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Integrated Climate Action Planning (ICLAP) tool to promote science-based climate planning in Asia-Pacific Cities

Mahendra Sethi [a,*] , Shilpi Mittal [a], Eva Ayaragarnchanakul [b,c] , Ram Avtar [d] , Li-jing Liu [e,f], Aki Suwa [g], Akhilesh Surjan [h]

[a] Indian Society for Applied Research & Development, New Delhi 110092, India
[b] Department of Economics, Prince of Songkla University, Songkhla 90110, Thailand, eva.a@psu.ac.th
[c] Sustainability Economics of Human Settlements, Technical University Berlin, Berlin 10623, Germany
[d] Faculty of Environmental Earth Science, Hokkaido University, Sapporo 060-0810, Hokkaido, Japan; ram@ees.hokudai.ac.jp
[e] Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China; liulijing@bit.edu.cn
[f] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China
[g] Faculty of Contemporary Society, Kyoto Women's University, Kyoto 605-8501, Japan; suwa@kyoto-wu.ac.jp
[h] Humanitarian, Emergency and Disaster Management Studies Program, Charles Darwin University, Darwin NT 0810, Australia; akhilesh.surjan@cdu.edu.au

* **Correspondence: mahendrasethi@hotmail.com**

Abstract

The climate change phenomenon has global greenhouse gas contributions and implications; yet there is a high agreement amongst scientists that the 2°C global warming challenge can be dealt with concerted actions intersecting multiple sectors and levels of governance. However, we are aware that local climate governance is fraught with complexity due to overlapping of numerous distinct variables like temperature and precipitation deviations at different locations, greenhouse gas scenarios under different Representative Concentration Pathways and timeline as well as different climate solutions being tried across the globe, particularly by urban agencies. This necessitates into developing smart tools having capability to integrate such wide-ranging and complex data, process it for city governments to undertake evidence-based decisions on future climate initiatives. The Integrated Climate Action Planning 2050 tool (ICLAP) is one such tool that has been designed for 5 million-plus population cities in the Asia-Pacific region considering future climate variability and emissions scenarios in the long-term while systematically informing about climate solutions being pursued by cities worldwide. This research can be useful for enhancing city-specific climate solutions and national urban policies along with promoting international and regional climate research cooperation.

Keywords: urban climate research, integrated climate action planning, climate variability, Asia-Pacific, GHG

Highlights

- ICLAP tool is designed for 49 five-million+ population cities in the Asia-Pacific
- It considers future city GHGs, regional climate variability & global best practices
- The methodology integrates bibliometric, statistical analytics and spatial approach
- It empowers researchers, policy makers and urban agencies in science based policy
- Bears urban, regional and global value in capacity building & climate cooperation

1. Introduction

According to the recent data consolidated by the World Meteorological Organization (WMO), years 2015 to 2022 were the eight warmest in the instrumental record back to 1850. The global mean temperature in 2022 was 1.15 (± 0.13) °C above the pre-industrial era levels i.e. 1850-1900 average (WMO 2022). The global warming and other long-term climate change trends are expected to continue as a result of record levels of heat-trapping greenhouse gases (GHG) in the atmosphere. Meanwhile, the Paris Agreement calls for all countries to strive towards a limit of 1.5°C of global warming through concerted climate action following realistic Nationally Determined Contributions (NDC) i.e. the individual country plans to slow down global warming. While the climate change phenomenon has global GHG contributions and implications; there is a high agreement amongst scientists that global warming can be dealt with concerted actions spread across multiple nations, sectors and levels of governance (UN 2015, UNFCCC 2015, IPCC 2018). The Asia-Pacific hosts a significant proportion of the world population, one of the most rapidly developing regions that contributes to over half of global GHGs. The region also has most of the world's low-lying cities and vulnerable small island states. The Asia-Pacific Climate Week 2021 held during the COP26, showcased how the region offers exceptional challenge in attaining global climate goals (UNFCCC 2021). The increasing intensity and frequency of extreme climate events lately, inducing forest fires, cyclones and floods in India, Pakistan, Japan, China, Indonesia, Australia, etc. displacing huge population highlights the necessity to tackle climate change through constructive and practical application of solutions. It is argued that local governments in the region are exposed to three-pronged challenge of ensuring economic development to improve living standards, reduction of GHG emissions and urban air-pollution while guarding population from climate induced disasters (Farzaneh 2019).

In reality, there is a high degree of complexity, uncertainty/ variability and fragmentation of knowledge that cities have about their climate situation (Sethi et al. 2021). As a part of this research, we reviewed ongoing climate action plans (CAPs) of 17 cities (Tokyo, Osaka, Beijing, Shanghai, Guangzhou, Tianjin, Shenzhen, New Delhi, Mumbai, Kolkata, Bengaluru, Chennai, Singapore, Bangkok, Manilla, Sydney and Melbourne) located in seven Asia-Pacific countries (Australia, China, India, Japan, Philippines, Singapore and Thailand) evaluating policy disintegration and in-availability of data pertaining to climate change and cities (Sethi et al. 2022). Urban climate research too is fraught with complexity due to overlapping of numerous distinct variables like temperature or precipitation deviations and GHG scenarios under different Representative Concentration Pathways (RCP) and timeline as well as different climate solutions and governance instruments being tried across the globe, particularly by urban agencies at the local level (Sethi et al. 2021). This mandates a concerted inquiry into having decision-making tool with capability to integrate such wide-ranging complex data and process it for decision-makers to frame evidence-based urban climate policies. With this aim, we develop an Integrated Climate Action Planning (ICLAP) tool that has been especially designed for 5 million-plus population cities in the Asia-Pacific which considers long-term climate variability and emissions scenarios along with systematically informing about climate solutions being pursued by cities worldwide. In this paper, we introduce the main methodological and analytical framework of ICLAP tool, essentially highlighting its spatial, statistical and bibliometric components (section 2). We further demonstrate how this framework is applied (section 3) to discern: (3.1) Global practices in urban climate field, (3.2) Climate variability and future GHG pathways at the city-level (3.3) Regional implications of these results, followed by a discussion into (3.4) Plausible urban climate solutions for different Asia-Pacific cities. The paper concludes with interpretation of key research findings and policy recommendations (section 4) to promote evidence based climate governance at multiple levels in the Asia-Pacific region.

