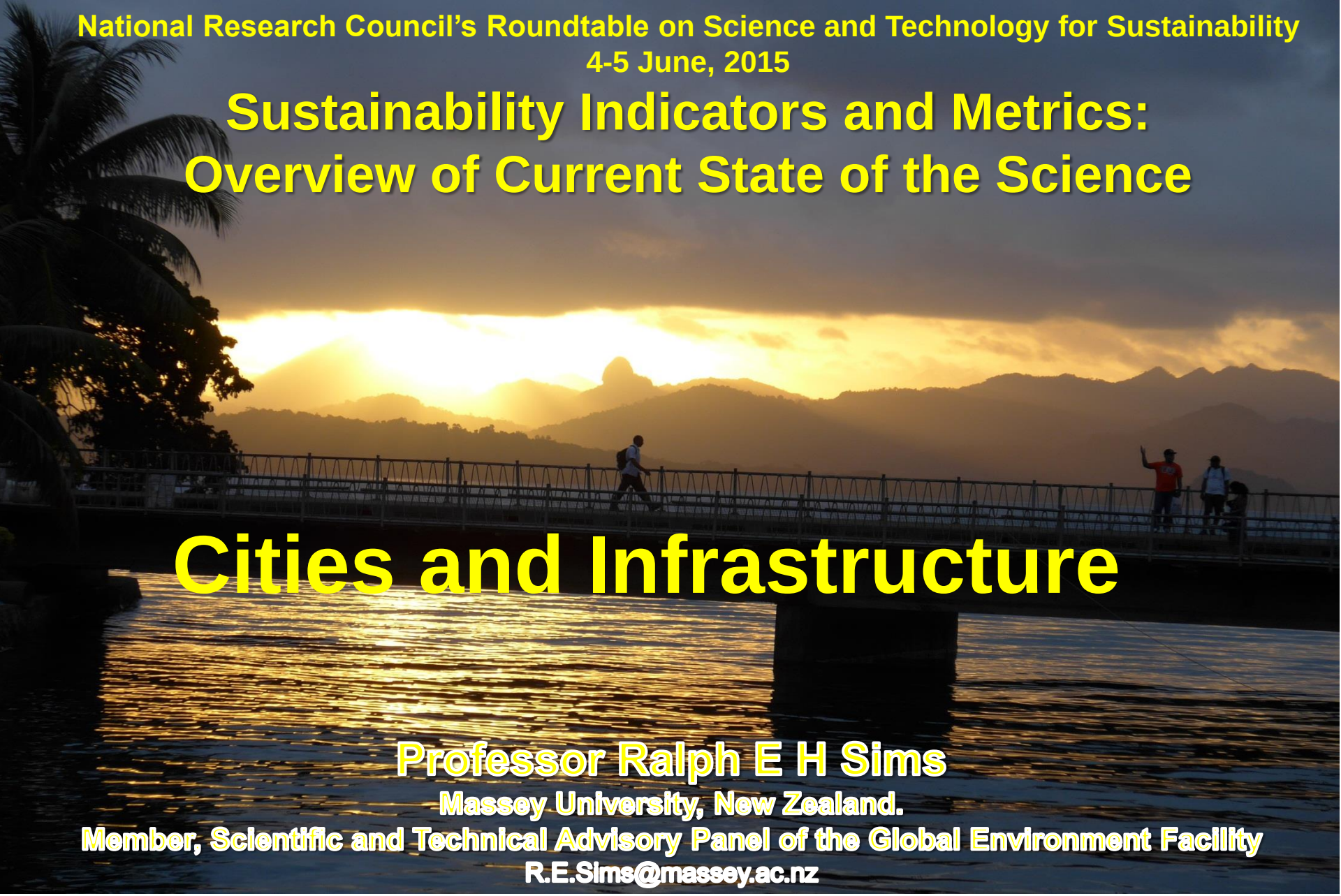
National Research Council's Roundtable on Science and Technology for Sustainability
4-5 June, 2015

Sustainability Indicators and Metrics: Overview of Current State of the Science



Cities and Infrastructure

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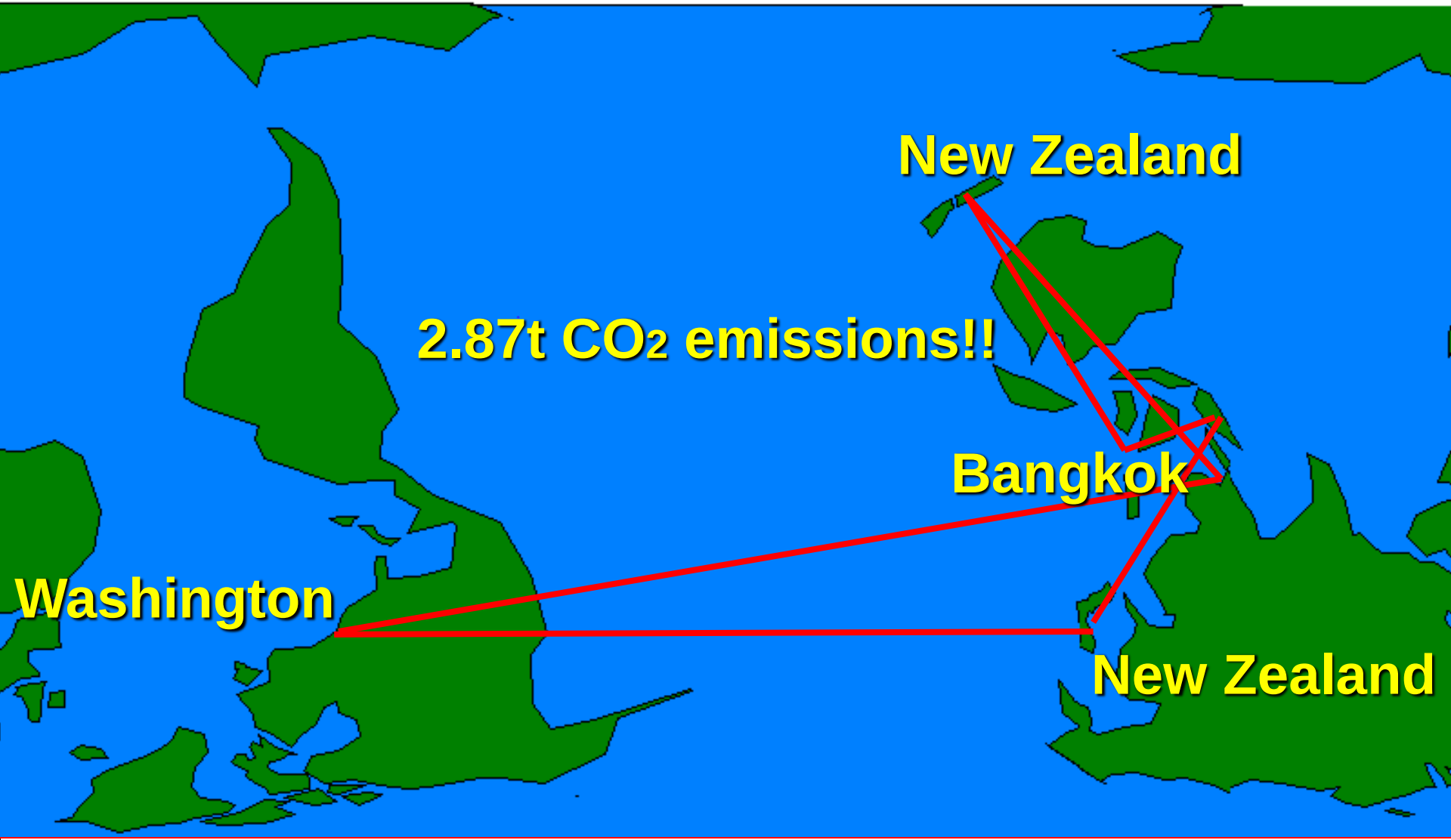
Scientific and Technical Advisory Panel of the Global Environment Facility

