Sustainability Metrics: A Time-Based Multilevel Framework

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Though the United States has signaled its intent to withdraw from the Paris climate accord, countries like China and India, major world cities, and numerous large corporations have asserted their commitment to engage in increasingly sustainable activities. A critical challenge which needs to be addressed is the measurement of sustainability. The paper reviews the literature on sustainability metrics (ecological, socio-cultural, and economic) from the perspectives of national, international, corporate, urban, and individual levels of analyses. A time-based framework with five stages is developed to track input resources and actions, predictors, outputs, outcomes, and impacts (temporal and spatial). Illustrative metrics are provided for each stage-level combination. The framework emphasizes the importance of linking metrics across and within levels to enhance overall effectiveness in sustainability performance. The time-based measures also serve a control function by enabling monitoring and taking corrective action if needed even before final outcomes are known.

INTRODUCTION: RECENT EVENTS

The Paris climate accord, negotiated over a period of years, was agreed to in December 2015 and signed a few months later by over 180 countries (UNFCCC, 2016). The initiative to address the threat of gradually worsening planetary conditions was driven by Western nations, notably the United States and a few European countries, with leading industrializers such as China, India, and Brazil being persuaded to play their part in minimizing the impact of human activity on "…our common home" as the Papal Encyclical Laudato Si' (2015), published a few months earlier, put it. The main features of the agreement were that efforts would be undertaken to limit the average rise in temperature of the earth to 1.5^0 C above pre-industrial levels. Each country agreed to limit greenhouse gas (GHG) emissions to specified amounts over future periods of time. For instance, the United States committed to achieve reductions in carbon emissions of 26% below 2005 levels by 2025, China agreeing to scale down emissions by 60% over the same period, while attaining an energy mix, which comprised 20% renewables. India, Mexico, Brazil, most countries in the EU, and other industrializing nations have made similar commitments. Measures to mitigate, and adapt to, climate change were laid out, with support in the form of financial and knowledge resources offered to poorer countries to enable them to deal with ongoing climate events while preparing for a less resource-intensive and low-carbon future.

Following the elections held in 2016, the US government's support for the climate agreement (and, indeed, for the need for action) appears to have waned if not vanished (Council on Foreign Relations, 2017). In fact, the Administration has asserted it will not abide by the terms of the accord (unless the latter are re-negotiated, which seems highly unlikely), and is, in fact, actively engaged in reversing many

of the environment-friendly policies of its predecessor. It might appear that the apparent revocation by the world's largest economy of its commitment to a painstakingly-negotiated agreement could doom the attempts to keep the rise in temperatures within the 1.5^0 C range. However, other developments could well offset the potential harm arising from the official American stand e.g. developments in solar and wind energy, and in electric vehicles (Flannery, 2015). China, for instance, is expected to reach peak fossil fuel usage well before the target date of 2030, has decelerated the rate at which coal-fired power plants are being added, and has mandated that 20% of all cars produced in 2025 be electric-powered (New York Times, 2017). (The recent strategic move by major automobile firms to rapidly scale up the production of electric cars is in part, driven by the need to adapt to what will soon become the world's largest car market.) India has announced similar policies, placing it well ahead of the trajectory it had committed to in Paris (Forbes, 2017). Regions comprising California and other states in the US (including many in the northeast), numerous cities across the world and transnational corporations in diverse industries have also jumped on the sustainability bandwagon.

Some experts contend that if the US were to go back on its commitments and policies, it would be impossible for the world to fight climate change, thus dooming the planet to ever-rising temperatures, with destructive consequences. On the other hand, given the momentum of efforts already in progress around the world at the national, regional, and organizational levels, to engage in sustainable initiatives, the argument is being made that the official US position will not detract from the worldwide efforts to address climate change.