2. Methodology

The concept of integrated planning towards climate action is already recognized in the Paris Agreement (UNFCCC 2015) and the UNFCCC's AR5 Report (IPCC 2014). Climate change in urban areas plays out in a highly complicated manner and requires systematic approach to assess intersecting linkages. During the last decade or so, there has been a marked advancement in preparation and usage of urban climate tools and models. For instance, in Europe, 300 million-plus strong urban population is represented by 10774 participants in the Covenants of Mayors. Its cities are sharing climate initiatives through a Good Practices database that documents city profiles, their case studies, videos of accomplished projects, etc. (Covenants of Mayors 2021). It is an easy to use tool for decision makers and policy planners disseminating a plethora of climate action information about other cities. Globally, Local Governments for Sustainability commonly known as ICLEI provides several smart tools for urban climate planning (ICLEI 2021), like Clean Air and Climate Protection (CACP) software, Adaptation database and planning tool (ADAPT) and Harmonized Emissions Analysis Tool Plus (HEAT+). Recently, C40-Cities initiated a smart tool that supports cities to better comprehend interlinkages between climate adaptation and mitigation aspects in jointly moderating climate induced risks (C40-Cities 2021). The development of practical and multi-faceted tools for urban climate assessment is a highly complex undertaking. A smart tool intended for the purpose of comprehensively guiding urban climate decision-making in a region has to be cross-cutting different functional sectors and scientific methods.

In terms of methods, evidence based climate planning in urban context is characterized by three distinct approaches (Sethi et al. 2021): (1) *Case studying or bibliometric* that involves intense qualitative assessment of case studies in specific context or peer practises, (2) *Statistical analytics* that depend on demographic & economic estimates, forecasts of energy & GHGs that can suggest policies for low-carbon development. (3) *Spatial approach* that appraises climate variability or vulnerability in managing disasters, identifying climate adaptation and resilience needs. In this research, we make use of ICLAP, a decision-making simulation model that combines spatial, statistical and bibliometric methods (Figure 1) while bridging climate mitigation, adaptation and data science (APN 2021). The model adopts an integrated approach to inform policy choices considering downscaled climate variability of temperature and precipitation (for 2030, 2050, 2080), custom-made scenarios for mitigation, and results from post-facto climate solutions in cities, in a highly systematized, transparent and easy to use digital interphase (Sethi et al. 2022), as summarized below:

1. <u>Spatial- Downscaling climate scenarios & GIS mapping of variability</u>: In order to forecast climate variabilities at urban-region scale, rainfall and temperature deviations from the normal would be downscaled from global/ regional MICROC6 scenarios SSP245 (RCP 4.5) and SSP585 (RCP 8.5) for 2030, 2050 (Saraswat et al. 2016) and even up to 2080, eventually being crucial in guiding adaptation alternatives.
2. <u>Statistical- Trend analysis of urban indicators and GHG forecasts</u>: Climate mitigation target would be supported by GHG forecasts (for business-as-usual, with upper and low limits) over urban data profiles covering population, economy, energy use in transport, buildings, agriculture/ landuse, waste and corresponding GHGs for 2030, 2050 (Fujimori et al. 2014). This would be instrumental in identifying climate mitigation initiatives.
3. <u>Bibliometric- Meta-analysis of evidence from case studies</u>: Data extraction and machine-learning are employed to systematically review 644 global case studies in local climate action. It employs Google Scholar and Web of Science database to undertake bibliometric analysis. This follows meta-analysing key policy solutions (Sethi et al. 2020, Lamb et al. 2018, Lamb et al. 2019) while coding for diverse GHG sectors (energy, industry, transport, landuse-landcover change, waste, etc.), their relative efficiency and governance modes for implementation (UN-Habitat 2011) like regulations, enabling mechanisms, economic instruments and voluntary measures.

For urban population, we make use of the standard dataset, *World Urbanization Prospects: The 2018 Revision* for population (UNDESA 2019). Data pertaining to cities i.e. land area, green area, built-up area, GDP, etc. are from a dataset, i.e. Global Human Settlement Layer Urban Centres Database (Florczyk 2019). For GHG data of individual cities, we extract data from Emissions Database for Global Atmospheric Research i.e. EDGAR v4.3.2 (Crippa et al. 2018) reporting anthropogenic GHGs (1970-2012). This covers GHGs like NO_x, CO_2, SO_2 from different production activities adhering to standard sector codes/ definitions (IPCC 1996), complied bottom-up ensuring consistency and comparability.