STAP gef UNEP

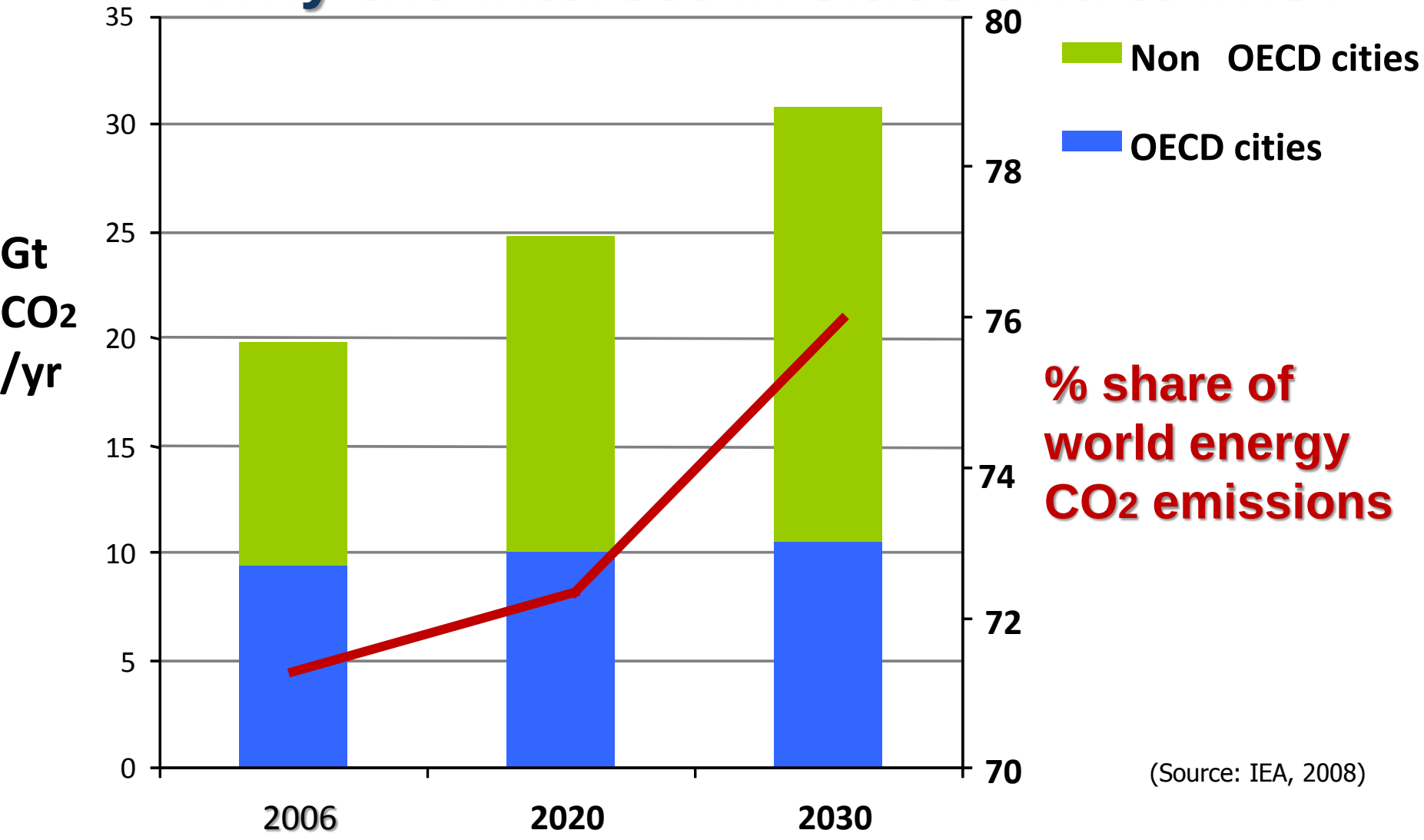
MASSEY UNIVERSITY

The Correct Map of the World




The GEF has a new “Integrated Approach Pilot” on *Sustainable Cities.*
23 cities in the pilot from 11 countries.
Given every city is unique, if a city receives say $50 - 100 M (from the GEF plus co-financing) to make it more sustainable, then what indicators can we apply to measure achievements in terms of local and global environmental benefits?
How has the city become more sustainable?
Note: This is a *work-in-progress!*

Why the interest in cities and towns?



The share of global energy-related CO_2 emissions will increase from 71% in 2006 to 76% in 2030

Cities can regulate

- land use
- infrastructure
- public transport
- water supply

Cities own

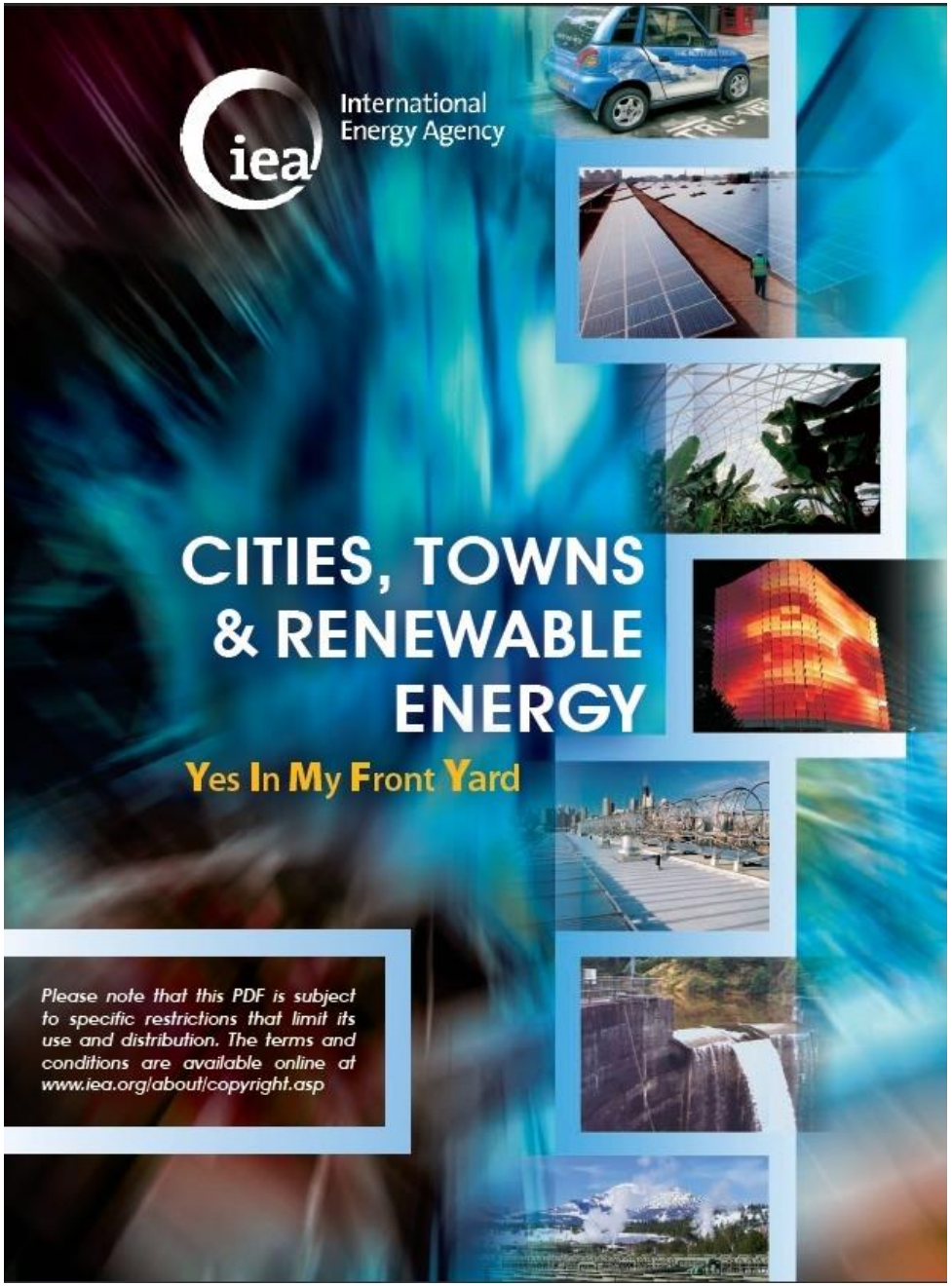
- public buildings
- land and green space
- vehicle fleets
- waste treatment facilities

Cities are close to the community

with proximity to

- citizens
- local businesses

“YIMFY”


International Energy Agency
iea
CITIES, TOWNS & RENEWABLE ENERGY
Yes In My Front Yard
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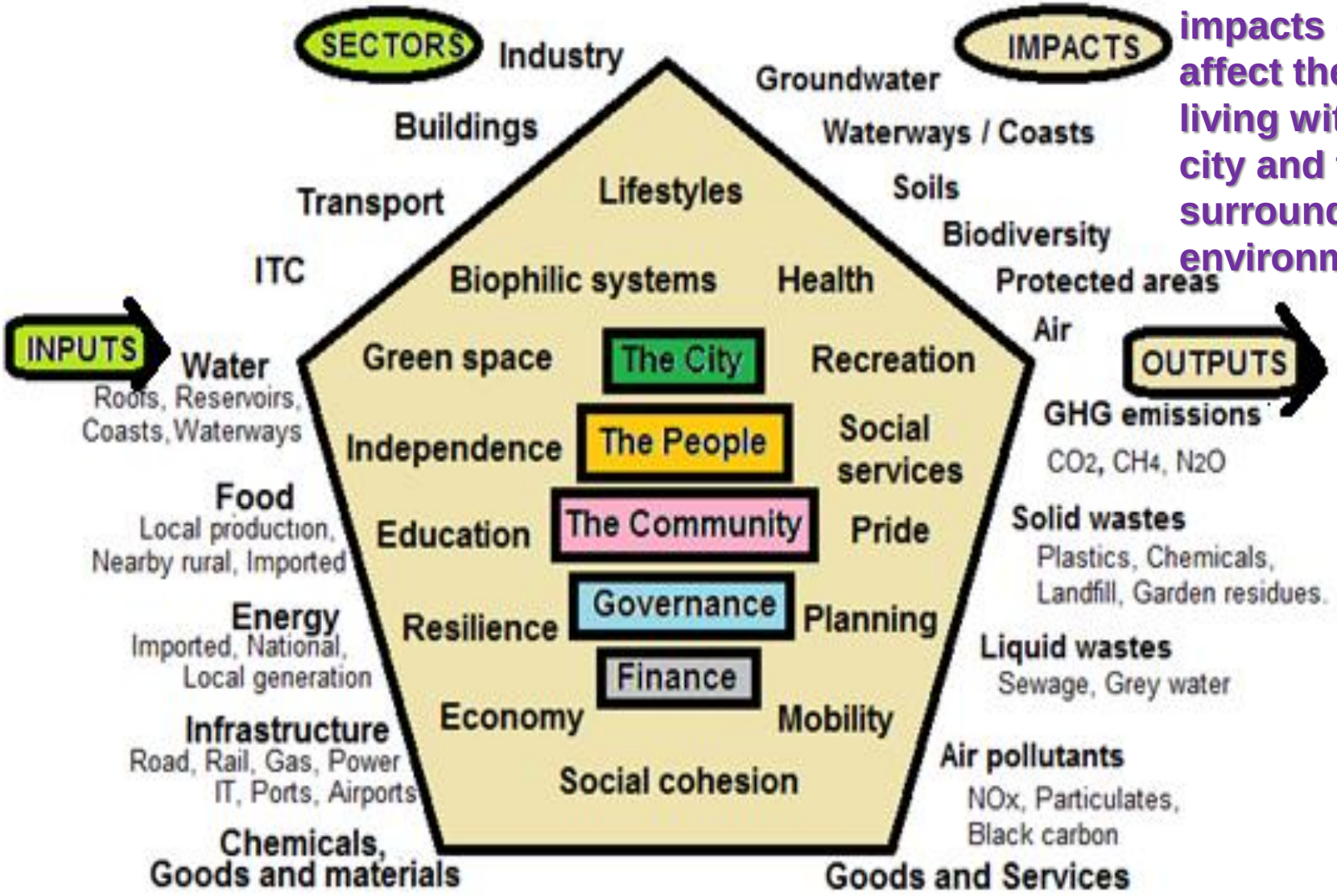
GEF Integrated Approach Pilots