THE NEED FOR MEASUREMENT

In order to better understand the net effect on sustainability of the various policies enacted and actions pursued by a multiplicity of players involved, a system of performance measurement for sustainability would be invaluable. *Nations* and national governments have played a central role in climate negotiations, in establishing targets and deadlines, and in specifying key initiatives to achieve the main goals formulated. However, while governments can frame policies (and facilitate their achievement), other entities are often closely involved in stimulating governments to act as well as in implementation of sustainable policies. One such actor is the business firm. *Corporations* have often been blamed for being blind to the externalities and social costs associated with their actions (though there is plenty of blame to go around, as we will see later), and clearly have to be integral to any solution to the challenge posed by the nexus of, and trade-off among, wealth creation, environmental health, and social well-being. In addition to the national and corporate levels, the *region/urban* area could be vital to advancing the cause of sustainability either by reinforcing the country-level actions or (when the latter appear to be on the wrong track) by adopting counter strategies. Measurements at the *international* level are obviously vital since they provide an aggregate indicator of how effectively actions adopted at all the lower strata are working. At the other extreme, an assessment of *individual* actions and progress towards minimizing environmental impact and maximizing social welfare could help determine to what extent public opinion and changes in values could serve as a continuing driver of sustainability in the future.

Measuring sustainability performance at the individual, corporate, regional, national, and international levels is clearly a difficult and complex task, even though not all possible units are covered (e.g. that of the product/service, industry, NGOs, etc.,). However, developing a multi-level measurement system could prove extremely fruitful by yielding information on progress at each level (or lack thereof), areas for improvement, actions to be adopted, and so on. Even more important, such a "nested" system could be invaluable in guiding top-down systems and helping them move from grand goals to orchestrated actions. For instance, China's ambitious intent to increase the number of electric cars on the road dramatically in less than ten years has to percolate down to the regional, urban, corporate, and individual levels for it to become reality. Setting measurable goals at each of these levels and assessing them periodically, is essential to making such stretch goals a reality. Again, corporations might undertake to refurbish/remanufacture products with a view to lowering resource and energy usage, but be reluctant to do so since the sale of new products, and sales revenues, might be adversely affected. However, if the

government were to offer incentives (such as eliminating sales taxes on such products), firms could be more inclined to act sustainably. Even where bottom-up systems are concerned, conformance among measures at different levels would be mutually reinforcing. For instance, social entrepreneurs who help install solar lamps in villages without electricity expect the inhabitants' lives to improve in terms of metrics like working outside the home, completing school, and security. However, without the support of local/regional authorities, socially responsible corporations, and facilitating national policies, performance at the level of the individual/village may fall short in terms of the measures articulated. Metrics established at one level could have a strong effect on, or be reinforced by, metrics and performance at another.

A FRAMEWORK FOR SUSTAINABILITY MEASUREMENT

The Pressure-State-Response (PSR) system is a useful tool to conceptualize the stresses imposed on the environment, the resulting conditions or state, and human efforts (response) to address the latter (OECD, 1998; Pissourios, 2013). The addition of Driving forces (D), and Impact (I) provides a further refinement (DPSIR) by tracing the origins of the pressures (e.g. the desire for more material goods, policies to stimulate economic growth), and the *impact* of the P-S combination, activating *responses* as needed. In this paper, we develop a multi-stage measurement framework loosely based on the DPSIR model, in the sense that we articulate a framework in which actions are undertaken to deal with a problem, which needs to be solved, the results then being measured in stages. Epstein (2014) expands on this approach by identifying Inputs deployed, and splitting the Impact stage in three parts: Process (how the inputs are used, Outputs (results viv-a-vis objectives), and Outcomes (lasting benefits/new problems). Building on the DPSIR and Epstein's four-step sequence, Arogyaswamy (2017) has proposed a five-stage, *time-based* method for measuring the performance of social enterprises. The metric consists of Actions, Predictors, Outputs, Outcomes, and Impacts. Actions include both inputs and efforts. Predictors are leading indicators, so to speak, of likely future performance, of whether the entity being measured (organization, country, region, etc.) is moving in the right direction. Outputs constitute early measurable results, while outcomes are determinants of whether the actions taken have met with success. Impact refers to long term, spatially extensive effects of the actions undertaken to respond to an unsatisfactory state. One of the instances discussed by the author is the delivery of medical care by providing diagnosis and treatment over the internet, through clinics employing qualified nurses. Stage-by-stage, the indicators employed are:

Actions: Setting up the internet platform, signing up clinics and doctors
Predictors: Enrolling members, support from local governments
Outputs: Number of patients treated, retention rate of patients, clinics, doctors
Outcomes: Scaling up to other areas, rate of enrollment increase
Impacts: Improved health, reduction in health care costs, the extension of benefits to other regions.