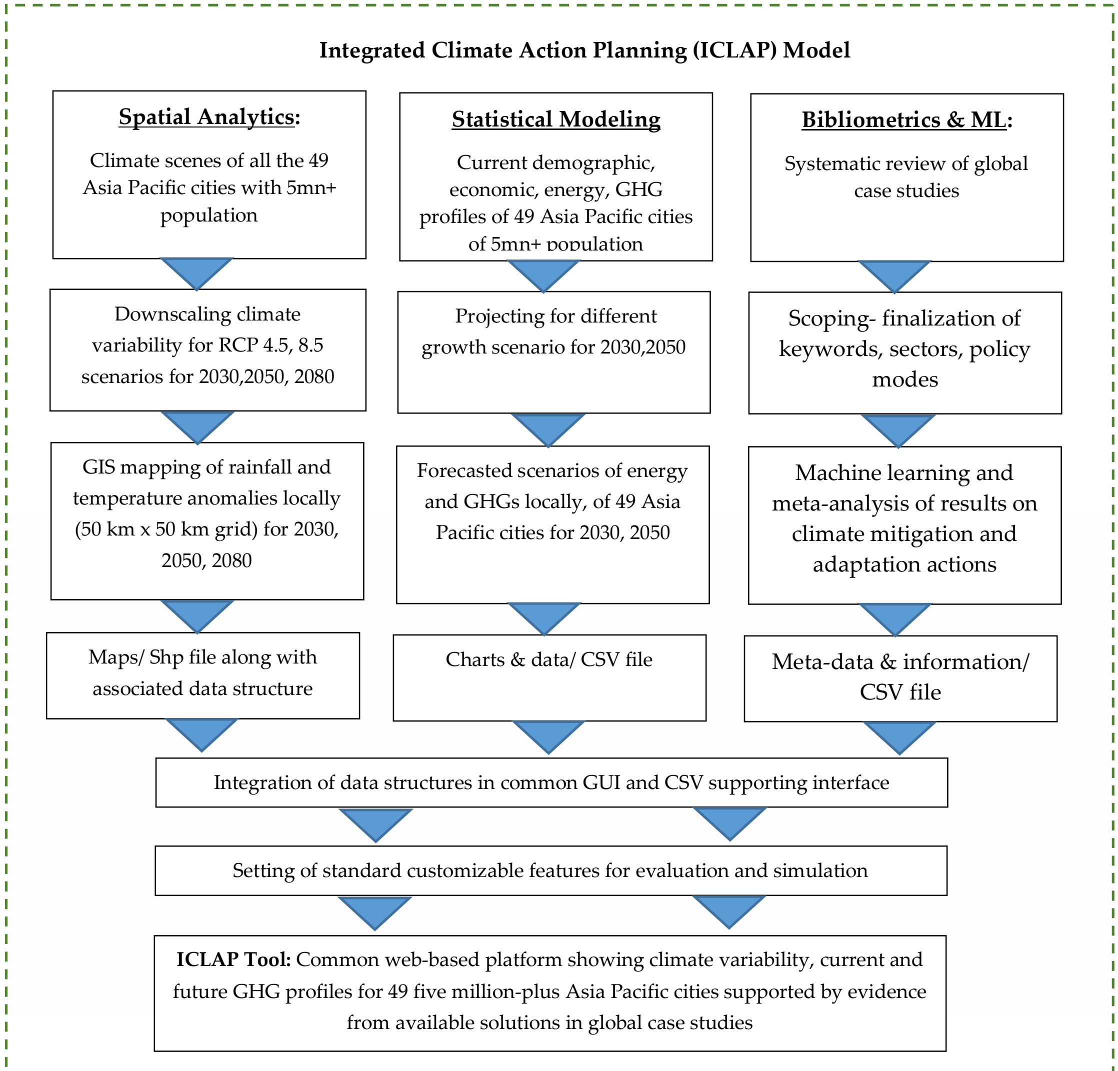


Figure 1: Integrated Climate Action Planning (ICLAP) Model

3. Results and discussion

3.1 Global practices in urban climate

The systematic review of best practices through machine-trained bibliometric analysis detects several climate solutions being implemented in cities worldwide. Out of 644 studies, 88 cases across 41 solutions provide quantitative data to estimate GHG abatement potential. We rank demand-side potential for abating climate change, benchmarked against business-as-usual scenario (BAU) as defined in each individual study. The results vary from 5.2 to 105% and thus we report these in four sets (from lowest to highest emission reduction potential).

Lowest potential (up to 26.25%): Building information system, Green building, Smart meters/ intelligent controls/ thermostats, Urban form, design, planning, Passive solar design, monitoring, Biomass, biomass gasification, Energy efficiency measures, Intelligent transportation system (ITS), biodiesel/ ethanol, Awnings or window glazing, Cogeneration or tri-generation (winters only), Fuel or technology shift, car free city, Photovoltaic solar, roof garden (higher latitudes), Energy storage- battery or from breaking energy, Afforestation & greening expansion, Smart grid, Cool roof/façade, District heating/cooling.