Taking Deforestation out of the Commodities Supply Chain

Sustainable Cities – Harnessing Local Action for Global Commons

Fostering Sustainability and Resilience for Food Security

Inputs and outputs of a city or town



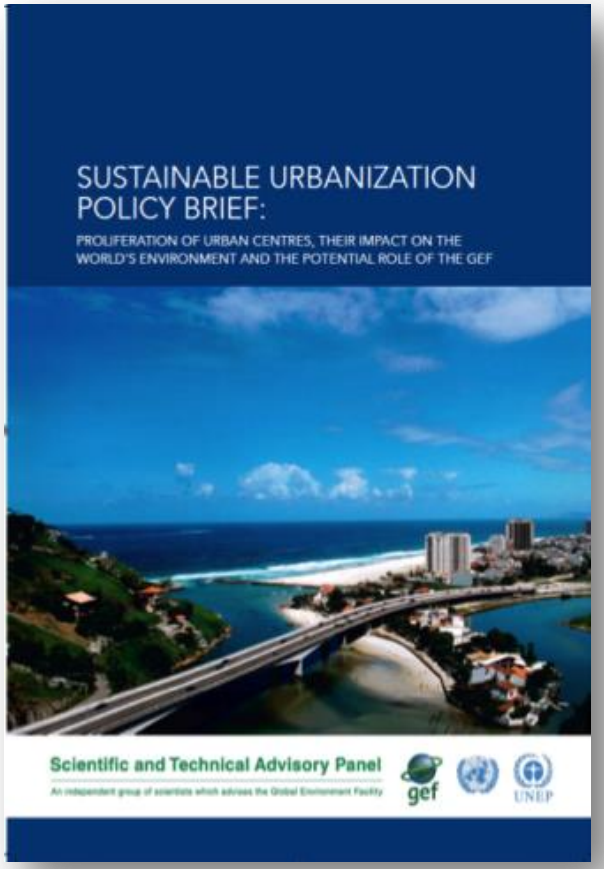
Potential impacts can affect the people living within the city and their surrounding environment.

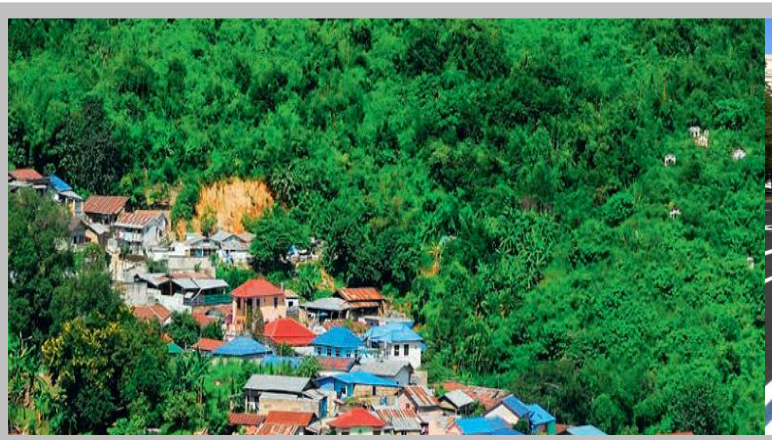
Sustainable cities has become a crowded space with many organisations using indicators.

ISO 37120 has 100 indicators that cities can measure and a pilot of 20 cities has been undertaken by WCCD (World Council on City Data).

The incentive for a city to be certified is to gain better credit worthiness.

A compilation of indicators has been produced by World Bank and STAP.





1) ENVIRONMENTAL Indicators

Planning	**Presence of a national sustainable urban and human settlements policy framework developed through participatory processes**
	Existence of a participative planning process
	Existence of participatory budgeting
	Public reporting sessions per year

Climate Mitigation	**Existence and monitoring of greenhouse gas inventory**
	Per capita GHG emissions
	GHG emissions / unit of GDP
	Existence of mitigation plans, with reduction targets by sector and a monitoring system in place
	Annual direct CO_2 emissions emitted from urban territory by major sector (industry, transport, households)

Resilience/Adaptation	**Percent of local governments that are implementing risk reduction and resilience strategies.**
	Existence of risk maps that include threats and a vulnerability analysis.
	Population living in informal settlements
	Existence of adequate contingency plans for natural disasters
	15 others

Energy	**Carbon intensity of electricity supply**
	Percentage of population with access to natural gas supply
	Total electrical energy use per capita (kWh/year)
	Existence and enforcement of energy efficiency regulations
	The percentage of total energy derived from renewable sources
	LPG , kerosene use for private heating (kg/household/year)
	District heating/cooling network (GJ/year)
	Energy consumption of public buildings (kWh/m^2)
	Energy consumption for public lighting (kWh/lighting point)
	27 Others

OTHER ENVIRONMENTAL Indicators

Solid waste: 27 indicators
Water supply and use: 13
Waste water and treatment: 12
Sanitation and drainage: 6
Transport
–passenger and freight: 35
Land use and green space: 21
Food supply: 5
Air pollution: 15
Biodiversity: 30
Material flows and resources: 14

2) SOCIAL Indicators

Access to Services	
Informality	Percentage of urban population living in slums or informal settlements
	Areal size of informal settlements as a per cent of city area (%)
Poverty and inequality	Percentage of the population below the poverty line/Percentage of city population living in poverty
	Percentage of housing located in informal settlements
Housing	Total number of occupied dwelling units (owned & rented)
	Persons per unit
	Dwelling density (per square kilometre)
	Housing quality (Average area of living accommodation m2)
	Housing cost (Average price per m2 for an apartment)
	Social housing (households living in social housing/total households)
Employment	Unemployment rate
	Percentage of persons in full-time employment
	Jobs/housing ratio

3) GOVERNANCE/FINANCE Indicators

Participation	Voter participation in last municipal election
	Citizens' representation
	City representatives who are women %
Budget	Existence of a multi-annual budget
	Gross operating budget per capita
	Gross capital budget
	Gross capital budget per capita
	Remuneration of personnel based on a system of performance indicators
	Own-source revenue as a percentage of total revenues
	Tax collected as a percentage of tax billed
Systems of public management	Existence of electronic systems for tracking the municipality's management
	Existence of electronic procurement systems
Taxes/fiscal autonomy	Own income as percent of total income
	Property taxes as a percentage of total income
	Total transfers as a percentage of total income
	Ear-marked transfers as a percentage of total transfers
	Income from other sources (external donors) as a percentage of total income
	Taxes collected as a percentage of taxes billed
Debt	Debt service ratio
	Total debt as a percentage of total income
	Annual growth in debt service
	Debt growth
	Contingent liabilities

Sustainable Cities – Harnessing Local Action for Global Commons

For this IAP, the STAP:

- contributed to concept development in working groups led by the World Bank;
- provided input on indicator development;
- agrees with having limited common indicators and the flexibility for a city to select others;
- sees benefits from having additional indicators related to resilience;
- recommends broader stakeholder engagement recognizing the complex social and governance issues; and
- offers to assist further with knowledge management aspects of the IAP.

Tools and metrics of the IAP

A common set of *tools* are essential to help cities develop and implement their sustainability plans, assess their short and long-term aspects, and arrive at comparable and agreed diagnoses between cities.

Four (4) tools have been identified:-

1: Common metrics and consistent terminology.

