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Discussion Paper on the Workplan of the North-East Asia Clean Air Partnership (NEACAP)

1. The NEACAP Terms of Reference adopted at the 22nd Senior Officials Meeting of NEASPEC in 2018 defines the partnership objectives as follows to ensure the protection of the environment and human health from air pollution in North-East Asia.

   a. To promote environmental cooperation, including its science, policy, and technical aspects, on atmospheric air protection in the transboundary context in the subregion;
   b. To enhance and further develop information and experience exchange in national and transboundary air pollution matters;
   c. To act as the key voluntary framework in addressing transboundary air pollution issues in North-East Asia;
   d. To contribute, as appropriate, to the development of relevant national and subregional policies addressing air pollution based on regional and national scientific research;
   e. To promote knowledge on environmental and human health aspects of air pollution in the North-East Asian subregion.

2. In support of obtaining the goals, NEACAP is expected to exchange relevant information and data, coordinate with relevant mechanisms and synthesize their results, and propose potential technical and policy measures to tackle air pollution. These core programmes will be undertaken through (a) regular meetings and ad hoc meetings; (b) annual or biennial subregional review reports; (c) seminars, workshops and trainings; and (d) research projects.

3. In this connection, this discussion paper elaborates the approaches and modalities of proposed work under the core programmes as follows.
   - Common information basis: Emission Inventory

- Consensual knowledge through interdisciplinary studies and open platform: Scientific Assessment Report
- Policy goals and measures: Integrated Assessment Modeling
- Policy experiences and technology information: Policy Dialogue

I. Building common information basis: Emission Inventory

4. The expected work of NEACAP requires a common information basis of air pollution emissions and related factors to support scientific assessment, policy dialogue, and technical cooperation. A key information basis is the Emission Inventory that provides decision makers with the information of total air pollutants emitted each year by each activity sector (anthropogenic and natural) and allows monitoring emission reduction efforts and trends for a given sector and country.

5. In particular, an Emission Inventory could support (a) quantifying the major activity sectors or those that influence local and regional air pollution patterns, (b) following emission trends over time and assessing the impact of control strategies, (c) providing information for raising awareness of the general public, (d) checking compliance with ceiling objectives set by local and national policies, (e) comparing and assessing the impact of different emission reduction options, and (f) providing inputs to chemistry-transport models. In this regard, the Convention on Long-range Transboundary Air Pollution (CLRTAP) operates the Centre on Emission Inventories and Projections (CEIP), hosted at the Environment Agency Austria, to compile emission data, carry out annual quality control of inventories, and develop emission data sets for modelers. The work of CEIP is supported by the Task Force on Emission Inventories and Projections (TFEIP) that supports Parties in the reporting of air pollutant emissions and projections data, provides a technical forum and expert network to harmonize emission factors, and establishes methodologies for the evaluation of emission data and projections.

6. In North-East Asia, multiple regional emission inventories, notably, the Comprehensive Regional Emissions inventory for Atmospheric Transport Experiments (CREATE), Regional Emission inventory in Asia (REAS) 2.1 and MIX, cover the geographical domain of NEACAP members (Table 1). MIX combines REAS and the best available national inventories of MEIC (Mainland China), JEI-DB (Japan), and CAPSS (Republic of Korea) (Figure 1) and includes other countries in Asia. CREATE serves as the emission inventory for the source-receptor relationship modelling under Long-Range Transboundary Air Pollutants in North-East Asia (LTP).[1]

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[1] Meng Le, et.al., 2017. MIX: a mosaic Asian Anthropogenic emission inventory under the international collaboration framework of the MICS-Asia and HTAP, Atmospheric Chemistry and Physics, 17, 935-963.

