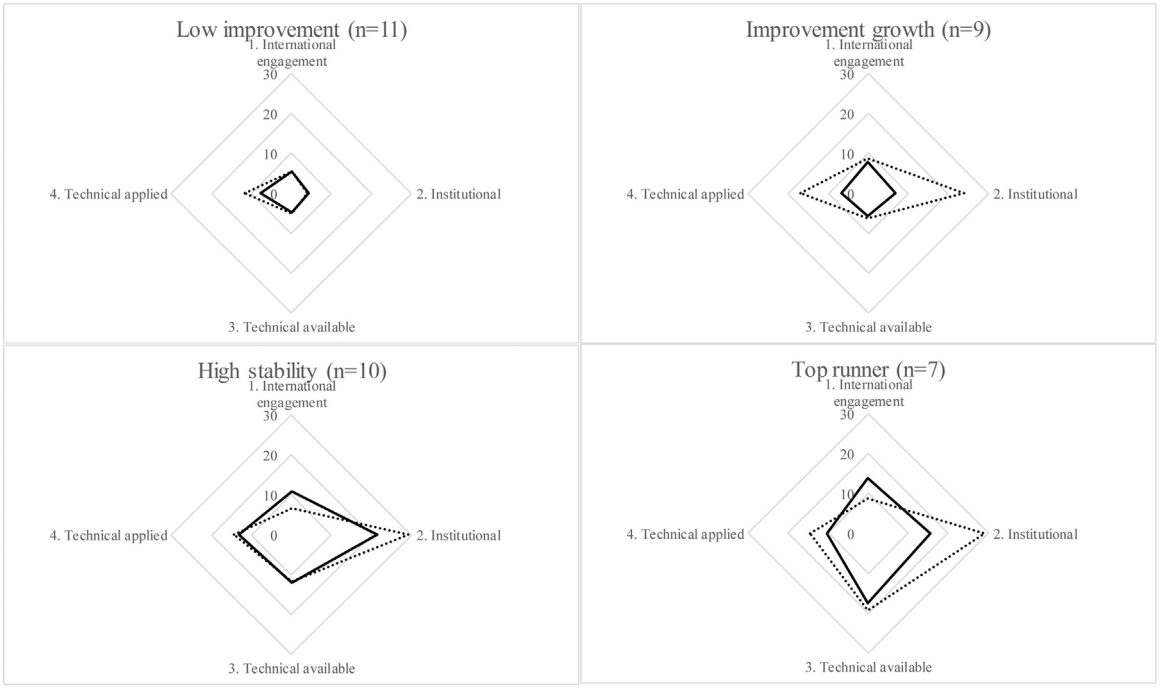


**Fig. 2.** Capacity values for the four assessment categories of NC1 (lines) and NC2 (dot lines) by different country groups.

**Table 7**
Support provided for different country groups for 2002–2011 and 2012–2014.

| | | Support level 2002–2011 | | | | |
|---|---|---|---|---|---|---|
| | | None | Low | Medium | High | Sum |
| Country group | Low improvement | 6 | 2 | 1 | 2 | 11 |
| | Improvement growth | 3 | 4 | 2 | 0 | 9 |
| | High stability | 4 | 4 | 1 | 1 | 10 |
| | Top runners | 2 | 1 | 0 | 4 | 7 |
| | Sum | 15 | 11 | 4 | 7 | 37 |
| | | Support level 2012–2014 | | | | |
| | | None | Low | Medium | High | Sum |
| Country group | Low improvement | 5 | 5 | 1 | 0 | 11 |
| | Improvement growth | 3 | 5 | 1 | 0 | 9 |
| | High stability | 6 | 2 | 0 | 2 | 10 |
| | Top runners | 2 | 2 | 1 | 2 | 7 |
| | Sum | 16 | 14 | 3 | 4 | 37 |

capacities for preparing GHG inventories on a regular basis. These countries can be perceived as being closest to fully implement the PA's transparency framework and do not require much additional efforts for capacity building. Another 19 countries had a relatively high capacity when they submitted inventories as part of NC2. These countries included both those which had a relatively high capacity at the time of their first GHG inventory as part of NC1 (e.g. China, Nepal, Philippines, Tajikistan) and the countries whose capacity sufficiently improved (e.g. Kyrgyzstan, Laos, Samoa, Yemen). The remaining 11 Asian countries in our analysis did not improve their capacity and remained as low capacity across GHG inventories. Further, there exist 18 more Asian developing countries that did not submit any reports or beyond their NC1, and thus were not subject to this study. We believe that these 29 Asian developing countries are with the highest priority for capacity building towards the implementation of the PA's transparency framework.