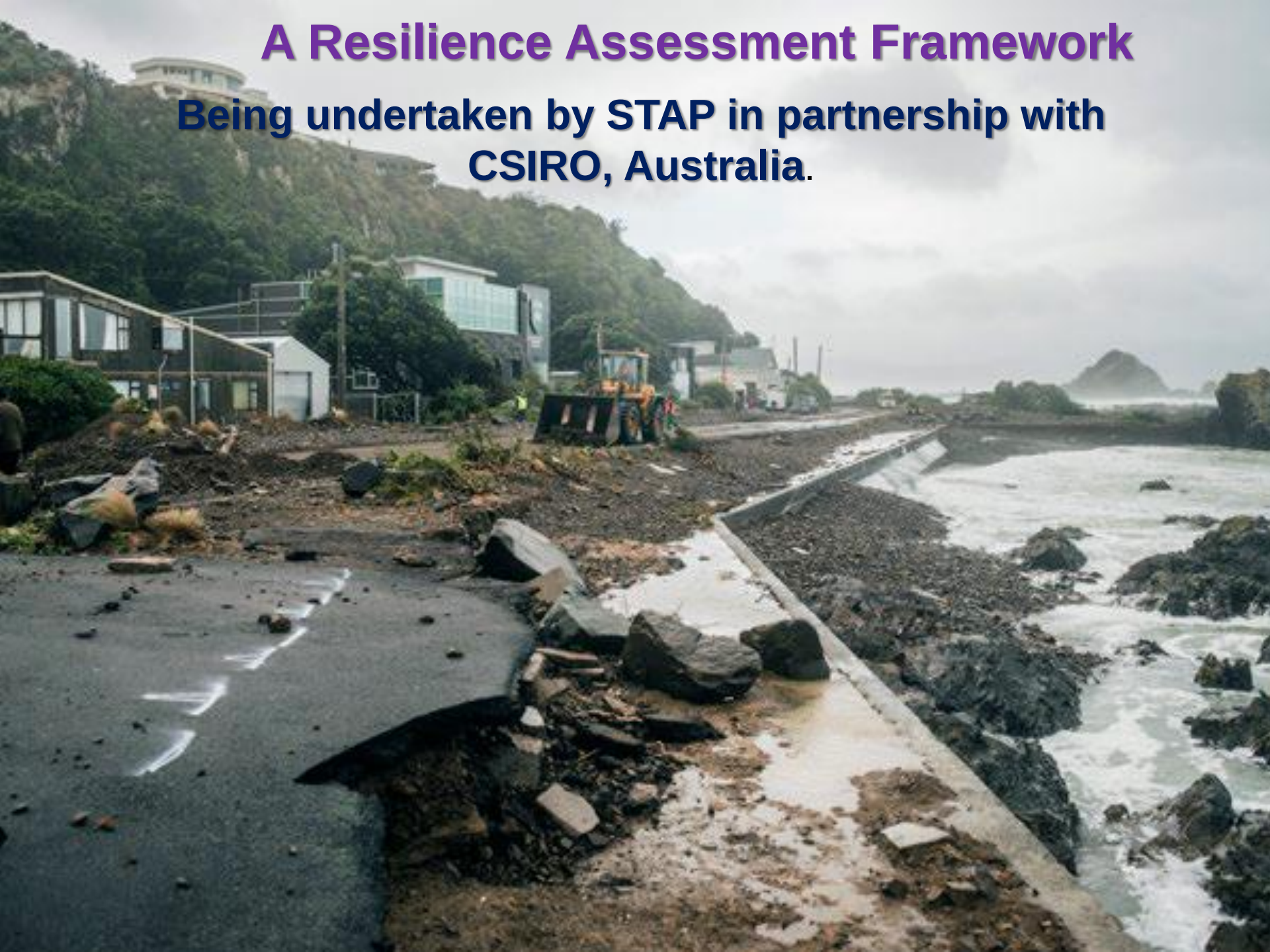
2: Quantifying energy and material flows through urban metabolism assessments.

3: Identifying and analyzing local and global system boundaries, key limits such as climate change and biodiversity, and consistency with the tenets of sustainable development.

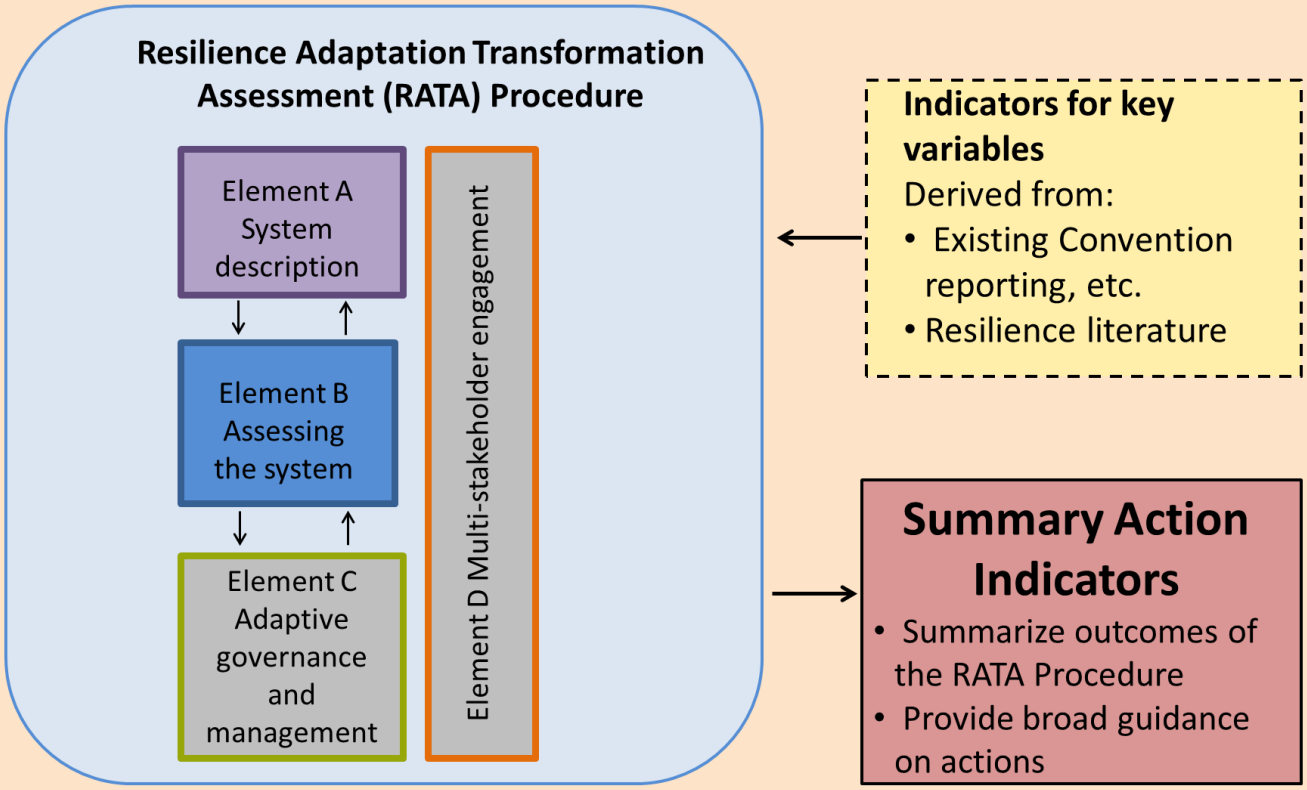
4: Identifying a hierarchy of urban management that prioritizes service provision, decreasing emissions and environmental impact, and increasing resilience.

A Resilience Assessment Framework

Being undertaken by STAP in partnership with CSIRO, Australia.



Resilience Adaptation Transformation Assessment (RATA) Framework



Meta-indicators

Coverage

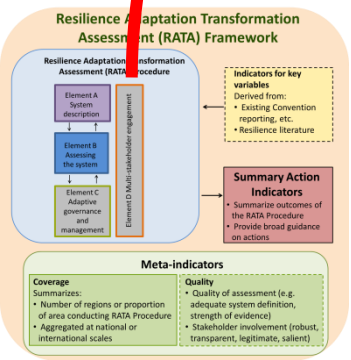
Summarizes:

- Number of regions or proportion of area conducting RATA Procedure
- Aggregated at national or international scales

Quality

- Quality of assessment (e.g. adequate system definition, strength of evidence)
- Stakeholder involvement (robust, transparent, legitimate, salient)

Resilience Adaptation Transformation Assessment (RATA) Procedure



Element A System description

Element A.1 Scope, scale, and a 'desirable' future system
Define purpose of analysis, system to be analysed. Define focal scale, and set system boundaries.

Element A.2 Resilience of what, to what?
Define what is valued by the users of the system, and the drivers and shocks that affect them.

Element A.3 Governance and social interactions
Describe levels of governance, rules for resource access and use, and the social processes for implementing them.

Element A.4 How the agroecosystem functions
Identify interactions between drivers, actors, main resource uses, main controlling variables, interactions across and within scales, and feedbacks.

Element A.5 Document A1-4 and synthesise conceptual model

Element B Assessing the system

Element B.1 Alternative regimes
Describe other regimes the system could potentially enter by preference or by crossing thresholds unintentionally.

Element B.2 General Resilience
Describe general capacity of the system to cope with unfamiliar shocks.

Element B.3 Specified resilience
Access trends in the controlling variables, proximity to thresholds, potential interactions among thresholds.

Element B.4 Identify the need for adaptation and/or transformation
Define the need for the system, or any described parts of the system, to adapt to maintain resilience, or transform to a different system.

Element B.5 Synthesis of Assessment and Summary Classification
Synthesize findings after multiple iterations, identify windows of opportunity (adaptive cycle), and document Resilience Summary Indicators for final reporting.

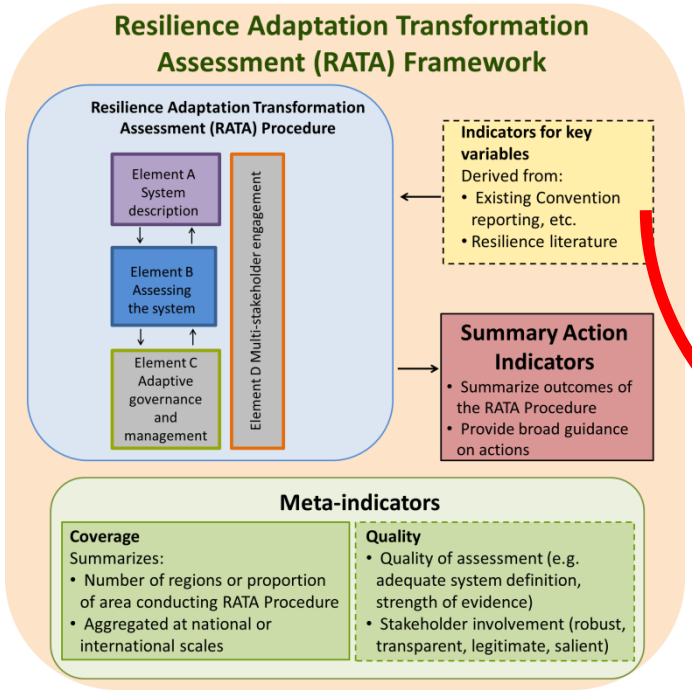
Element C Adaptive governance and management

Element C.1 Identify possible intervention options
Including changes in laws, policies, investments and management practices and considering decision sequencing, path dependencies, based on B.5 outcomes and windows of opportunity.