Figure 1. Overview of emission inventories

GLOBAL INVENTORY

- EDGAR (Emission Database for Global Atmospheric Research) – HTAP (Hemispheric Transport of Air Pollution) Emission Inventory: MIX, GAINS, EMEP, UNFCCC

REGIONAL INVENTORY in East Asia

- Greenhouse Gas-Air Pollution Interactions and Synergies (GAINS) Asia
- MIX Inventory: REAS, MEIC, CAPSS, ANL-India, PKU-NH_3
- KORUS-AQ Inventory: CREATE, MEIC, CAPSS, ACAP, SEAC4RS
- Regional Emission Inventory in Asia (REAS)
- Comprehensive Regional Emissions inventory for Atmospheric Transport Experiments (CREATE)
- Intercontinental Chemical Transport Experiment-Phase B (INTEX-B)

NATIONAL INVENTORY

- China Multi-resolution Emission Inventory (MEIC)
- Japan Auto-Oil Program Emission Inventory-Data Base (JEI-DB)
- ROK Clean Air Policy Support System (CAPSS)
- Annual overview of air emissions from major settlements and federal subject of the Russian Federation (by SRI Atmosphere)
- Annual compilation of air pollutants (by Mongolia National Agency for Meteorology and Environmental Monitoring)

Table 1. Overview of regional emission inventories

	Geographical Scope	Species	Year	Spatial/Temporal Resolution
MIX	East Asia, South Asia and Central Asia and Asian Russia	SO_2, NO_x, CO, NMVOC, NH_3, BC, OC, PM2.5, PM10, and CO_2	2008, 2010	0.25° × 0.25° Monthly
KORUS-AQ	East Asia and South Asia	CO_2, NO_x, PM10, PM2.5, SO_2, VOC, NH_3, CO	2016	0.1° × 0.1° Monthly
CREATE	East Asia, South Asia and Asian Russia	CO_2, NO_x, PM10, PM2.5, SO_2, VOC, NH_3, CO, CH_4, N_2O, Mercury	2010, 2015	0.1° × 0.1° Monthly
REAS 2.1	East Asia, South Asia and Central Asia and Asian Russia	SO_2, NO_x, CO, NMVOCs, NH_3, PM10, PM2.5, BC, OC, CH_4, N_2O, CO_2	2000-2008	0.25° × 0.25° Monthly
INTEX-B	East Asia and South Asia	SO_2, NO_x, CO, NMVOC, PM10, PM2.5, BC, OC, CH_4, NH_3	2006	0.5° × 0.5° Monthly

7. They are also gridded emission inventories that describe the geographical distribution of emissions, present maps of emissions, facilitate communication with the public, and feed chemistry-transport models. However, there are significant challenges in the timely update as shown in Table 1, as well as uncertainty originating from inaccurate activity data, emission factors depending on location or emission sources, and temporal/spatial allocation of total emissions. This uncertainty needs to be well addressed to enable more accurate scientific assessment and policy development.

8. Furthermore, supporting policy-oriented studies requires a more comprehensive set of data that includes not only the emission data of each pollutant, but also socio-economic parameters including indicators of economy, technology, energy, etc. The assessments and consultations towards NEACAP also indicated the need for developing and improving a subregional inventory that provides accurate, complete, and up-to-date data with a common methodology for comparability between national data. Thus, the TOR of NEACAP includes the plan of "subregional emission inventory development and maintenance" by coordinating with relevant mechanisms and synthesizing their results.

9. Developing the NEACAP emission inventory would take into account the following basic properties (or criteria):

   - **Comparability**: Inventories should be built up following the same methodological approach regarding the sectoral distribution, the variables used to describe the activity, and the emission factors.
   - **Transparency:** Inventories should be correctly documented with data and assumptions chosen and are likely to be challenged by national or international experts.
   - **Accuracy and Completeness:** Gaps in estimations should be avoided, all agreed targeted pollutants and sectors should be considered, and emissions provided with the best estimates.

10. In this regard, the CLRTAP Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) Emission Inventory guidelines[2] provide a reliable methodological reference for NEACAP. The first step for the data collection for the UNECE/EMEP emission database (WebDab) is the official submissions by the Parties to the LRTAP Convention. Parties report their emission inventories to the LRTAP Convention as sectoral emissions (NFR14) and National Total emissions according to the UNECE guidelines for reporting emissions and projections data under the Convention. The second step is to aggregate the sector data to 13 National gridded data of emissions by source category (GNFR sectors). The third step is plausibility checks of all reported data with the comparison of time series data, ratio to population and GDP, sectoral distribution, etc. The final step is the gap-filling or change of the inventory. Gap-filling or replacement of data is applied if (1) no data are submitted by a Party, (2) the reporting is not complete, (3) the data are erroneous, or (4) no reported data due to no reporting obligation.[3]

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[2] EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016: Technical guidance to prepare national emission inventories; and Methodologies applied to the CEIP GNFR gap-filling 2018, Technical report CEIP 01/2018.