We propose employing the same five-stage framework to measure sustainability from the ecological and social perspectives. Though the economic dimension is not explicitly addressed in our model, suggestions are offered on how this vital aspect of all modern societies needs to go beyond output measures such as GDP by accommodating social, political, cultural, and quality of life variables. The indicators used combine the assessment of outcomes and impacts in regard to the physical environment as well as of human/social development. Juxtaposing the five levels of analysis with the five-stage process of measurement yields a complex approach to evaluating sustainability, a complexity which is difficult to avoid given the interrelated nature of the levels, and the need to track, over time, progress made (or not) in achieving enduring sustainability.

NATIONAL LEVEL MEASURES: ECONOMIC

From the literature reviewed, it appears that the level most studied and measured for sustainability in terms of ecological and social results is that of the nation. The fact that national measures of sustainability are the most fully developed and most widely used is quite natural given the sovereignty accorded to the nation-state, by international bodies such as the United Nations and the World Trade Organization, to enact its own laws and formulate policies. The global impact of climate change does not detract from the authority of national governments to act in keeping with their best interests, which has often meant the pursuit of economic growth both to raise the standing of their respective countries as well as to benefit their citizens. The predominance of economic factors, particularly GDP, in the calculus of nations, has made it more difficult for policy makers and leaders to shift their focus to ecological (pollution, emissions, access to water, etc) and social (disparities, health, human rights) factors, even when it is obvious that a single-minded focus on economic growth could, in the long or even medium term, jeopardize the prospect of enduring prosperity. Thiry (2015), and Strezov, Evans, and Evans (2017) have reviewed other measures used to evaluate national performance (with an emphasis on the economic dimension) such as the Human Development Index (HDI), Change in Wealth Index (CWI), Genuine Savings Index (GSI), the Sustainable Society Index (SSI), and the Index of Economic well-being (IEWB). All of these indices are multidimensional, encapsulating economic and other (environmental and social) variables. For example, the GSI includes resource depletion and expenditures on education in addition to savings and use of fixed capital; the HDI takes into account national income, life expectancy, education, and gender rights; the SSI encompasses numerous economic, ecological, and social aspects in a country. Ashford and Hall (2011) note that societies have become so conditioned to the notion that GDP is the single best indicator of national performance and standing (despite ignoring inequalities, human and gender rights, child mortality, resource depletion, pollution, etc.) that it remains the most widely used economic index at the national level. While we strongly advocate the use of an index such as the SSI, say, we also need to recognize that, given current reality, separate measures of ecological and social well-being need to be used to complement the economic indicators (predominantly GDP) presently being used. We now turn our attention to these non-economic aspects.

NATIONAL LEVEL MEASURES: ENVIRONMENTAL AND SOCIAL

The Sustainable Development Goals (SDGs,2016) have helped to focus the attention of countries individually and collectively on working toward the elimination of poverty, ameliorating climate change, providing drinking water, ending hunger, providing affordable energy, achieving gender equality, the protection and restoration of ecosystems, reducing inequalities by building inclusive economies, and so on. The SDGs encapsulate the essence of the "triple bottom line" at the country level, and are an excellent basis for assessing a country's performance and actions needed to achieve durable improvements. The SDGs offer a sweeping overview of a country's progress towards sustainability, providing guidance in the form of targets, though not on how to achieve the goals. Moreover, the SDGs tend to frame goals in terms which make it more likely that richer nations are more likely to achieve them. Another lacuna is that the entity responsible for implementation and result achievement is typically not identified. Keeping these problems with the SDGs in mind, we shall incorporate some of them into developing suitable measures, along with other methods as discussed below.