The analysis showed that those Asian developing countries which improved their institutional capacity and technical capacity specific to GHG inventories, also improved their overall GHG inventory capacity between the submission years of NC1 and NC2. However, when it comes to the more frequent and regular reporting of BURs, it appears that what matters for the overall GHG inventory capacity is basic technical capacity available in a country (e.g. statistics and the scientific expertise) to support the GHG inventory development process. This indicates that improvement in basic technical capacity in countries will be essential for enabling their implementation of the PA's transparency framework.

### 4.2. The gaps in international support

We found that international support was not sufficiently provided to the countries with the most capacity building needs. Instead, there was a trend that support was provided more to the countries that already had advanced capacities at an earlier stage of inventory development in Asia. Other than the fact that provision of support by donor countries is closely linked with diplomatic policy of each country, one possible reason for why high capacity countries exhibited receiving a higher level of support is that donors generally pay more attention to countries with larger GHG emissions. This is because countries with larger GHG emissions are considered to have higher potential to reduce emissions, therefore supporting these countries would have larger impacts on global climate. Of the 11 Asian developing countries with limited capacity improvement, four were Small Island Developing States (SIDSs) and two were Least Developed Countries (LDCs) with modest GHG emissions (UNESCO, 2016; UNFCCC, 2016d). We believe these trends in the allocation of support call for reconsideration, at least, for two reasons.

Firstly, the PA's transparency framework, in principle, applies to all Parties, although flexibility will be built in for developing countries with limited capacity. How exactly flexibility should be formed in practice depends on negotiations that follow, but this raises the expectation that all Parties should be able to participate in and fully implement the transparency framework, if not now, then later in the future (UNFCCC, 2016e). Parties agreed that the PA's transparency framework will be enhanced from what the current arrangements require. Therefore, low capacity countries need more international support, if they are to ultimately participate in and fully implement the

transparency framework under the PA. Secondly, for donors, it should be reminded that some of those countries with smaller emissions now could be later larger emitters as their economy grows. Without taking into this account, deciding on where to investment would not be acceptable even from a global climate's point of view.

The study revealed that support was scarce in many of the countries whose capacity was improved across GHG inventories. In other two countries, support level was high, although their capacity improvement was limited. These facts suggest the need for further research to investigate in more detail the effectiveness of capacity building approaches. For instance, it is reported that many of existing capacity building approaches have focused on improving individual capacity by means of technical advice and training and have not deeply addressed the needs for capacity building of national institutions (Dagnet et al., 2015). However, one could also argue that improvements in institutional capacity largely requires internal decision-making and coordination, thus support from the international community may not be an important factor. We need to investigate further what approaches, both domestically and internationally supported, have been effective in building necessary capacities for regular GHG inventory reporting.

### 4.3. Policy recommendations

Parties agreed at COP21 on the urgent need to enhance capacity building, and established a new Capacity-building Initiative for Transparency (CBIT) (UNFCCC, 2015a,b). The purpose of the CBIT is three-fold: strengthening national institutions; providing relevant tools, training and assistance; assisting in the improvement of transparency over time (UNFCCC, 2015a,b). The CBIT and other international efforts and activities would need to focus on the improvement of capacity in countries where its capacity was barely improved and only limited international support was provided. To implement this, the international community needs to conduct an assessment of capacity in each developing country for implementing the PA's transparency framework and monitor its implementation. Using the existing reporting scheme under the UNFCCC, namely BURs, would be an option to minimize the incremental costs involved in collecting information on the capacity status and supporting the needs of developing countries. However, as not all developing countries have been able to submit their BURs, there is a need for other assessment channels (Umemiya et al., 2016). The cost for collecting and assessing information can be reduced by utilizing existing networks among countries and experts, which were created through previous capacity building activities and initiatives (GEF, 2016). Those networks can also be used to enhance the understanding of what capacity building approaches have been effective in a given context, especially with respect to their long-term impacts on developing country capacities (Umemiya et al., 2016). To appropriately allocate resources, it is essential to properly monitor the state of capacity and the effectiveness of capacity building approaches.