[3] UNECE, 2015. Guidelines for reporting emissions and projections data under the Convention on Long-range Transboundary Air Pollution.

11. Thus, the first SPC meeting is proposed to discuss the direction of the NEACAP Emission Inventory as follows.

(1) Overall framework of the inventory including geographical scope, target pollutants and socioeconomic parameters, methodology for data collection, inventory structure, baseline year and update frequency, resolutions, validation and use of the inventory, etc.
(2) Coordination with the existing regional and national inventories
(3) Operation of the Working Group on Emission Inventory (WGEI) including the composition of members and ad hoc coordinator
(4) Potential hosting institution of the emission inventory and collaborating institutions
(5) First meeting of the WGEI and the preparation of a draft plan for developing the NEACAP Emission Inventory

II. Consensual knowledge through interdisciplinary studies and open platform: Scientific Assessment Report

12. The key goals of NEACAP are to support information exchange and promote knowledge on the impact and trend of air pollution at the subregional level. Various global and regional mechanisms of environmental cooperation have proved a central and instrumental role of information and particularly consensual knowledge on the state and trend of the environment. Consensual knowledge is defined as structured information that is generally accepted by the relevant expert community. It often consists of interdisciplinary knowledge and information given the scientific complexity and its socio-economic and policy implications.

13. As shown in Table 2, there have been growing numbers of international and domestic journal papers focusing on air pollution in the respective countries. Also, there have been various processes for joint studies involving experts from North-East Asia while limited to China, Japan and the ROK. Formal platforms of such studies include the Model Intercomparison Study Asia (MICS-Asia) on the performance and uncertainties of chemical transport models (CTMs) in East Asia; Joint Research on Long-range Transboundary Air Pollutants in North-East Asia (LTP) on the modelling of source-receptor relationship as well as monitoring of the transboundary dynamics; and the Science Panel of the Asia Pacific Clean Air Partnership (APCAP) on the development of the "Air Pollution in Asia Pacific: Science Based Solutions Report".

Table 2. Journal Papers on Air Pollution on North-East Asian Countries

Year	China		Japan		RO Korea		Russia		Mongolia	
	INT	I&D	INT	I&D	INT	I&D	INT	I&D	INT	I&D
2018	510	6540	27	465	30	491	15	291	11	142
2017	422	5678	30	467	33	426	9	273	11	129
2016	293	5380	15	512	14	406	7	275	10	128
2015	192	4769	15	578	14	371	10	288	7	98
2014	148	3912	14	520	15	390	1	286	5	92
2013	141	3421	9	461	3	342	2	223	2	72
2012	85	2998	10	526	11	304	2	240	5	60
2011	88	2555	16	436	10	341	5	223	4	53
2010	68	2111	3	361	6	276	4	218	5	56

(INT: international journals accessed by Sciencedirect; Key words: country name and air pollution;
I&D: international and domestic journals accessed by the Web of Science using the same key words.)

14. Such growing interactions with peer groups at international levels are key to the development of consensual knowledge across countries. This progress could be further strengthened with an open and institutionalized platform for interdisciplinary studies that supports (a) building consensual knowledge among wider groups of experts, policy makers and other stakeholders, and (b) serving as a key reference for policy and technical cooperation. In this regard, NEACAP could develop a scientific assessment report on the state, trend and impact of air pollution, as well as policy responses.[4] The report would be prepared by the analysis of the existing studies, evaluation of monitoring and modelling data, and policy review and formulation by multidisciplinary expert panels. This process would also provide an open platform for diverse stakeholders to strengthen the basis of consensual knowledge and generate new knowledge and perspectives.