Like the SDGs, the Environmental Performance Index or EPI (EPI, 2016) and the Environmental Sustainability Index (ESI) (Babcicky, 2013) are based on a range of measurable components. They also enable the computation of a composite score for each country, thus allowing for cross-national comparisons. The EPI covers 25 factors including household air quality, particulate air pollution in terms of $PM_{2.5}$, carbon intensity, forest cover, extent of protected areas on land and at sea, and so on. The ESI incorporates 21 dimensions some of which overlap with those in the EPI (air quality, greenhouse gas emissions, eco-efficiency, natural resource management) and others, which introduce additional elements of concern such as population pressure, and waste and consumption trends. The EPI, similarly,

encompasses elements not explicitly focused on in the ESI, such as access to drinking water and food stocks. The EPI and ESI, by deriving a composite index, make it easier to track a nation's progress over time, as well as relative to the rest of the region and the world. In a sense, these indices could introduce a competitive element into the "race for sustainability". Since neither the EPI nor the ESI incorporate elements of economic performance, it is not clear how many countries' leaders would be willing to pursue better EPI/ ESI rankings at the expense of rising outputs and wealth creation. There are also methodological issues underlying the weighting and combination of the various dimensions (Singh, et. Al., 2009). Despite the problems arising from the use of the two indices and the SDGs, it is clear they have identified the main factors contributing to environmental sustainability. The EPI and ESI also tap into measures of social sustainability (vulnerability to natural disasters, child mortality, and human health). However, the SDGs and other indicators like the Human Development Indicator (HDI), and the Social Sustainability Index (SSI) offer a cocktail of factors from which we can derive not only social but also economic elements from which policy makers could settle on the optimal mix for their current position and future direction (Strezov, Evans, and Evans, 2017). The first row of Table 1 lists some of the possible national-level ecological and social factors drawn from the indicators cited above.

The timeline ranges from T_1 through T_5, representing the five stages specified earlier i.e. inputs/effort, predictors, outputs, outcomes, and impacts. Some of the inputs/efforts (at time T_1) may be, categorized as *regulations* pertaining to carbon emissions, NO_x, farming (e.g. use of pesticides), forest preservation, loss of biodiversity, and so on. National efforts could also be encapsulated by *policies* including subsidies/incentives for use of renewable energy, refurbished, recycled, or remanufactured products, carbon tax/cap and trade, and by *investments* in sanitation, water access, health care, and education (as a percentage of national economic output). Predictors are comprised mainly of *trends* (observed at time T_2) in expected results e.g. percent change in emissions, in renewable energy capacity, in the number of people with access to potable water, and affordable health care, college/skills-based education. Outputs (at time T_3) refer to the results of the inputs applied and could include sales of recycled, remanufactured, refurbished products as a percentage of total sales, growth in sustainable farming, rise in fish stocks, decline in health care expenditure, increase in college educated individuals, closing of the jobs-skills gap (number of people looking for work plus number of open jobs), and so on. Outcomes (at time T_4) include benefits to society measured by air quality, rate of species loss, carbon emissions in ppm, NO_X levels, eco-efficiency (e.g. Btu per ton of carbon), income disparities, social mobility, gender equality, life expectancy and awareness among the public of human activities' connection to climate change. The final stage of the process is impact assessment (at time T_5) which could include health-related indicators such as incidence of cardiac, lung and similar diseases/mortalities, incidence of extreme weather events (flooding, droughts), speed of recovery from the latter, rate of additions to landfills, extraction rate of minerals and fossil fuels, and size of ecological footprint. The time periods T1 through T5 may be scaled in years, perhaps even decades (especially for impacts) with wide variations depending on the indicator in question. For instance, an increase in the share of renewable energy might follow a couple of years after suitable policies are enacted and incentives for/investments in research are made by the government, while fish stock recovery might take much longer after suitable regulations have been put in place. Again while energy efficiency might rise (T4) in a period of less than five years, carbon ppm would be much slower to respond (in part because it is partly dependent on global emissions) to actions initiated at T1. The anticipated impacts at T5 could take up to a decade (e.g. rates at which raw material/fossil fuel extraction decline) or more (say, in the case of health effects, extreme weather events). Though the variation in time scales introduces a degree of complexity into the process of assessment, it also helps sensitize national decision-makers to the need for a diverse set of measures, tracked periodically, with a view to taking corrective action particularly at T2 and T3 if the trends and outputs respectively diverge from expectations.