Element C.2 Act on assessment: Initiate and manage adaptation/transformation pathways

Element C.1 Monitor, learn, revisit, report, etc.

Element D Multi-stakeholder engagement-robust, salient, legitimate, transparent

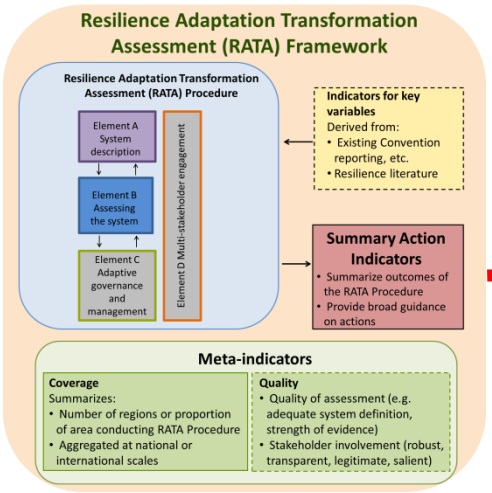


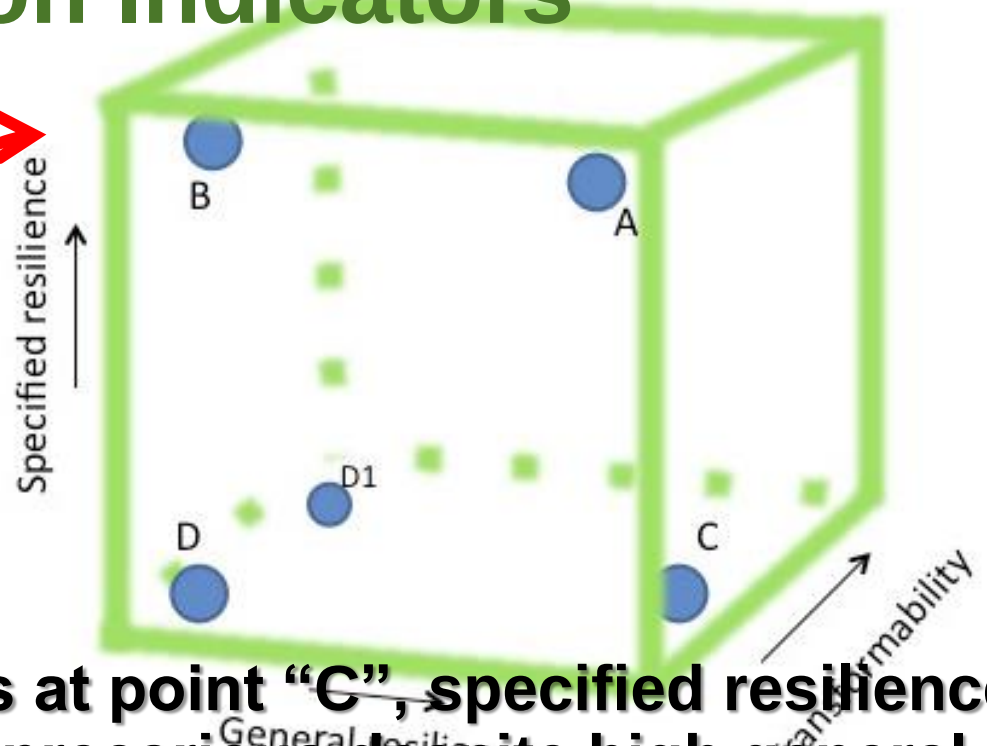
For key input variables, many existing indicator sets could be used (WCCD, UNFCCC).

- **Need a 'screen' to find the most appropriate indicators for the purpose.**
- **GEF, STAP and WB focusing resources and effort on determining the most relevant indicators for the Cities IAP.**

General resilience Indicators	Rationale and assumptions	Potential sources of information on levels and trends
Ecosystem diversity and productivity of native vegetation rangelands	Natural ecosystem enhances this agroecosystem's general resilience, and degradation trends are eroding that general resilience	Remote sensing, field measurements
Connectivity of transhumance routes	Loss of options for seasonal transhumance places more pressure on rangelands in the wet season, so reducing quality forage productivity and so general resilience	Household surveys, land use maps
Seasonal migration opportunities	Options to for dry-season migration relieve pressure on household food stores and bring in additional household income	Household surveys
Participation in farmer-led institutions	Farmer empowerment (for men and women) is a key way to strengthen the sharing of conceptual models (between farmers, and between farmers, researchers and development agencies), learning and experimentation, so building general resilience.	Household and institutional surveys, statistics on membership of associations and political parties
Human Development Indicators and Gender Inequality Indices	These indicators are extremely poor at present, and improvements would indicate some lifting of human and social capital, which is a necessary underpinning for general resilience	UNDP, access to education, health, communication services
Capital reserves (per capita)	Human, natural, social and built capital reserves all build options, and so general resilience	National accounts, availability of insurance, banking, grain stores, livestock census
Institutions governing	Good stewardship of shared resources increases	Household surveys, National

Summary Action Indicators



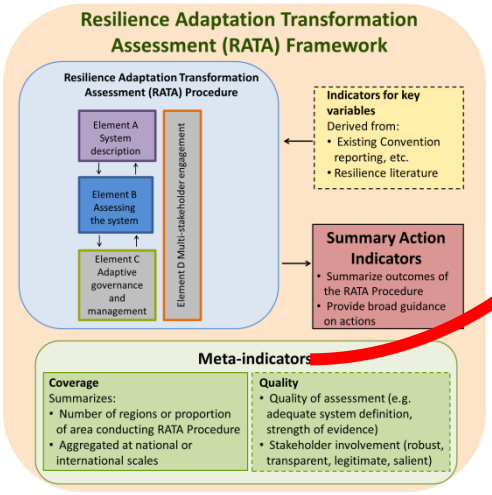


If for example, a city is at point "C", specified resilience is low so the future is precarious despite high general resilience because it is approaching thresholds.

Possible interventions:

- **Improve high general resilience to move away from the threshold.**
- **If likelihood of this is low, intentional Transformation is necessary.**
- **If either of above options are not feasible, then have a back-up plan for crises (eg famine relief; flood control).**
- **Urgency depends on the trend rates and closeness to thresholds.**

Meta-indicators:



Coverage indicators

The number of sub-national regions or agro-ecosystems.

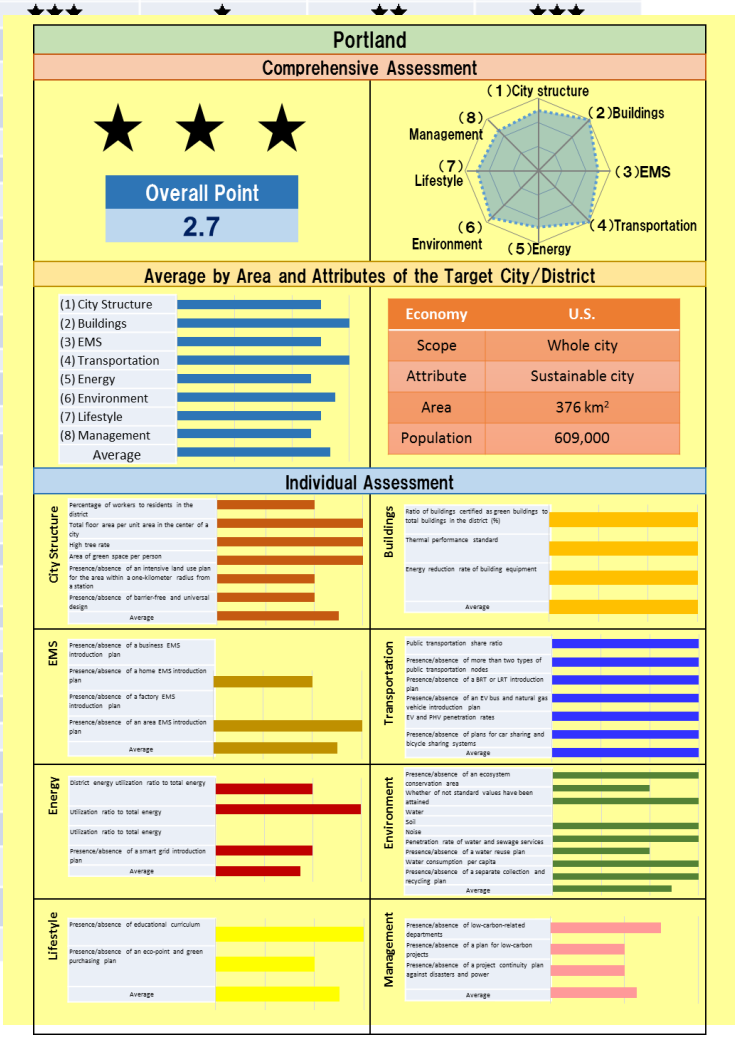
Proportion of area in any nation that has conducted a resilience assessment.