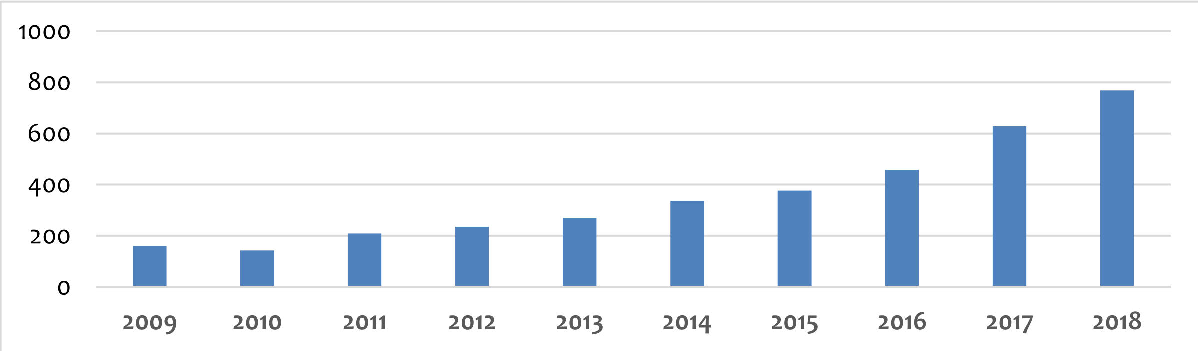
15. Concerning the analysis of the state and trends, the report could benefit from (a) the expanding networks of monitoring stations, (b) the new generation of integrated air quality monitoring with the high density of particular matter (PM) monitoring sensors, notably in China, and (c) geostationary satellites such as Geostationary Ocean Colour Imager (GOCI) on the Communication, Ocean, and Meteorological Satellite (COMS), Advanced Meteorological Imager on Geo-KOMPSAT-2A, the ROK, and the Advanced Himawari Imager (AHI) on Himawari-8, Japan. In particular, the assessment of $PM_{2.5}$ in most parts of North-East Asia which still face limited spatial coverages of ground monitoring stations could utilize satellite-derived data from GOCI, AHI and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) by NASA as

[4] References include Review on the State of Air Pollution in East Asia, EANET, 2015; "Towards Cleaner Air: scientific assessment report", UNECE, 2016; and "Air Pollution in Asia and the Pacific: science-based solutions", UNEP, 2018. "A Review of 20 Years' Air Pollution Control in Beijing, UNEP and the Beijing Municipal Ecology and Environment Bureau (BEE), 2019 provides a useful reference for the analysis of policies, outcomes and the way forward.

well as a new Geostationary Environmental Monitoring Spectrometer (GEMS) to be launched by the ROK in 2020.[5]

16. The impact assessment could benefit from the increasing epidemiological studies on air pollution and mortality, and acute time-series studies on the associations between air pollution and daily hospital admissions as well as the Global Burden of Disease (GBD) study.[6] Figure 2 indicates the international trends of scientific studies on air pollution and health. Utilizing this accumulated stock of knowledge, the scientific community in North-East Asia has also improved the scope and depth of studies.

Figure 2. Number of International Journal Papers on Air Pollution and Health



(International journals accessed by Sciencedirect; Key words: air pollution and health)

17. The assessment of policy responses can also utilize cumulative policies and technical measures and their impacts since many countries have initiated and implemented comprehensive action plans for air pollution reduction, such as the Action Plan of Air Pollution Prevention and Control of China, the National Program on Reduction of Air and Environmental Pollution of Mongolia, and the Comprehensive Measures for Particulate Matter Management of the ROK. As respective governments and various stakeholders have extensively reviewed the progress in meeting the policy targets, the subregional assessment could utilize their review results for an in-depth analysis of policy impacts, successful cases, and required actions.

18. Thus, the first SPC meeting is proposed to discuss the direction of the Scientific Assessment Report as follows:

(1) Overall approach to the analysis of the state, trend and impact of air pollution, and policy responses

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[5] D. Goto, et al., 2019, Aerosol model evaluation using two geostationary satellites over East Asia in May 2016, Atmospheric Research, 217: 93-113; Z. Ma, et.al. Effects of air pollution control policies on PM2.5 pollution improvement in China from 2005 to 2017: a satellite-based perspective, Atmospheric Chemistry and Physics: discussions.

[6] HEI, 2010, Outdoor Air Pollution and Health in the Developing Countries of Asia: A Comprehensive Review; Z. Cheng, et.al., 2013, Characteristics and health impacts of particulate matter pollution in China, Atmospheric Environment, 65:186-194

(2) Operation of the Working Group on Scientific Assessment Report (WGSAR) including the composition of members and ad hoc coordinator
(3) Composition of lead authors and contributors
(4) Scoping meeting to develop a draft outline of the report

III. Policy goals and measures: Integrated Assessment Modelling

19. A core programme of NEACAP is to propose potential technical and policy measures through science-based, policy-oriented consultations, and the development of technical and policy scenarios. Implementing this programme entails carrying out integrated assessment modelling (IAM) which is a corner stone of interactive processes between science and policy by analyzing emission trends and their impacts on health and environment, potentials and measures of emission reduction, and cost-effective options of emission control.