TABLE 1
STAGE-WISE SUSTAINABILITY MEASUREMENT
(NATIONAL, INTERNATIONAL, CORPORATE)

Stage / Level	Inputs/Effort (Actions)	Predictors	Outputs	Outcomes	Impacts
National	*Regulations*: Emissions, Farming, Forests *Policies*: Subsidies/ Incentives- renewables, recycling, Reuse/remanufacture. *Investments:* Sanitation, water access, health care, education.	*Trends:* percent change in emissions, renewables capacity, people with access to potable water, college/skills-based Education.	Percent of recycled, refurbished products in total sales, sustainable farming outputs, fish stocks, decline in health care expenditures.	Air quality, slowdown in species loss, carbon/NO_x emissions, energy efficiency, income disparities, gender equality.	Cardiac/lung disease and mortality, extreme weather events/recovery speeds, landfill growth, shrinking ecological footprint.
International	Coordinated efforts and shared investments: funds transfers to developing nations; knowledge in farming, renewables ; comparisons and benchmarking.	Worldwide *trends* in emissions, renewables capacity, water access, education and health indicators.	Growth in recycling, reuse; fish and farm outputs; sanitation and healthcare access; percent of clean/public transportation.	Average land and water temperature rise; ocean acidification, sea level rise; emissions; income disparities, gender inequalities.	Health and longevity; collaboration among nations; resource extraction as percent of total world outputs.
Corporate	R&D for reuse, energy efficiency; investments in renewable energy, supplier audits, reduced water usage, employee retraining and empowerment, gender equality.	Reducing life cycle energy costs, supply chain emissions, increase in "circularity", employee volunteering, community wellbeing.	Rise in ratio of sales to life cycle emissions and to water usage, reduction in material sent to landfills, sales increase of reusable, recycled goods.	Reputation, customer loyalty for sustainable practices, increase in price premium, demand increase for sustainable goods, employee ecological/social initiatives.	Smaller eco. footprint, rising customer expectations/ industry standards, societal expectations of sustainability, profits.

Single number indicators such as the EPI and ESI are attractive to use since they offer an easy way of comparing countries. In addition to the methodological issues mentioned earlier, as Singh, et al (2009) note, whether the method employed be a simple summation of country rankings, ratio or percentage difference from the mean, standardized/re-scaled values, indicators above minus number below the mean, etc. each has its own drawbacks. Apart from these problems, another issue is that of practical implications

for countries. If a country's rank is relatively unsatisfactory, its ability to improve depends on identifying which specific factors have "dragged" it down. (Moreover, factors, which are important for one country, may not be as important for another. For example, a landlocked nation with little fish stock but extensive forestland would likely accord greater importance to the latter relative to the former, which requires a differential weighting of variables). Looking at individual components is essential to understanding a country's environmental and social position and determining its direction, as we have proposed in Table 1.

INTERNATIONAL LEVEL

Most of the indicators for *worldwide* efforts, progress, and achievements on the ecological and social fronts (row two of Table 1) may be developed by aggregating and comparing measures at the national level. That is, carbon dioxide levels, fish stocks, biodiversity, share of renewables in the energy mix, ocean temperatures and acidities, incidence of various diseases, and so on can be tracked for the world as a whole. Such monitoring would be helpful in determining the effectiveness of the actions by nations separately as well as collaboratively. Sharing of *investments* (e.g. the transfer of $100 billion post 2020 from developed to developing nations), of *knowledge* (new technologies in renewables, ideas for shoring up food stocks, etc.), of successful *policies and regulations* (in education, farming, air quality improvement, addressing income disparity), are among the inputs which could be brought to bear in ensuring that nations without the wherewithal to act on their own are not left behind. *Comparisons* between countries based on some of the major measures mentioned above would then be invaluable in attaining consistency in outcomes and impacts. For instance, countries, which have enjoyed success in reducing carbon emissions, organic farming, increasing access to potable water, moderating income disparities, and so on, could serve as models and benchmarks to others which may have fallen short on any of these measures.

CORPORATE LEVEL MEASURES

Researchers such as Dahl (2012) have called for measurement of sustainability to be conducted at different, interlinked levels. While national goals and performance assessment are indispensable, given the sovereignty of the nation-state, sustainable development is a global concern with far-reaching impacts. Again, while governments are critical to formulating policies, regulations, and actions, their implementation typically occurs at the sub-national level. The extent to which corporations commit themselves to an internationally consistent strategy aligned with sustainability principles could serve as powerful reinforcements/deterrents to national-level performance. Some of the proposed corporate-level measures are listed in row three of Table 1.