Quality indicators

can be used to test robustness, transparency, legitimacy and prominence of stakeholder engagement.

APEC's "Low-Carbon Towns" project.
Sensitivity analysis and trial use of Indicators

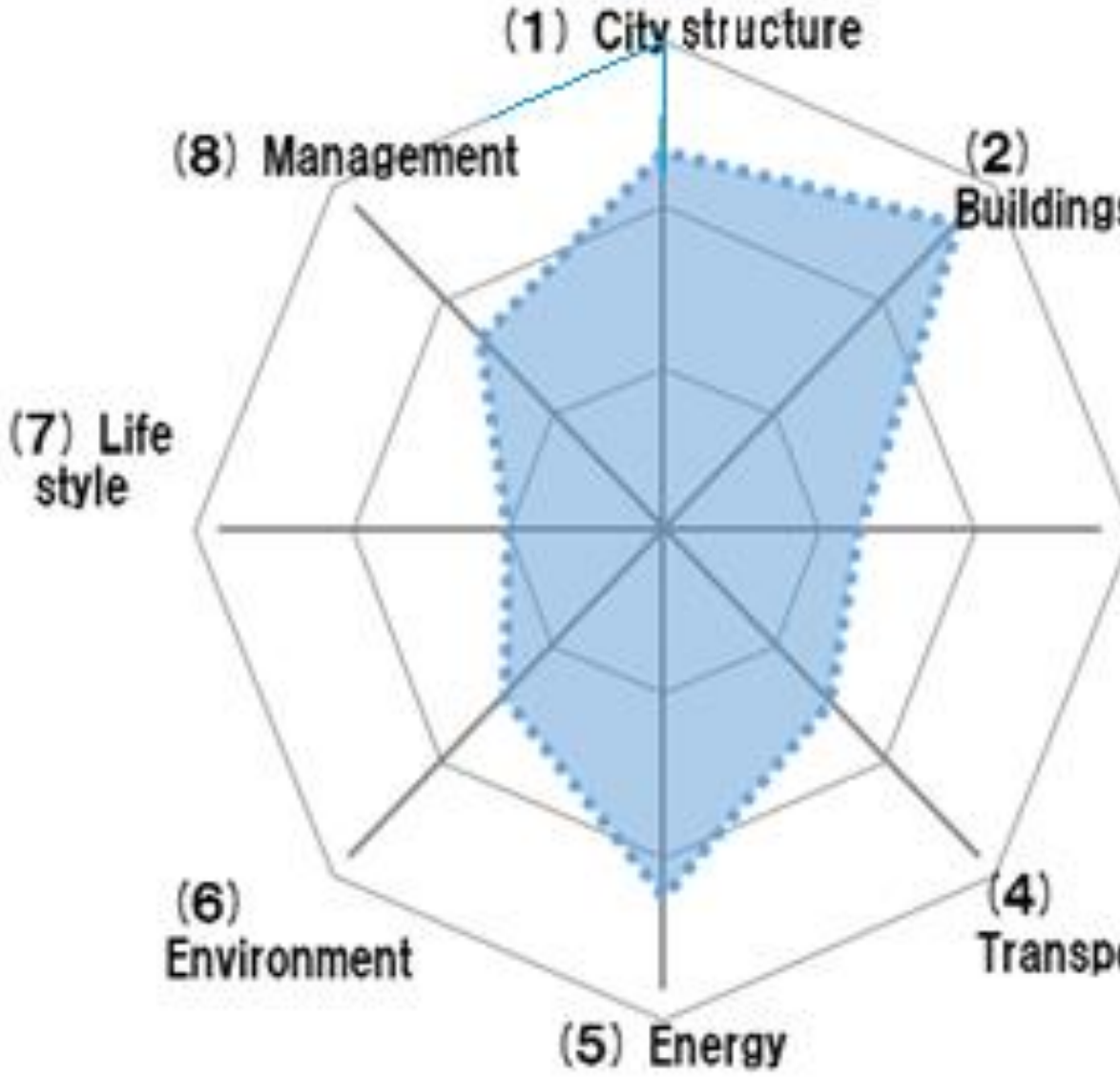
		Kashiwanoha	Yokohama	Portland	Denver	Kazan	Kaluga
(1) City Structure	Percentage of workers to residents in the district	★★★	★	★★	★★	★★★	★★
	Total floor area per unit area in the center of a city	★★★	★★★	★★★	★	★★	★★★
	High tree rate	★★	★	★★★	★★★	★★★	★★★
	Area of green space per person	★★★	★★	★★★	★★★	★★★	★★★
	Presence/absence of an intensive land use plan for the area within a one-kilometer radius from a station	★★★	★★★	★★★	★★★	★★★	★★★
	Presence/absence of barrier-free and universal design	★★★	★★★	★★★	★★★	★★★	★★★
(2) Buildings	Ratio of buildings certified as green buildings to total buildings in the district (%)	★★★	★★	★★★	★★★	★★★	★★★
	Thermal performance standard	★★★	★★	★★★	★★★	★★★	★★★
	Energy reduction rate of building equipment	★★★	★★	★★★	★★★	★★★	★★★
(3) EMS (Energy Management Systems)	Presence/absence of a business EMS introduction plan	★★	★★	★★★	★★★	★★★	★★★
	Presence/absence of a home EMS introduction plan	★★	★★	★★★	★★★	★★★	★★★
	Presence/absence of a factory EMS introduction plan	★★	★★	★★★	★★★	★★★	★★★
	Presence/absence of an area EMS introduction plan	★★★	★★	★★★	★★★	★★★	★★★
(4) Transportation	Public transportation share ratio	★★★	★★★	★★★	★★★	★★★	★★★
	Presence/absence of more than two types of public transportation nodes	★★★	★★★	★★★	★★★	★★★	★★★
	Presence/absence of a BRT or LRT introduction plan	★★★	★★★	★★★	★★★	★★★	★★★
	Presence/absence of an EV bus and natural gas vehicle introduction plan	★★★	★★★	★★★	★★★	★★★	★★★
	EV and PHV penetration rates	★★	★★	★★★	★★★	★★★	★★★
	Presence/absence of plans for car sharing and bicycle sharing systems	★★★	★★★	★★★	★★★	★★★	★★★
(5) Energy	District energy utilization ratio to total energy	★★★	★★★	★★★	★★★	★★★	★★★
	Utilization ratio to total energy	★★★	★★	★★★	★★★	★★★	★★★
	Utilization ratio to total energy	★★★	★★	★★★	★★★	★★★	★★★
	Presence/absence of a smart grid introduction plan	★★★	★★★	★★★	★★★	★★★	★★★
(6) Environment	Presence/absence of an ecosystem conservation area	–	★★★	★★★	★★★	★★★	★★★
	Air	★★★	★★★	★★★	★★★	★★★	★★★
	Water	★★★	★★★	★★★	★★★	★★★	★★★
	Soil	★★★	★★★	★★★	★★★	★★★	★★★
	Noise	★★★	★★★	★★★	★★★	★★★	★★★
	Penetration rate of water and sewage services	★★★	★★★	★★★	★★★	★★★	★★★
	Water consumption per capita	★★★	★★	★★★	★★★	★★★	★★★
	Presence/absence of a separate collection and recycling plan	★★★	★★★	★★★	★★★	★★★	★★★
(7)Lifestyle	Presence/absence of educational curriculum	★★★	★★★	★★★	★★★	★★★	★★★
	Presence/absence of an eco-point and green purchasing plan	★★★	★★	★★★	★★★	★★★	★★★
(8)Management	Presence/absence of low-carbon-related departments	★★★	★★★	★★★	★★★	★★★	★★★
	Presence/absence of a plan for low-carbon projects	★★★	★★★	★★★	★★★	★★★	★★★
	Presence/absence of a project continuity plan against disasters and power outages	★★★	★★★	★★★	★★★	★★★	★★★



Note that the purpose of this indicator system is not to compare cities.

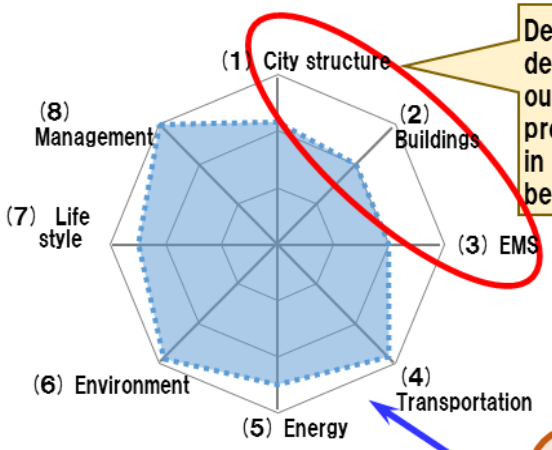
APEC sensitivity analysis and trial use of Indicators

Rader charts for a comprehensive assessment

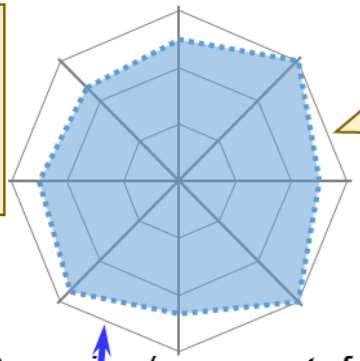


Energy management systems

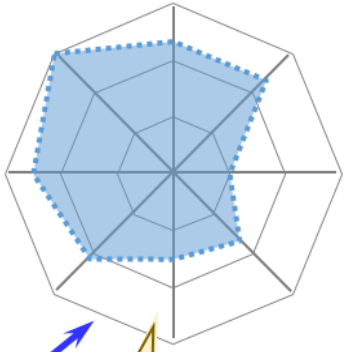
The attributes of a city as shown by a radar chart



Delay in the development outside the preceding districts in a large city can be observed.