20. The IAM approach has been well practiced by the CLRTAP to link scientific results to policies and present various scenarios of cost-effective emission reductions, which is supported by the Task Force on Integrated Assessment Modelling (TFIAM) and the Centre for Integrated Assessment Modelling (CIAM). The Regional Air Pollution Information and Simulation (RAINS) model developed by the International Institute for Applied Systems Analysis (IIASA, the host of CIAM) was used for exploring cost-effective emission reduction pathways for air pollution including NH_3, SO_2, and NOx.[7]

Table 3. Overview of Integrated Assessment Modelling

IAM can be broadly grouped into two main categories: (a) the scenario analysis which consists in defining a set of abatement measures and assessing its impact on air quality through modelling and; (b) the optimization analysis which uses algorithms to automatically minimize costs and/or maximize benefits on top of the emission-concentration relationships with a view of delivering a set of cost-efficient abatement measures to the policy maker. While measures are the input in the scenario analysis, they constitute the final results of the optimization in the second. The optimization approach can include:

- **cost-benefit analysis** that balances all costs and benefits associated to an emission scenario and identifies an optimal solution;
- **cost-effective analysis** that has been introduced in order to take into account the high uncertainty affecting the quantification of costs and benefits of non-material issues (e.g. cost of human life);
- **multi-criteria approach** used to explicitly consider multiple criteria in decision-making environments;
- **multi-objective analysis** that performs a selection of the efficient solutions, considering in a vector objective function all the targets regarded in the problem, and stressing conflicts among them.

Source: P. Thunis, et al. 2016. Overview of current regional and local scale air quality modelling practices: Assessment and planning tools in the EU, Environmental Science & Policy 65, 13–21

[7] Laurence ROUÏL, 2016. Review of Regional Air Pollution Control Mechanisms: Focus on the LRTAP Convention, NEASPEC.

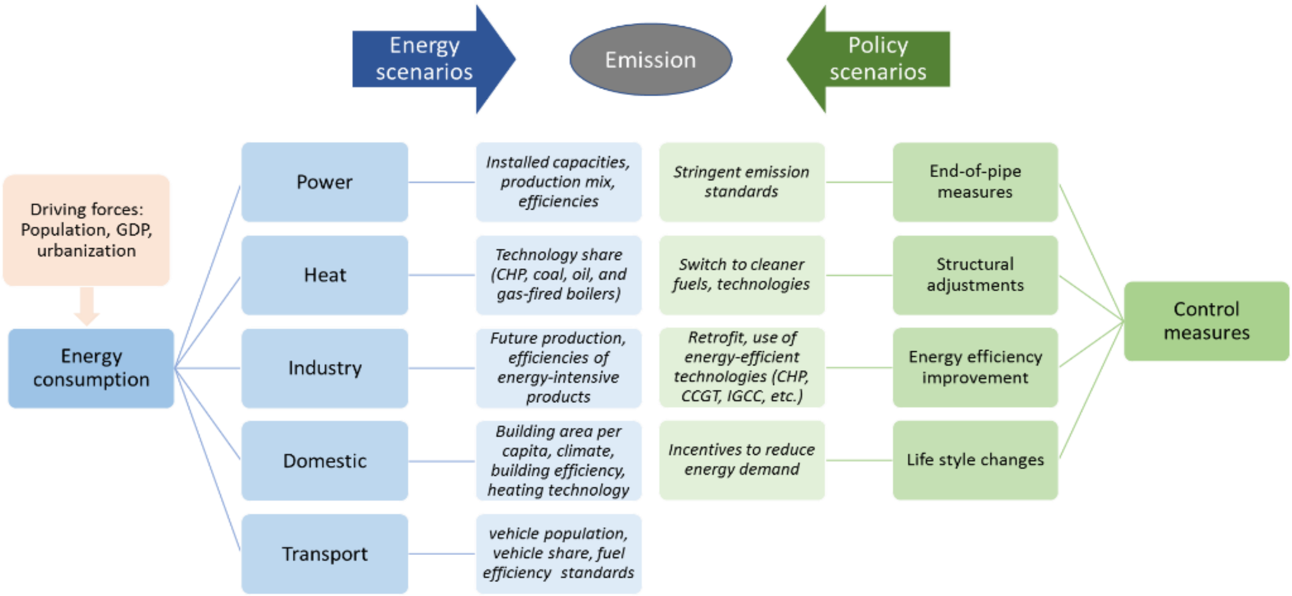
21.Particularly, the model was used as a groundwork for the adoption of the 'Second Sulfur Protocol' on Further Reductions of Sulphur Emissions in 1994 has demonstrated the potential of IAM in supporting major international negotiations. Since then, RAINS was continuously applied to assist policy formation including the Gothenburg Protocol (1999) and the National Emission Ceilings Directive of the European Union (2001). The initial RAINS model started with NH_3, SO_2 and NOx has now evolved to encompass the Greenhouse gas–Air pollution Interactions and Synergies (GAINS) model to include a wider range of pollutants including PM, O_3, VOCs and GHGs. The GAINS model has been also extended to enable structural policy measures other than end-of-pipe options and present economic activity pathways, emission control strategies, emissions scenarios, emission control costs and impacts.