The corporate *inputs* in sustainability include R&D expenditure (redesign for reuse, remanufacture, separation of components, being less energy-intensive), investments in renewable energies, in supplier audits, in afforestation, in water access and quality, in social causes (education, health care, human rights, gender equality), employee training and re-skilling, and so on. Clearly, firms do not need to invest resources in all of these efforts to be deemed sustainable. As Laszlo and Zhembatseva (2011) note, corporate sustainability strategies can range from legal compliance and cost reduction to driving industry standards and radical innovation, alignment with the core competencies, differentiation, and reputation building being intermediate steps. Companies starting out on the sustainability journey might be satisfied with lowering costs (materials, water, and energy usage) while those more committed to sustainability might attempt more ambitious strategies, thus moving in the direction of strong sustainability (McKinsey, 2013). Instances of the latter: Pepsi has committed itself to developing more healthy snacks and beverages, invested in renewable energy, and reduced supply chain distances, while also minimizing use of scarce resources such as water; Interface carpets not only has eliminated the use of harmful chemicals, but also offers modular carpets (enabling customers to replace only the worn out sections), and uses mainly renewable energy in its manufacturing facilities. For national policies in sustainability to be

effective, corporations must become fully engaged, which depends, in part, on incentives and subsidies, and transparency, as well as on the vision of business leaders (Keeble, Topiol, and Berkeley, 2003). It appears that the latter have become more engaged with the issue over the past five years, which has resulted in more and more firms undertaking planet and people-friendly directions and actions. *Predictors* of corporate sustainability include progress made in reducing energy used in production and by consumers, carbon emissions by suppliers, increase in cradle-to-cradle/circularity (reuse, refurbishing, etc.), renewable energy usage, employee volunteering rate, community improvements, and so on. *Outputs*, measured with a suitable time lapse after inputs (say, two or three years) may be a combination of efficiency (e.g. revenues/carbon emissions), reductions in materials sent to landfills, water usage relative to sales revenues, life cycle carbon emissions as a proportion of sales, the ratio of sales to supplier carbon emissions, the success of firms specialized in disaster remediation, and so on. The assessment at this stage deals with measuring how sustainably the firm is able to compete in its core business by aligning sustainability with strategy. The next phase of measurement, *outcomes*, encompass factors such as higher customer appreciation of corporate sustainability strategies (reputation, loyalty, demand), satisfaction among suppliers' and the firm's employees, social results (graduation rates if investments were made in education), embedding of sustainability in the firm's culture (demonstrated by employee-driven initiatives), and so on. Among the *impacts* of corporate sustainability strategies are the firm's ecological footprint, industry standards and customer expectations rising in tandem, long term benefits to society (as well as sharing successful social responsibility efforts regionally, nationally and across borders) in terms of education, population health, gender equality, increasing ability to adapt to climate disasters (Garcia and Vale, 2017). It may be noted that outputs, outcomes and impacts at the corporate level, when aggregated, could play a vital role in achieving national and (in the case of multinationals), international impacts. Increases in the rate of reuse and remanufacturing, reduced emissions, rise in renewable energy use, and improved outcomes in education, health care, and other social areas, if achieved by a significant number of firms, would help nations reduce landfill usage, enhance air quality, lower carbon emissions, attain better health and educational results, and so on. The cause-effect relationship between levels could work both ways. That is, though national policies and goals are typically viewed as spurring action by corporations, if the latter view sustainability as integral to their strategies and success, national initiatives may well be determined by actions pursued by businesses (and their allies), particularly if firms' strategies are built on knowledge shared across corporate locations (Rezaee and Homayoun, 2017).