As indicated earlier, capacity building efforts will be increasingly necessary for strengthening the fundamental technical capacity in a country, such as the ability to collect and manage statistics, as well as foster and maintain the scientific community to support GHG inventory development. The current focus of the CBIT, as mentioned above, does not appear to take into consideration this need for improvement of basic technical capacity (GEF, 2016). However, building the basic technical capacity is not only an essential foundation for regular reporting of quality GHG inventories, but also a necessity for sound environmental and development policy formulation. Therefore, we recommend improvements in basic technical capacity, thereby helping developing countries, particularly those with limited capacity, to meet with international reporting requirements and form and implement NDCs in line with its national priorities.

By its nature, capacity building for strengthening the basic technical capacity of a country requires more resources in the longer term compared to, for instance, increasing the technical understanding on GHG inventories. To move in this direction, we believe that the co-benefits of national systems for the transparency framework in other fields have to be addressed and promoted, e.g. public health, air pollution, forest conservation, waste management. Firstly, this could motivate developing countries to enhance and sustain capacity, because these non-climate issues are likely to be of higher priority in their national development plans. Secondly, co-benefits could be a good reason for donors to devote more international support, since such support could bring benefits to multiple environmental and development issues.

### 4.4. Limitation of data and methodology

In this study, we used information expressed in submitted communications, particularly the section of these documents devoted to reporting a country's GHG inventory. These reports were the primary source of data for scoring indicators. When a lack of information in these reports was noted, corresponding indicators were given lower scores. However, because there is no common reporting format for NCs and BURs, it was up to countries to decide what to report and in how much detail. Therefore, it is possible that even if a country had institutional arrangements, this study gave it a low score, because there was little information available in the submitted reports to the UNFCCC. Future data collection efforts would be useful to account for this potentially missing information. In addition, data for international support were aggregated at the country level based on information from related capacity building projects. As indicated above, it is not only the quantity of support but also the quality of support that needs to be considered if we are to fully assess the appropriateness of available support in contrast to capacity building needs. This study used only the aggregated quantitative data, as the purpose of this study was to analyze the general correspondence of changes in capacity and the scale of support. It would be valuable for future research to cover the qualitative information of respective capacity building projects.

## 5. Conclusions

Among the 37 Asian developing countries assessed in this study, 20 countries had low capacity at the time of submitting GHG inventories as part of NC1. Among them, 11 countries remained as low capacity at the time of submitting NC2, while 9 improved their capacity. Seventeen Asian developing countries had relatively high capacity from the time of submitting NC1. They continued to exhibit high capacity for GHG inventories in NC2. Seven of them submitted quality GHG inventories as part of BUR1, indicating established capacity as the top runners in the region. Basic technical capacity, such as the ability to collect, manage and access to national statistics as well as to foster and maintain the scientific expertise to support GHG inventory process, in accordance with the IPCC guidance and guidelines, is identified as a key necessity for countries to respond to the more frequent and regular reporting in the PA's enhanced transparency framework. Increasing basic technical capacity is also beneficial for countries to form and implement NDCs and other economic and development policies.

In Asia, international support from developed countries was not adequately allocated to the countries with the most capacity building needs. In order to ensure that all Parties can participate in the PA's transparency framework, there is need for reconsidering how to allocate international support. Low capacity countries need more support, especially for strengthening basic technical capacity.

Enhancement of basic technical capacity in Asian developing countries with limited capacity improvement and support is essential in future capacity building efforts. Otherwise, only a handful of countries will be able to meet with the PA's enhanced transparency requirements, undermining the core objective of the PA and its transparency framework in which all countries are expected to take part.