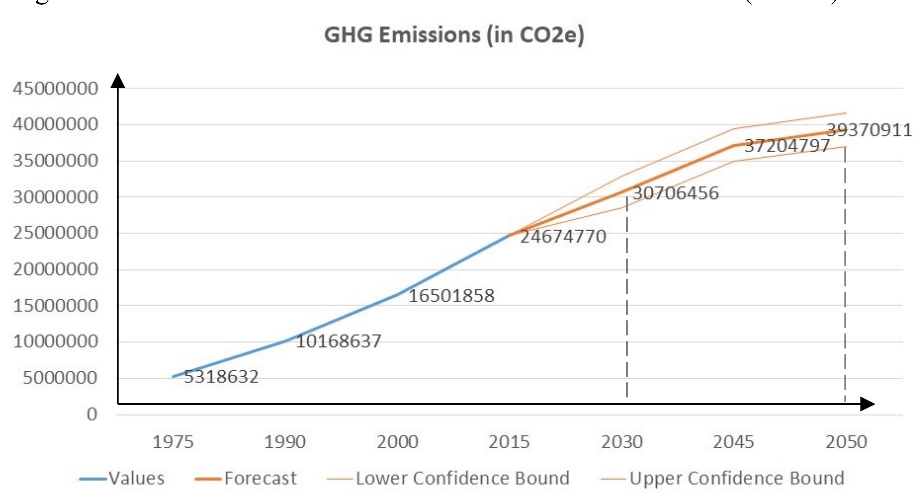
Moderate potential (26.25–52.5%): Wind energy, Public transport expansion, Buildings, energy& transport combined solutions (B+E+T), Cogeneration or tri-generation (city or urban district), Waste heat recovery, Geothermal heat pumps, Thermal comfort & insulation, Transit oriented development, Composting and biological treatment of waste, Retrofitting old buildings, Cool roof/facade, roof garden (lower latitudes), Combined walls/ roofs, Life cycle assessment, DSM- optimization, peak shifting/ shaving, Travel demand management optimizing mobility. The *higher potential* (52.5–78.75%) solutions include Solar tri-generation CPVT, EE + PV, PV thermal, Private and public transport, Integrated waste management, EE + RE + EV. The *highest potential* (78.75–105%) include some of the most effecient urban climate solutions include Electric mobility- electric vehicles (EV) & hybrid electric vehicles (HEV)- in public & private vehicles, Net zero emission building (NZEB), Energy from waste (WtE/EfW) or Waste to energy.

3.2 Climate variability and GHG pathways for 49 Asia-Pacific cities

Using the ICLAP model, climate variability and GHG pathways for our sample of 49 Asia-Pacific cities having 5 million-plus population is analysed and reported. The result sheet for each city presents the latest data on GHG contributions, historic GHG pathways and estimates for future GHG up to 2030, 2050 (2 scenarios) based on BAU, as well as the spatial results of average temperature and average precipitation deviation under moderate GHG (SSP245) up to 2030, 2050, 2080 (2x3=6 scenarios) along with spatial results of average temperature and average precipitation deviation under high GHG (SSP585) up to 2030, 2050, 2080 (2x3=6 scenarios). Thus each city, in addition to the current situation presents 2 GHG, 6 temperature and 6 precipitation scenarios spanning from 2030-2050. For the sake of simplicity, in this section we share the results for three temperature variability, three precipitation variability and two GHG pathways (under moderate SSP245 scenario) for the city of Mumbai. This is followed by a tabulation of similar results for the entire sample of Asia-Pacific cities.

Mumbai: The GHG emissions of Mumbai was 5.3 $MtCO_2e$ in 1975, that escalated to 10.2 $MtCO_2e$ in 1990 and 24.7 $MtCO_2e$ in 2015. A majority of the GHG emissions in 2015 were contributed by both the energy sector (48%) and industry sector (36%), trailed by the residential sector (9%) and the transport sector (9%). As per the ICLAP model estimates (Figure 2), there would be an increase in emissions at 3.9% per annum, leading to 30.7 $MtCO_2e$ in 2030 and 39.4 $MtCO_2e$ in 2050. The results for climate variability in Mumbai indicate that the scenario corresponding to the pathway with moderate GHGs (MIROC6_SSP245) exhibits an increase of 0.5 degC during 2030s (above the 1980 baseline temperature), 0.7 degC in 2050s, peaking to 1.0 degC during 2060s and continue to remain so till 2080s (Figure 3, top). Meanwhile, the precipitation change for Mumbai shows high variability in the long run, ranging from over 200 mm during 2030s (above the 1980 baseline rainfall) to 370 mm in 2050s, dipping again to 200 mm during 2060s and thereafter stabilizing around 360 mm during 2070-80s (Figure 3, bottom).

Figure 2: ICLAP estimates for Mumbai's GHGs for 2030 & 2050 (bottom)