REGIONAL AND URBAN

With the national level as the fulcrum, so to speak, of our work, we have suggested corporate and international sustainability indicators that could be derived from, and reinforce national measures. It might seem that all entities (such as states and counties/ districts) falling geographically within national boundaries would be subordinate to the latter level. In theory, this hierarchic relationship should hold, but that would mean neglecting local needs and sensitivities. For instance, one part of a country might emphasize water quality and access while another might focus on carbon emissions, each driven by pressing local concerns. Another reason why a distinct set of indicators is useful, indeed essential, for areas enclosed within a country is that some of these constituent parts may embark on more ambitious efforts than the country as a whole. In some cases, these smaller geographic entities may even formulate policies and initiatives, which contravene those at the national level or at least serve as the testing ground or harbinger for actions to be adopted on a larger scale. The most common sub-national focus of efforts undertaken to minimize resource usage, carbon emissions, etc., while improving social conditions for its people, using standards which could exceed those at the national level, is that of the *city*. The Sustainable Cities Initiative (SCI) now has a burgeoning membership of cities worldwide, which have served as magnets for people from small towns and villages looking for work. In particular, cities such as Shanghai, Beijing, Delhi, Mumbai, New York, Mexico City, Munich, London, Sao Paolo, and many others, are increasing in population and are likely to generate far more than 70 percent (their present share) of the

world's resource usage and harmful emissions. The world's urban population grew about 3.5 times as fast as the population as a whole in the period 1900-2000 (Ponting, 2000). As Portney (2013) notes, cities and local governments are closer to people's lives, placing them in a position to influence citizens' behavior. Conversely, people's preferences and attitudes guide policy and the choice of indicators to assess effectiveness of actions. The author discusses in detail measures of sustainability deployed in cities such as San Francisco, Seattle, and New York, and some of these are included in the five-stage assessment of Regional/Urban Sustainability (shown below in Table 2.)

Among the *efforts* undertaken/*investments* made at the urban (or regional) level are incentives for replacing fossil fuel based electricity generation and/or transportation (both public and private) with renewable sources, support for new or retrofitted energy-efficient buildings, number of pedestrian-friendly spaces, incentives for recycling, reduced landfill waste, expenditure on cleaning up hazardous waste sites, reducing food waste, and the percentage of the budget devoted to sustainability criteria. *Predictors* include trends in renewable sources for electricity, vehicle fuel consumption per capita, increase in pedestrian-only area, reduction in area of hazardous sites, trends in per capita water consumption, and change in average distance traveled to work, schools, shops, and medical care. *Outputs* may be measured by volume of garbage and electricity used per capita, percentage of recycled, remanufactured products relative to total products sold, percentage of locally-grown food, graduation rates from school and college (as well as variation across districts or counties), and rise in ridership on public transportation. *Outcomes* may be measured by air quality, carbon and NO_x emissions, time spent per capita on travel within the city, per capita water consumption, reduction in percent of food wasted to total consumed, increased use of public spaces, income disparity (say, income earned by the top 20% as a multiple of the bottom 20%), and highest unemployment rate as a multiple of the average. *Impacts* arising from the SCI and similar processes (as well as regional policies) may encompass one or more of the following: improvements in health (e.g. reduction in pulmonary, cardiac, gastrointestinal diseases), health care expenditures per capita, increase in local, particularly, organic farming outputs, elimination of hunger, reduction in the poverty rate, employment in sustainable businesses, and the spread of local policies and corporations to initiatives undertaken outside the area.

TABLE 2
STAGEWISE SUSTAINABILITY MEASUREMENT:
REGIONAL/URBAN AND INDIVIDUAL

Stage / Level	Inputs/Effort (Actions)	Predictors	Outputs	Outcomes	Impacts
Regional/urban	Investments in energy efficient buildings, public transport, pedestrian-friendly spaces; incentives for reuse/recycling, reduced food waste; lower fuel consumption for vehicles, net metering.	Trends in energy, fuel, water usage; in average distance traveled per capita; rise in energy efficient buildings.	Waste, energy, water, food wastage per capita; graduation rates from college, school; Employment adaptation to technology shifts.	Carbon, NOx emissions; time spent on travel per capita; reduction in distance traveled by private vehicles; lower inequality, unemployment.	Locally grown food; organic farming; health improvements; poverty rate; replication of effective policies to other cities/regions.

Stage / Level	Inputs/Effort (Actions)	Predictors	Outputs	Outcomes	Impacts
Individual	Purchase energy conserving goods; Rooftop solar; Reuse, repair products; Transport-public, low-emission, ride sharing, volunteerism.	Trends in energy, water usage; period of product ownership.	Garbage generated, food wasted; personal carbon footprint.	Rise in savings rate; Preference for sustainable products; support for eco-friendly and socially beneficial policies.	Value community over individual interests; being over possession; long term over immediate consequences of action.