It demonstrates a well-balanced shape reflecting the overall efforts of the small-sized city.

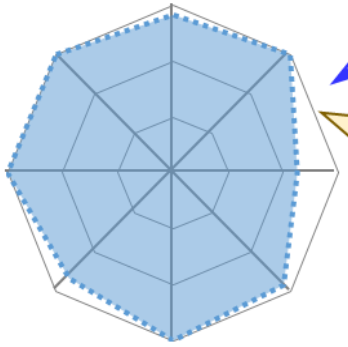


Comparison/assessment of the region's attributes

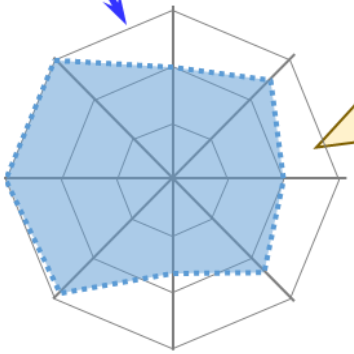
The attributes of a city and the shape of a radar chart (1)

Japan	U.S.	Russia
Yokohama	Portland	Kaluga
City vs District	*Low-carbon city vs Conventional city*	*Conventional city vs Low-carbon city* / *City vs District*
Kashiwanoha	Denver	Kazan

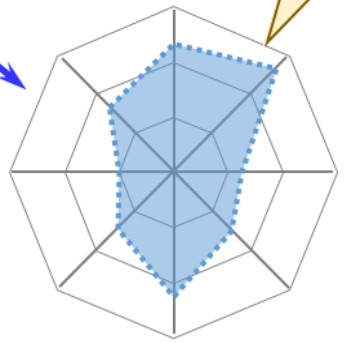
In an emerging region which is low-carbon and environmentally friendly by nature, no particular difference is observed between low-carbon and conventional cities and between a city and a district.



Kashiwanoha is a smart city representing Japan, and all items are well-balanced.



A conventional city in an environmentally advanced country is highly evaluated in the Environment, Life Style and Management categories.



Some principles for indicators

- Should be intuitive and easy to understand.
- Use existing datasets where possible.
- Reflect economic circumstances of the country.
- Should grasp the achievements made over time.
- Reflect the characteristics of the project.
- Should not obstruct sustainable development.
- Reflect global trends - such as smart community infrastructure assessment indicators (ISO TC268).
- Allow for “informal settlements” – whether to be included or not?
- Be comprehensive for the whole project as well as for each individual component.

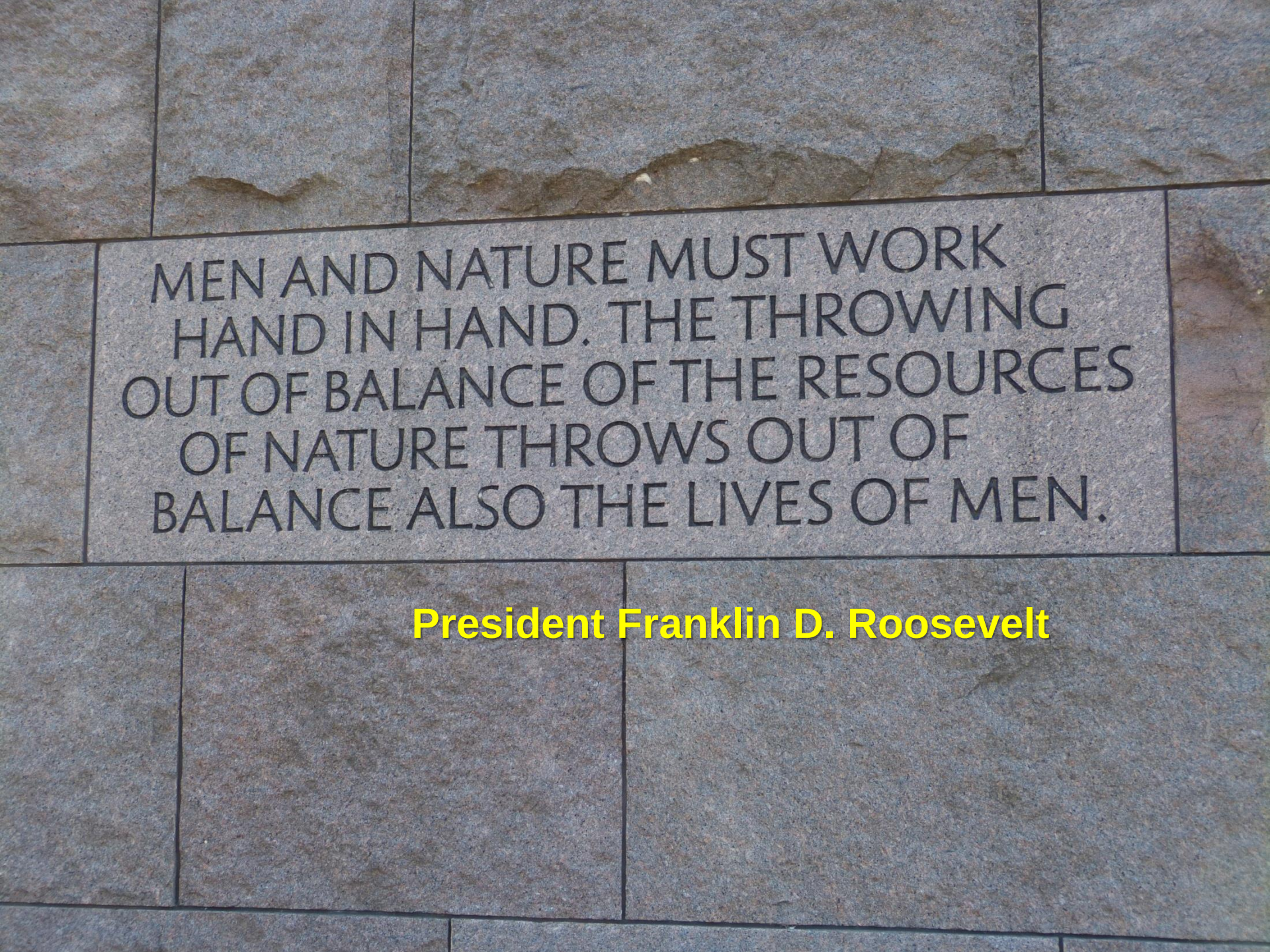
Indicators fit for purpose

A city assessment process is akin to a medical check-up:

- diagnosis of individual components;
- optional follow-up examinations;
- comprehensive diagnosis of the whole body;
- comments and treatment prescribed by a specialist;
- instructions for an additional examination in future;
- monitoring and evaluation by periodic check-ups.

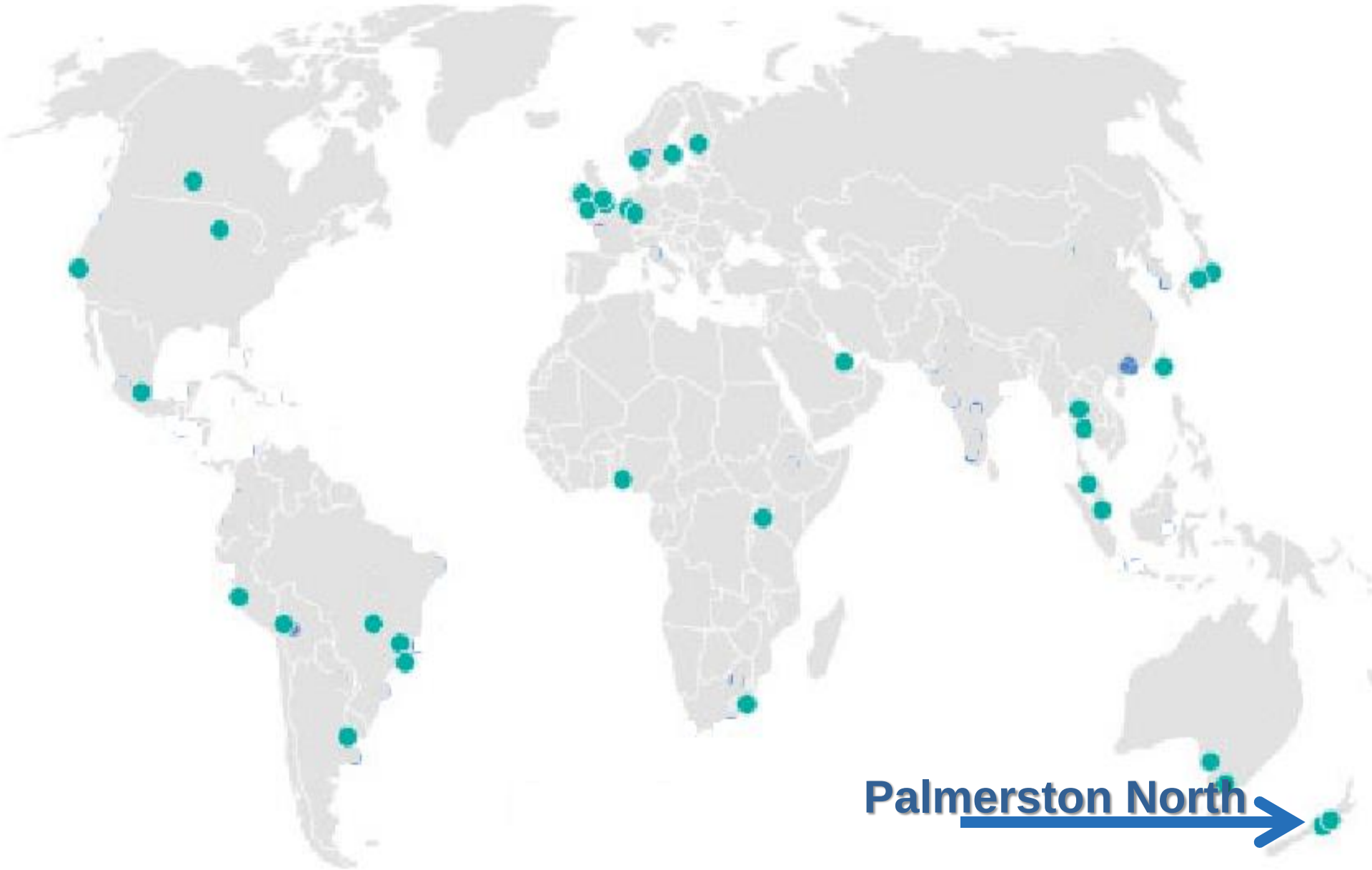
Overall, indicators for monitoring the move of a city towards improving its sustainability in the future:

- can be used for benchmarking or for making comparisons between cities but this is not the ideal purpose;
- should not be aimed at budget allocations by national governments or donor agencies; and
- can be most useful for assessing the quality of life for citizens, overall sustainability, and resilience to future shocks.


MEN AND NATURE MUST WORK
HAND IN HAND. THE THROWING
OUT OF BALANCE OF THE RESOURCES
OF NATURE THROWS OUT OF
BALANCE ALSO THE LIVES OF MEN.
President Franklin D. Roosevelt

The Greenhouse Gas Protocol gives cities a method to measure their emissions, develop effective emissions reduction strategies, set measurable and ambitious emission reduction goals, and accurately track their progress.

35 GHG Protocol Pilot Cities



Tool #1: Common metrics and consistent terminology

Common metrics and consistent terminology will be sought through applications of existing and emerging tools. Includes opportunities to work with WCCD, GCIF, ICLEI, C40, WRI et. al.

Additional Thoughts from STAP

- With the concept of the planet's physical boundaries in mind, how much are these taken up in the current suite of tools and indicators used for cities? Is there consideration of the supporting, provisioning, regulating and cultural services or benefits of ecosystem services in the creation of city indicators?

Eg. Apart from climate related considerations, how are biodiversity and soil productivity threats (eg Nitrogen) captured in city indicators?

Tool #1: Common metrics and consistent terminology (Additional Thoughts cont'd)

In order to create quality indicators there must be an evaluation of **ontology.** It could be that there may be several levels of this. Eg:-

- In the effort to make city indicators more sensitive to planetary and social boundary issues, one must consider the most meaningful, interrelated family of indicators that will help derive a realistic picture of trade-offs and consummate impact of a given development choice or action.

- In some instances, eg. The concept of "resilience", we need to make sure that we have a common understanding of "resilience", so we know what we want to capture.
  - Ecosystem services used socially and economically by humans,
  - Resilience is tied to sustainability*.
  - Therefore apart from the biophysical, can we consider other aspects of resilience (eg of social, institutional, risk management and knowledge systems?)

Tool #1: Common metrics and consistent terminology (Additional Thoughts cont'd)

- Can there be consideration of data flow vs statistical indicators? Is there a preference for one or other in the Cities Indicator sphere?

Tool #2: Quantifying energy and material flows through urban metabolism assessments

Seeks to quantify energy and material flows of cities, or urban metabolism. Can cover:-

- ✓ GHG inventories,
- ✓ measures of water consumption,
- ✓ waste and pollutant production,
- ✓ influence of cities on nitrogen and phosphorus cycles.
- ✓ emerging methods of determining the impacts of cities on global biodiversity loss also rely upon energy and material flow data (Singh and Kennedy, 2014).
- ✓ Recently standardized approaches to quantifying urban metabolism (Kennedy and Hoornweg, 2012; Kennedy et. al 2014)

Tool #2: Quantifying energy and material flows through urban metabolism assessments (cont'd)

Additional Thoughts from the STAP

- How are informal water, electricity, gas et. al. connections accurately captured?
- In general how to capture the urban metabolism elements of the informal settlements?

Manila Bay, Philippines.
Photo credits Dr. Veronique Morin

Tool #2: Quantifying energy and material flows through urban metabolism assessments (Additional Thoughts cont'd)

- ***Source**: UNEP DTIE Sustainable Consumption Branch*. One might consider the key findings of the Sustainability Institute (2013)* research on urban metabolism assessment methods and sustainable city indicators.
  - Current methodologies for assessing urban metabolisms are difficult for urban practitioners to translate into remedial actions that improve urban resource efficiency.
  - The dynamics of flows and stocks *within* the city are generally not accounted for in most methodologies, making it difficult to identify where interventions should take place.
  - Existing methodologies all have limitations when they are applied to cities, and need to be combined with other tools (or hybridized) to enable explicit decision making and policy formulation.
  - Simulation methods offer the most potential to compare optimal interventions in terms of their future impact on resources.

Tool #2: Quantifying energy and material flows through urban metabolism assessments (Additional Thoughts cont'd)

- Key findings arising from the examination of sustainable city indicator sets from the perspective of their usefulness in assisting city decision makers to improve resource efficiency* :

  - Metabolic flows are seldom considered or even mentioned in the predominant conceptions of sustainable cities, and measures of resource flows at city level are rare.

  - The conception of urban resource efficiency in sustainable city indicator sets is quite narrow, typically limited to improvements in resource productivity.

  - None of the indicator sets address issues of resource efficiency at the city scale holistically.

  - An understanding of resource flows is not sufficient to achieve a sustainable city. Resource efficiency needs to be complemented by social, cultural and political sustainability.

Tool #2: Quantifying energy and material flows through urban metabolism assessments (Additional Thoughts cont'd)

- A key limitation in quantifying resource flows and efficiency indicators in a systematic manner is a lack of adequate data.
  - ✓ lack of city-level data,
  - ✓ unsuitable data formats,
  - ✓ incompatible boundary delineations (i.e. what constitutes "the city"),
  - ✓ data confidentiality issues,
  - ✓ lack of data on informal sectors and locations,
  - ✓ difficulties in capturing data and inaccurate downscaling of national data.

Tool #2: Quantifying energy and material flows through urban metabolism assessments (Additional Thoughts cont'd)

A focus on 6 key resource types has been proposed for simplification of the data collection process: "first order" resources that all cities should measure, and "second order" resources that can be measured once cities have built sufficient capacity for data collection.

- ✓ First Order Resources: Water, Energy, Solid Waste*
- ✓ Second Order Resources: Food, Construction Materials, Land Use

Critical first step is to establish a city's baseline efficiency level with an assessment of a city's unique needs, and identification of locally available resources to meet those needs. This is a type of boundary setting exercise.

Tool #3: Identification of a hierarchy of urban management that prioritizes service provision, increasing resilience and decreasing emissions and environmental impact:

The IAP focuses heavily on urban waste management hierarchies (reduce, reuse, recycle, and recover), and improvements through the lens of an urban management hierarchy of: (i) basic service provision; (ii) service coverage and reliability; (iii) connectivity, resilience, integrated finance; and, (iv) sustainability.

***Additional STAP Thoughts*:-**

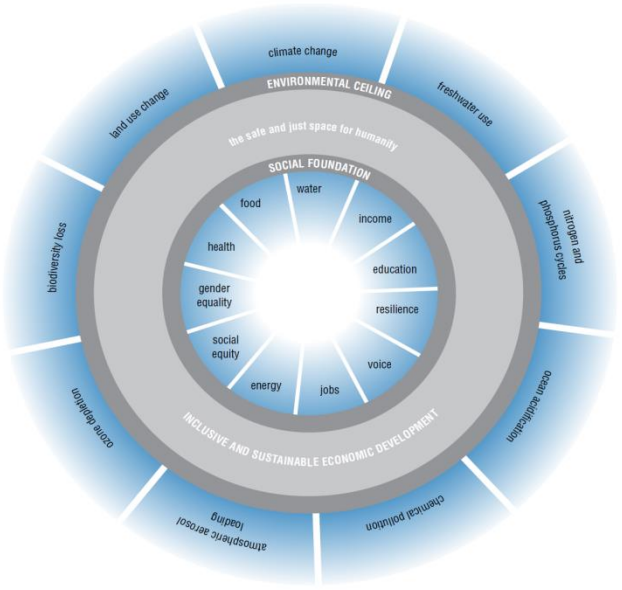
An expanded consideration of urban resource metabolic flows (as discussed for Tool #2) will necessitate a more comprehensive approach to Tool #3.

Tool #4: Identification and analysis of local and global system boundaries

The IAP seeks to develop a tool for urban system boundaries analysis (biophysical and social-economic) (recall the Raworth/Rockstrom "donut") . Additional tools that may be considered include urban credit worthiness assessments, sustainability cost curve applications, and others.

Additional Thoughts of STAP

This will be heavily dependent on the quality of the development of the previous tools.



Source: K. Raworth (2012), "A safe and just space for humanity: Can we live within the doughnut?" discussion paper, Oxfam, Oxford, based on J. Rockström et al. (2009), "A safe operating space for humanity", *Nature*, Vol. 461, pp. 472-475.