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## References

Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention (CGE), 2016. Handbook on Building Sustainable National Greenhouse Gas Inventory Management Systems. . Available at: http://unfccc.int/national_reports/non-annex_i_natcom/training_material/methodological_documents/items/349.php (Accessed on 06 October, 2016).

Dagnet, Y., Northrop, E., Tirpak, D., 2015. How to Strengthen the Institutional Architecture for Capacity Building to Support the Post-2020 Climate Regime. World Resources Institute, Washington, DC (Working Paper).

Damasa, T., Elsayed, S., 2013. From the GHG Measurement Frontline: A Synthesis of Non-Annex I Country National Inventory System Practices and Experiences. Working Paper. World Resources Institute, Washington, DC. Available at: http://www.wri.org/publication/non-annexone-country-national-inventory-system-practices-experiences (Accessed on 06 October, 2016).

Global Environment Facility (GEF), 2016. Programming Directions for the Capacity-building Initiative for Transparency. Available at: https://beta.thegef.org/sites/default/files/council-meeting-documents/EN_GEF.C.50.06_CBIT_Programming_Directions_0_0.pdf (Accessed on 06 September, 2016).

Intergovernmental Panel on Climate Change (IPCC), et al., 1997. In: Houghton, J.T. (Ed.), Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC/OECD/IEA, Geneva, Switzerland.

IPCC, 2000. In: Emmanuel, S., Buendia, L., Hoppaus, R., Meijer, J., Miwa, K., Tanabe, K., Takada, K. (Eds.), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Institute for Global Environmental Strategies (IGES) for the IPCC, Hayama, Japan (IGES for the IPCC, Hayama, Japan).

IPCC, 2003. Good practice guidance for land use. In: Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., Wagner, F. (Eds.), Land-Use Change and Forestry. IGES for the IPCC, Hayama, Japan.

IPCC, 2006. In: Eggleston, H., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.), 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IGES for the IPCC, Hayama, Japan.

IPCC, 2013a. In: Hiraishi, T., Krug, T., Tanabe, K., Slivastava, N., Jamsranjav, B., Fukuda, M., Troxler, T. (Eds.), Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. IGES for the IPCC, Hayama, Japan.

IPCC, 2013b. In: Hiraishi, T., Krug, T., Tanabe, K., Slivastava, N., Jamsranjav, B., Fukuda, M., Troxler, T. (Eds.), 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. IGES for the IPCC, Hayama, Japan.

National Communication Support Unit (NCSP), 2005. National Communication Support Unit Handbook: Managing the National Greenhouse Gas Inventory Process. Available at: http://ncsp.undp.org/sites/default/files/461.pdf (Accessed on 06 October, 2016).

National Institute for Environmental Studies (NIES), 2006. In: Umemiya, C. (Ed.), Greenhouse Gas Inventory, Development in Asia. CGER/NIES, Tsukuba.

Nakhooda, S., Fransen, T., Kuramochi, T., Caravani, A., Prizzon, A., Shimizu, N., Welham, B., 2013. Mobilising International Climate Finance: Lessons from the Fast-Start Finance Period.

Organisation for Economic Co-operation and Development (OECD), 2016. Aid Activities Targeting Global Environmental Objectives. Available at: http://stats.oecd.org/Index.aspx?DataSetCode=RIOMARKERS (Accessed on 10 October 2016).

Romijn, E., Herold, M., Kooistra, L., Murdiyarso, D., Verchot, L., 2012. Assessing capacities of non-Annex I countries for national forest monitoring in the context of REDD +. Environ. Sci. Policy 19–20, 33–48.

UN, 1992. United Nations Framework Convention on Climate Change. Available at: http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf (Accessed on 06 October, 2018).

UN, 2014. United Nations Regional Groups of Member States. Available at: http://www.un.org/depts/DGACM/RegionalGroups.shtml (Accessed on 06 October, 2016).

UN, 2015. Paris Agreement. Available at: http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf (Accessed on 06 October, 2018).

UNESCO, 2016. UNESCO List of Small Islands Developing States (SIDS). Available at: http://www.unesco.org/new/en/natural-sciences/priority-areas/sids/about-unesco-and-sids/sids-list/ (Accessed on 06 October, 2018).