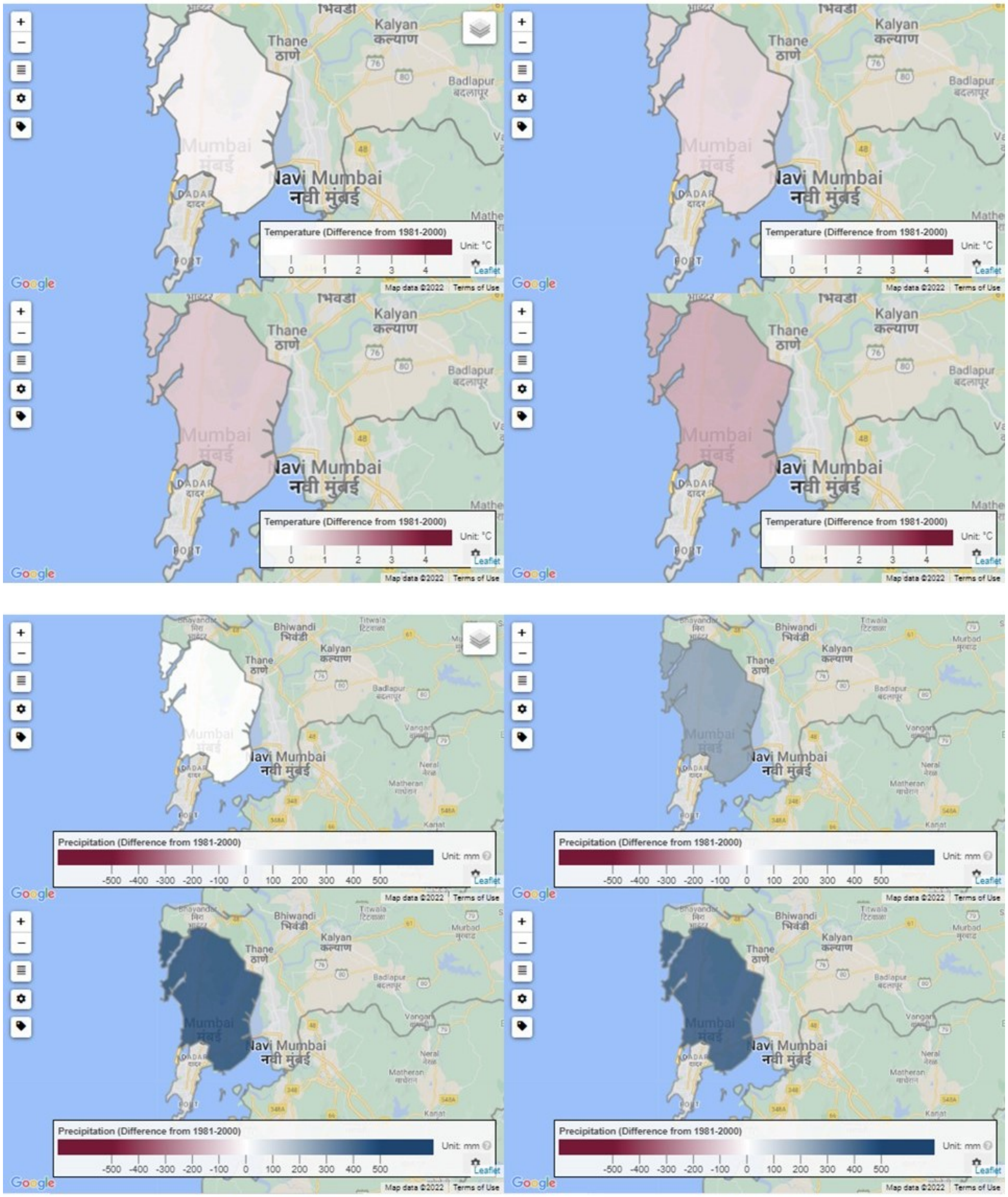


Figure 3: Spatial results of avg. temperature variability (clockwise from top left: current, 2030, 2050, 2080) under moderate (SSP245) GHG scenario (top); Spatial results of avg. precipitation variability (clockwise from top left: current, 2030, 2050, 2080) under moderate (SSP245) GHG scenario (bottom)

Upon tabulation of results for entire sample under SSP245 scenario (Table 1), it is observed that the GHG deviation in Asia-Pacific cities varies substantially from -0.3% (Fukuoka) to +7.9% (Shanghai). The mean annual temperature deviation is consistently positive across all the cities corroborating global warming in the region, its magnitude varying though from 0.011 degC (Jakarta) to 0.29 degC (Bangkok).

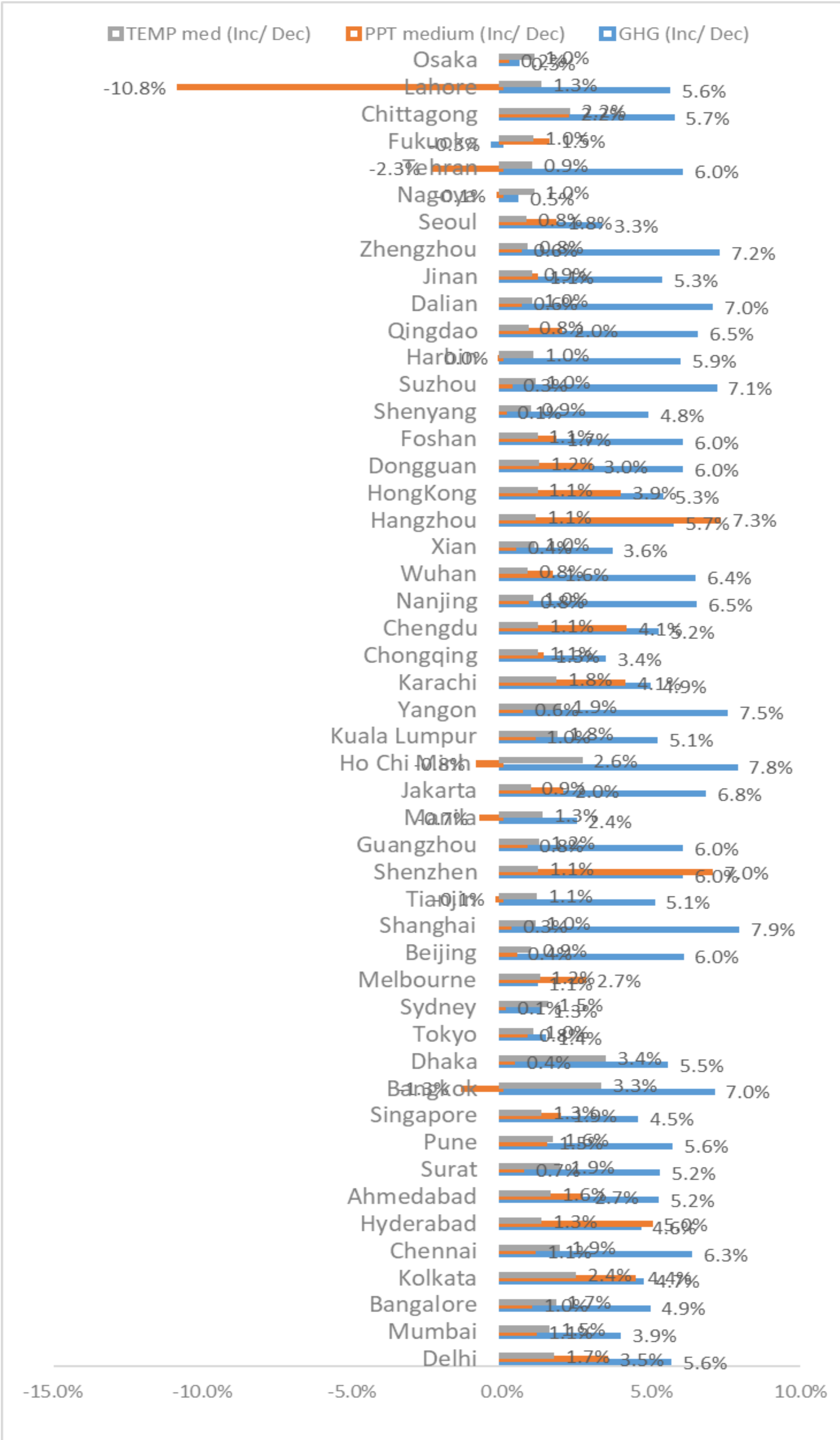
Meanwhile. the mean annual precipitation variability from the normal ranges considerably, from a decline of 2.221 mm/year (Ho Chi Minh) to a rise of 5.145 mm/year (Foshan).