22.Processes and outcomes of CRLTAP on the integrated assessment modelling are of high relevance to the work of NEACAP for identifying such pathways and strategies. The scientific community in North-East Asia has also utilized IAM for developing policy scenarios for mitigation options of air pollution mostly at the domestic levels, but very limited at the level of North-East Asia. An IAM which was conducted at the subregional level involving experts from China, Japan and the ROK analyzed the emission trends of SO_2, NOx, PM and NMVOC in North-East Asia, and presented their future emissions up to 2030 with six emission scenarios based on end-of-pipe control strategies and energy saving policies.[8]

23.This subregional IAM shows the potential of IAM for analyzing the mitigation potentials and measures for air pollution reduction with six different pathways and providing a policy goal and direction to be pursued at the subregional level. However, it also shows the need to expand the scope of such studies from modelling of mitigation scenarios to the assessment of detailed abatement technologies, specific sectoral policies and measures, intergovernmental scientific and policy cooperation, etc. This work requires a multidisciplinary approach with the involvement of experts from diverse fields, up-to-date information on emission, energy system and technologies in key sectors, and government policies as shown in Figure 3. Furthermore, if such study were conducted under NEACAP, the process should involve policy makers and practitioners to formulate emission control measures, in particular, pertaining to intergovernmental cooperation.

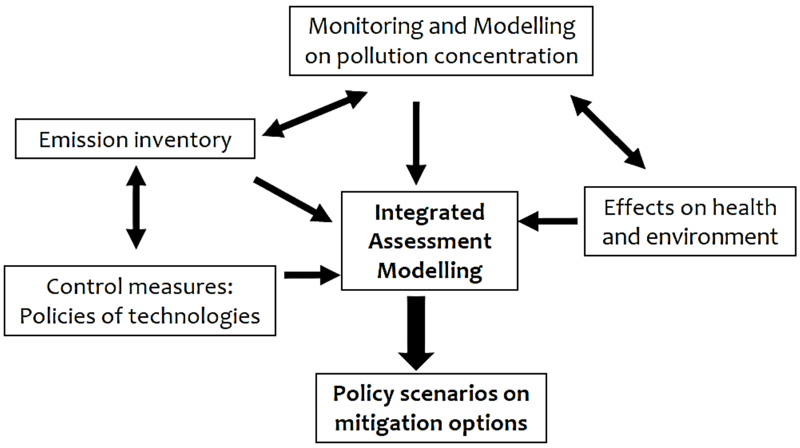
[8] S. X. Wang, et al. 2014. Emission trends and mitigation options for air pollutants in East Asia, Atmospheric Chemistry and Physics, 14, 6571–6603

Figure 3. Key parameters in energy and policy scenarios in IAM[9]



24. The process towards the launching of NEACAP reviewed the concept of utilizing IAM as a key connecting point between various scientific works, as a tool for identifying optimized solutions for air pollution reduction, and as a catalyst for formulating areas of science-based, policy-oriented cooperation.