UNFCCC, 1999. Guidelines for the Preparation of National Communications by Parties Included in Annex I to the Convention, Part I: UNFCCC Reporting Guidelines on Annual Inventories. FCCC/CP/1999/7.

UNFCCC, 2002. 17/CP.8. FCCC/CP/2002/7/Add.2.

UNFCCC, 2003. National Communications from Parties Not Included in Annex I to the Convention. Provision of Financial and Technical Support. Information on Activities by the Global Environmental Facilities. Note by the Secretariat. FCCC/SBI/2003/INF.15.

UNFCCC, 2011. 2/CP.17. FCCC/CP/2011/9/Add.1.

UNFCCC, 2012. Information on Financial Support Provided by the Global Environment Facility for the Preparation of National Communications from Parties Not Included in Annex I to the Convention. FCCC/SBI/2012/INF.7.

UNFCCC, 2013a. 24/CP.19. FCCC/CP/2013/10/Add.3.

UNFCCC, 2013b. Toolkit for Non-Annex I Parties on Establishing and Maintaining Institutional Arrangements for Preparing National Communications and Biennial Update Reports. UNFCCC Secretariat, Bonn.

UNFCCC, 2015a. 1/CP.21.FCCC/CP/2015/10/Add.1.

UNFCCC, 2015b. Information Provided by the Global Environment Facility on Its Activities Relating to the Preparation of National Communications and Biennial Update Reports. Note by the Secretariat. FCCC/SBI/2015/INF.15.

UNFCCC, 2015c. Summary Report on the Technical Analysis of the First Biennial Update Report of the Republic of Korea Submitted on 29 December 2014. FCCC/SBI/ICA/2015/TASR.1/KOR.

UNFCCC, 2015d. Summary Report on the Technical Analysis of the First Biennial Update Report of Singapore Submitted on 8 December 2014. FCCC/SBI/ICA/2015/TASR.1/SGP.

UNFCCC, 2016a. Submitted Biennial Update Reports (BURs) from Non-Annex I Parties. . Available at: http://unfccc.int/national_reports/non-annex_i_natcom/reporting_on_climate_change/items/8722.php (Accessed on 06 October, 2016).

UNFCCC, 2016b. Submitted National Communications from Non-Annex I Parties. . Available at: http://unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php (Accessed on 06 October, 2016).

UNFCCC, 2016c. UNFCCC Capacity Building Portal. Available at: http://unfccc.int/capacitybuilding/core/activities.html (Accessed on 06 October, 2016).

UNFCCC, 2016d. LDC Country Information. Available at: http://unfccc.int/cooperation_and_support/ldc/items/3097.php (Accessed on 06 October, 2016).

UNFCCC, 2016e. Ad-hoc Working Group on the Paris Agreement (APA). Agenda Item 5?Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement. Informal Note by the Co-Facilitators. Available at: http://unfccc.int/files/meetings/marrakech_nov_2016/in-session/application/pdf/apa_item_5_informal_note_v2.pdf (Accessed on 26 November, 2016).

US-EPA, 2016. National System Templates: Building Sustainable National Inventory Management Systems. Available at: http://www.epa.gov/climatechange/Downloads/EPAactivities/Complete-Template-Workbook.doc (Accessed on 06 October, 2016).

Umemiya, C., Goodwin, J., Gillenwater, M., 2016. How Did Intended Nationally Determined Contributions (INDCs) Address Capacity Building? Implications For Future Communication By Parties On Capacity Building Under The Paris Agreement. Available at: http://pub.iges.or.jp/modules/envirolib/upload/6691/attach/IGES_Coalition_INDCs_fin2.pdf (Accessed on 06 October, 2006).

Umemiya, C., 2006. Improving GHG inventories by regional information exchange: a report from Asia. Carbon Balance Manage. 1, 9.

World Bank Group (WB), 2016a. Researchers in R & D (per Million People). Available at: http://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6?view=chart (Accessed on 18 October, 2006).

World Bank Group, 2016b. Statistical Capacity Indicator Dashboard. Available at: http://datatopics.worldbank.org/statisticalcapacity/SCIdashboard.aspx (Accessed on 18 October, 2006).