In order to have a comparative and long-term perspective of how GHGs, mean temperature and mean precipitation will simultaneously behave for any city, compound annual growth rate (CAGR) is computed for all the three indices. Figure 4 shows year on year growth/ decline of these (in percentage terms) up to 2080. Here, GHG emissions of 49 Asia-Pacific cities on an average show a rise of 5% per annum. Who leads this change? On an average, barring few cities located in Japan, South Korea and Australia that show GHG increase of 1.1-1.2%, it is mostly the developing cities in South-east Asia (5.9%) and China (5.8%) that are the frontrunners, followed by the ones in Rest of Asia (5.5%) and India (5.1%).

Table 1: GHG, temperature and precipitation changes for 49 cities under SSP245 scenario

	CITY	GHGs (Inc/ Dec)	TEMP med (Inc/ Dec)	PPT medium (Inc/ Dec)
1	Delhi	5.6%	0.022	1.520
2	Mumbai	3.9%	0.014	3.234
3	Bangalore	4.9%	0.016	0.730
4	Kolkata	4.7%	0.021	4.246
5	Chennai	6.3%	0.017	2.205
6	Hyderabad	4.6%	0.014	2.160
7	Ahmedabad	5.2%	0.018	1.372
8	Surat	5.2%	0.015	1.119
9	Pune	5.6%	0.015	3.088
10	Singapore	4.5%	0.012	3.326
11	Bangkok	7.0%	0.029	-1.827
12	Dhaka	5.5%	0.028	0.427
13	Tokyo	1.4%	0.021	0.705
14	Sydney	1.3%	0.015	0.099
15	Melbourne	1.1%	0.012	1.042
16	Beijing	6.0%	0.018	0.560
17	Shanghai	7.9%	0.019	0.222
18	Tianjin	5.1%	0.020	-0.191
19	Shenzhen	6.0%	0.015	4.068
20	Guangzhou	6.0%	0.017	4.672
21	Manila	2.4%	0.016	-0.600
22	Jakarta	6.8%	0.011	4.115
23	Ho Chi Minh	7.8%	0.022	-2.221
24	Kuala Lumpur	5.1%	0.014	2.791
25	Yangon	7.5%	0.018	2.674
26	Karachi	4.9%	0.021	-1.012
27	Chongqing	3.4%	0.023	1.290
28	Chengdu	5.2%	0.021	2.731
29	Nanjing	6.5%	0.019	0.696
30	Wuhan	6.4%	0.016	3.825
31	Xian	3.6%	0.021	0.335
32	Hangzhou	5.7%	0.020	2.694
33	Hong Kong	5.3%	0.015	4.032
34	Dongguan	6.0%	0.016	4.308
35	Foshan	6.0%	0.016	5.145
36	Shenyang	4.8%	0.020	0.114
37	Suzhou	7.1%	0.020	0.246
38	Harbin	5.9%	0.023	-0.019
39	Qingdao	6.5%	0.016	2.016
40	Dalian	7.0%	0.019	0.989
41	Jinan	5.3%	0.017	1.547
42	Zhengzhou	7.2%	0.017	0.522
43	Seoul	3.3%	0.017	1.253
44	Nagoya	0.5%	0.021	-0.042
45	Tehran	6.0%	0.023	-0.299
46	Fukuoka	-0.3%	0.019	0.352
47	Chittagong	5.7%	0.020	3.385
48	Lahore	5.6%	0.025	0.654
49	Osaka	0.5%	0.021	0.103
	Mean:	5.0%	0.018	1.518

Figure 4: Average temperature, precipitation and GHG deviations of 49 Asia-Pacific cities computed year on year (in %) under SSP245 scenario



3.3 Regional implication of results

The results vary significantly across different sub-regions of Asia-Pacific. Under the medium GHG scenario (SSP245) for climate variability (see Table 2), the mean temperature in 49 Asia-Pacific cities is expected to rise by 0.018 degC per annum (at 1.4%). The cities in South-east Asia (1.9%), India (1.7%) are more prone to global warming than those in Australia (1.3%) and China, Japan & South Korea (1.0%). Meanwhile, the mean precipitation deviation observed from the normal is +1.518 mm per annum (at 1.4%). The Indian cities are most prone to increasing rainfall (2.3%) above the normal than Chinese (1.8%) and Australian (1.4%). On the other hand, cities in Japan, South Korea (0.8%), South-east Asia (0.4%) and Rest of Asia (-1.3%) show negligible to negative precipitation rise. In nutshell, within the Asia-Pacific region, it is the Indian cities that consistently demonstrate high susceptibility to both annual temperature and annual precipitation increase while Japanese cities show low susceptibility. Of course, results during seasonal/ monthly, diurnal and short-spell assessments may vary.