Figure 4. Key parameters in energy and policy scenarios in IAM



25. However, IAM accompanies significant uncertainties, by nature, in the assumptions made for economic growth, emission control measures, best available technologies, as well as their costs and benefits that are not proportionally shared between stakeholders and countries. To serve as a key reference for policy formulation and intergovernmental cooperation, IAM requires reliable

[9] Zhao, B., et al., 2013, Impact of national NOx and SO2 control policies on particulate matter. *Atmospheric Environment*, 77, 453-463.

emission and projection data which is acknowledged by all stakeholders as relevant and representative. The choice of one or several chemistry transport models to assess the impact of scenarios should also be agreed by the stakeholders.

26. This condition underlines the significance of a reliable emission inventory, information and data exchange, and an agreed methodology and process. Concerning the methodology and process, NEACAP could consider two options, i.e., (a) assigning IAM to a dedicated group/institution while it coordinates the involvement of wider group of experts, and (b) taking an "ensemble" approach that builds on model results from the combination of work by multi-models/multi-teams to extensively utilize model capacities from diverse groups.

27. Thus, the first SPC meeting is proposed to discuss the direction of the Integrated Assessment Modelling as follows:

(1) Overall approach to IAM including scope, timeframe, institutional modality (dedicated center or ensemble approach), etc.
(2) Operation of the Working Group on the IAM (WGIAM) including the composition of members and ad hoc coordinator
(3) First meeting of the WGIAM

IV. Policy experiences and technology information: policy dialogues

28. NEACAP aims to facilitate the exchange of information on emission control technologies, policies and practices. While the information exchange serves its own purpose, NEACAP also looks at it as a means to formulate and propose technical and policy measures. Currently, China, Japan and the ROK hold an annual "Tripartite Policy Dialogue on Air Pollution (TPDAP)" since 2014. The Dialogue also operates Working Group I for scientific research on air pollution prevention and management; and Working Group II for technology and policy research on air quality monitoring and forecasting.

29. The 3rd Policy Dialogue held in 2016 formulated an action plan (2015-2019), which request WG I to conduct policy sharing and research activities for reduction and management of air pollutant emissions, including VOC control and mobile source air pollution (roads and non-roads); and WG II to deliver policies and exchange information regarding air quality monitoring and forecasting, air pollutant monitoring techniques for O_3 and $PM_{2.5}$, emission inventory technology and approaches, as well as remote measurement of air pollutants and modeling. Furthermore, recent Tripartite Environment Ministers Meetings (TEMM) reaffirmed tripartite cooperation for air quality improvement.

30. In Europe, the programme of Best Available Techniques (BAT) has been a key approach to information exchange and guideline on emission control technologies. BAT is defined as follows.

- **Best:** Most effective in achieving a high general level of protection of the environment as a whole
- **Available:** Developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions
- **Techniques:** Both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned

31. Under the EU Industrial Emissions Directive (2010), BATs are determined by a Technical Working Group and documented in Best Available Techniques reference documents (BREFs), which generally give information on a specific industrial sector in the EU, the techniques and processes used in this sector, current emission and consumption levels, techniques to consider in the determination of BAT and emerging techniques. To facilitate BAT approach, the Directive gives a mandate to the Commission to organize an exchange of information between Member States, the industries concerned, and non-governmental organizations on the performance of installations and techniques, economic and technical viability, emerging techniques, etc.[10]

32. Considering the ongoing tripartite dialogue and other relevant processes, the NEACAP programme on information exchange and policy consultation could explore the need and opportunity for (a) utilizing the tripartite dialogue process and outcome for other NEACAP countries, (b) developing technical cooperation in connection with IAM outcomes, (c) developing a voluntary/pilot approach of the Best Available Techniques, and (d) holding an open forum on technology for diverse stakeholders, in particular, to share information on emerging technologies.

33. Thus, the first SPC meeting is proposed to discuss the direction of the Policy Dialogue as follows:

(1) Overall approach to policy dialogue
(2) Need and feasibility of pilot BAT approach and a technology forum
(3) Coordination with the TEMM process

[10] Georgios Chronopoulos, 2016. The European Best Available Techniques (BAT) approach, UNECE/CLRTAP/TFTEI Workshop, 20 April 2016.