Climate variability is expected to be even more pronounce (i.e. 2.4% per annum) in SSP585 scenario (Table 3) for both temperature rise (0.45 degC) and precipitation increase (2.95 mm). The temperature rise is significant in all sub-regions (ranging 2.8–3.3%), except China (1.8%), Japan & South Korea (1.7%). Meanwhile, precipitation increase would be pronounced in cities of China (3.4%), India (2.6%), moderate in Japan, South Korea (1.9%), Rest of Asia (1.8%) while being negligible in South-east Asia (1.2%) and (-0.9%) Australia.

Table 2: Classification of results for different sub-regions of Asia-Pacific under medium GHG scenario

CONTINENT	GHG	TEMP	TEMP VARIATION	PPT	PPT VARIATION
Australia	1.2%	0.014	1.3%	0.571	1.4%
China	5.8%	0.019	1.0%	1.757	1.8%
India	5.1%	0.017	1.7%	2.186	2.3%
Japan, S. Korea	1.1%	0.020	1.0%	0.474	0.8%
South-east Asia	5.9%	0.017	1.9%	1.180	0.4%
Rest of Asia	5.5%	0.024	1.9%	0.631	-1.3%
Range	-0.3 - 7.8%		0.8 - 3.4%		1.3 - 4.4%
Mean	5.0%	0.018	1.4%	1.518	1.3%

Table 3: Classification of results for different sub-regions of Asia-Pacific under high GHG scenario

CONTINENT	GHG	TEMP	TEMP VARIATION	PPT	PPT VARIATION
Australia	1.2%	0.051	3.2%	-0.433	-0.9%
China	5.8%	0.048	1.8%	3.400	3.4%
India	5.1%	0.040	3.3%	3.535	2.6%
Japan, S. Korea	1.1%	0.045	1.7%	3.525	1.9%
South-east Asia	5.9%	0.039	3.1%	2.421	1.2%
Rest of Asia	5.5%	0.050	2.8%	1.606	1.8%
Range	-0.3 - 7.8%		1.5 - 5.1%		4.8 - 6.2%
Mean	5.0%	0.0451	2.4%	2.954	2.4%

3.4 Plausible urban climate solutions for different Asia-Pacific cities

Through bibliometric and machine-learning within ICLAP, we reviewed how global best practices in urban climate (section 3.1) can respond to a city's climate variability and imminent GHGs. Based on increasing GHG, and varying temperature and precipitation profiles, in principle, four different situations emerge (Table 4). Situation 1 points to increase in both projected temperature and projected precipitation. Situation 2 reflects increase in projected temperature but decrease in projected precipitation. Situation 3 indicates decrease in both projected temperature and projected precipitation, while Situation 4 points to decrease in projected temperature but increase in projected precipitation. We observe that Situation 3 and Situation 4 is not detected in our sample of Asia-Pacific cities

Situation 1: With rising temperature and precipitation, a majority (42 out of 49) of Asia-Pacific cities are predisposed to high annual temperature along with heavy rainfall and inundation that is hazardous to both human and urban infrastructure. These are cities spread evenly across China, Japan, India, South-east Asia and the Rest of Asia. As precipitation intensity increase in events of extreme climate, intense downpour leading to urban floods are likely to occur frequently in several densely compact settlements and urban-regions. This can pose significant harm to structures, electricity and transportation in residential and commercial zones in the city. The reduction or avoidance of such impacts requires proper inclusion of climate adaptive solutions into urban planning and governance. For e.g. integrating green-blue infrastructure at locality, city and regional levels that promote roof gardens, soft-landscapes around roads, revival of urban lakes and forestry, ground-water recharging, etc.

Situation 2: Around 7 out of 49 cities show depleting precipitation along with spiking temperatures, that will thwart air-conditioning load and urban energy demand particularly during summers. Cities like Bangkok, Tianjin, Manila, Ho Chi Minh, Nagoya, Tehran, Lahore endure declining levels of rainfall conditions will need to spend heavily in water infrastructure, efficient-management of potable water system, demand-side management and consumer awareness, making power systems and transportation resilient, heat resistant, energy saving buildings, controlling urban sprawl and carbon footprint, transit-oriented development, urban farming, etc. Over withdrawal of water has severe environmental, social and economic impacts that range from social disputes and tensions over water, dominance of water-mafia, disturbance or exploitation of ground-water, land subsidence to name a few. Thus, such communities or municipal governments will require adaptive measures focused on wastewater recycling, rainwater harvesting and rejuvenating natural aquifers.

Table 4: Description of impacts and plausible solutions for sample of Asia-Pacific cities experiencing different temperature and precipitation in future

Case	Projected temperature (Med)	Projected precipitation (Med)	Observation	Cities	Description of Impacts	Plausible solutions
1	Increase	Increase	42	New Delhi, Mumbai, Kolkata, Bangalore, Chennai, Hyderabad, Ahmedabad, Surat, Pune, Singapore, Dhaka, Tokyo, Sydney, Melbourne, Beijing, Shanghai, Shenzhen, Guangzhou, Jakarta, Kuala Lumpur, Yangon, Karachi, Chongqing, Chengdu, Nanjing, Wuhan, Xian, Hangzhou, Hong Kong, Dongguan, Foshan, Shenyang, Suzhou, Harbin, Qingdao, Dalian, Jinan, Zhengzhou, Seoul, Fukuoka, Chittagong, Osaka	Increase in thermal loads (air-conditioning) particularly during monsoons, energy consumption, urban flooding, rising pumping energy and costs in drainage, submergence of power systems and transportation routes during floods, preventive power-cuts,	Green building, Smart meters, DSM- peak shaving devices, rain-water harvesting, recharging of ground water aquifers, rejuvenating surface water bodies, creating roof gardens and soft landscapes for greater percolation, flood resilient mobility alternatives
2	Increase	Decrease	7	Bangkok, Tianjin, Manila, Ho Chi Minh, Nagoya, Tehran, Lahore	Ground water depletion, heat waves, urban heat island, drought like conditions, Increase in air-conditioning particularly during summers, rising pumping energy and costs in water supply, melting and deformation of power cables/ installations, short-circuits in electric and metro systems, load-shedding, etc.	Afforestation & greening, green building, smart-grids, installation of rooftop solar PV, recycling water and rainwater harvesting in buildings, demand management systems or building information systems, smart meters, geothermal heat pumps, heat resistant power networks, transport systems, power back-up for industries, offices and homes during load shedding
3	Decrease	Decrease	-	None observed	-	-
4	Decrease	Increase	-	None observed	-	-

Beyond the select cases discussed here, Asia-Pacific cities bearing different geo-climatic, economic and policy conditions have a range of promising urban climate solutions to opt from. Several of the highest-potential solutions for e.g. transit oriented development, electric mobility, net-zero emission buildings, waste to energy, rainwater harvesting, green roofs are applicable in most situations. These can be applied further keeping into consideration local factors like techno-economic feasibility of projects, their environmental and social impacts as well as governance mechanisms for ground-level implementation.

4. Conclusions & Recommendations

The ICLAP tool empowers climate researchers, policy makers and urban agencies equally about mitigation and adaptation targets, evaluate possible policy alternatives (based on factual data and global case studies) as per their own circumstances. It facilitates the process of data integration ensuring that decision-making becomes more scientific, realistic and verifiable. We conclude by recommending short to long-term implication of using ICLAP in urban climate policy across multi-levels of governance, highlighting its relevance in city-level climate planning and monitoring, regional climate action, implementing global Sustainable Development Goals (SDGs), capacity development and environmental cooperation:

Urban climate planning and monitoring: Effective climate planning and management requires to develop a strategy, evaluation plan and monitoring framework to pursue urban climate agenda in a city's overall development objectives. Measurable indicators as used in ICLAP provide quantifiable information about baseline conditions and planned actions. ICLAP integrates datasets from three different knowledge domains– regional climate variability (temperature, rainfall, etc.), GHG emissions and ex-post studies capturing urban climate practices from across the world. Using such a smart monitoring framework, a city can orient their urban strategy with their climate goal. This enables a feedback loop in planning process by which local stakeholders and decision-making agencies have verifiable data to evaluate outcomes of their climate actions and influence future targets. Thus, by sheer practicability, ICLAP finds direct application in not just city CAPs but also national urban policy and financial initiatives to assist concerned stakeholders in evaluating their targets, stock-taking and prioritizing actions.

Regional climate action: ICLAP directly contributes to the goals of the Asia-Pacific Network's ongoing Fifth Strategic Plan i.e. research, capacity development, science-policy interactions, community engagement (APN 2015) and relating issues identified for innovative evidence-based decision making tools (APN 2019), including improving climate projections to address impacts at multiple-levels, extreme events related to monsoons, increasing resilience of local communities to climate impacts, policy research on the implementing NDCs, and facilitating mitigation policies on energy efficiency and GHG reduction. In particular, application of ICLAP is highly pertaining to the current environmental, climate mitigation, adaptation and urban development programmes of rapidly developing and urbanizing Asia-Pacific countries like India (GNCTD 2017), Thailand (ONEP 2015) and China (NDRC 2007).

Contribution to global sustainability

ICLAP bears global relevance in supporting implementation several global SDGs (Assembly 2015), mainly Goal 7, 10-13 & 17 and the New Urban Agenda (UN-Habitat 2016) in purposefully guiding local development strategies. For e.g. the tool demonstrates how controlled urbanization, compact city-development, integrated landuse-transport, greater urban greens can contribute in reducing local pollution along with minimizing global GHGs. As such, outcomes from ICLAP relate to programmes of several international organizations/ networks like UN-Habitat, UN, World Bank, WWF, Cities Alliance, World Resources Institute, ICLEI- Local Governments for Sustainability and directly relevant to IPCC's Sixth Assessment Report and national reporting of NDCs to the UNFCCC.

Developing inter-disciplinary knowledge and capacities: Finally, integrated models provide an opportunity for partnership between inter-disciplinary experts, city managers to facilitate platform for exchanging knowledge that can ultimately build capacities for technical and local governance processes. In the long-term, ICLAP like metrics and tools act as an instrument of science-based policy application in multi-level sustainable development, encouraging public-participation and cooperation with the private sector. Since the climate change phenomenon has global causations and consequences, ICLAP like urban climate tools promote inter-city comparisons, interactions with intercontinental city forums, scientist community, non-governmental organizations, businesses and general public. In this regard, national governments, regional and international scientific bodies (like APN in this case) have potential in supporting integrated and collaborative scientific tools bearing significant applicability on the ground to combat global climate challenge.

END

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