COMMUNITIES AND INDIVIDUALS

While nations, groups of nations, business firms, and urban agglomerations are undoubtedly critical to making progress toward the overarching goal of sustainable development, acceptance and action by smaller societal units is essential for change to be achieved on a lasting basis. Community groups, for example, have a significant role to play in setting and realizing goals specific to their constituents' interests and lives. Religious organizations, educational institutions, cooperatives, non-governmental organizations, social service groups, and so on, can work toward the larger vision formulated at the urban, regional, corporate, and national levels. Action at the level of small units such as these is vital to enlist individuals in their diverse roles (as consumers, parents, citizens, employees, shareholders, students, farmers) in contributing to sustainable development. The five-stages of indicators at the individual level are shown in Table 2). The willingness of individuals and small groups to expend resources (money, time, convenience) to advance environmental and social wellbeing may be demonstrated in the purchasing of energy-conserving goods, investing in rooftop solar and low emission vehicles, volunteerism, and being satisfied with reusing/refurbishing products, are included among the i*nput* indicators. *Trends* in energy and water usage rise in ride-sharing, and increased period of ownership (of durable goods) would be indicative of individuals moving in the direction of greater sustainability. Personal quantity of garbage generated, food wasted, the personal carbon footprint, and a higher level of personal donations for social expenditures (e.g. to non-governmental organizations) help evaluate whether output measures reinforce the inputs and trends. Among the *outcomes* of individual commitment one might expect are a rise in the savings rate (arising from lower consumption), a preference for sustainable products even at a price premium, and an overall support for sustainability-friendly actions by governments (urban, regional, and national) and corporations (driven by citizen initiatives and customer demand respectively). The individual impacts envisioned are primarily in the value system guiding a person's beliefs e.g. a sense of community over individual interests, of one's worth being a function of being and reflection rather than of possessions and ownership, being able to relate to distant (in a geographic and cultural sense) societies' needs, and the ability to exercise impulse control favoring long term outcomes over immediate gratification.

The outcomes and impacts envisioned at the level of the individual are significant, even radical, particularly in individualistic, consumption-oriented societies favoring instant gratification. However, a combination of factors such as incentives provided by local and national authorities, education and better dissemination of information, results achieved by other societies/communities, the persistence of calamitous weather events, and so on could effect a change in behaviors (e.g. a move to extend products'

useful lives), the accumulated force of which could change mindsets. In other words, to transform societies from designing products to designing systems fostering contemplation and caring over consumption and seclusion, as Walker (2013) frames it, that is, to achieve a major *cultural* shift, individuals' actions and behaviors could be informed and guided by investments, regulations, incentives, outcomes and impacts at other levels (Garcia and Vale, 2017). On the other hand, a radical change in values and beliefs, involving trade-offs between individual and communitarian as well between egalitarian and libertarian ideals (Philips, 2006), is essential to making change at other levels effective and durable.

CONCLUSION

Pissourios (2013) observes that indicators may be descriptive, efficiency-driven, function as performance measures, and achieve change in areas critical to policy efforts. The framework developed in this paper fulfils these purposes: descriptions of measures at various stages in time are proposed, likely future performance is predicated on whether the suggested indicators are attained, resource usage and wastage (efficiency) are measured, and inferences for policy may be deduced from whether results (especially in terms of outcomes and impacts) have been reached. Though the multilevel indicators laid out here establish examples of measures to be adopted at each of five stages, *how* these measures are derived has not been addressed. For instance, in encouraging a shift to electric/fuel cell vehicles, should incentives be offered to users, subsidies to producers, investments in charging stations made by the local/national government? In popularizing rooftop solar, should a corporate strategy of leasing and revenue sharing from net metering be complemented by urban authorities' investments in commercial solar arrays? These and other similar issues have been left unaddressed partly because they are too numerous to deal with here. Also, as stated earlier, the measures actually adopted by any country, region/city, or corporation should be derived from the specific needs of the country (e.g. is air quality a more pressing need than dealing with material sent to landfills?), region (are carbon emissions more immediate a concern than food waste?), or business (given our global supply chain should we focus our efforts on the latter and pay less attention to reuse and refurbishing?) A third, and perhaps, even more important reason lies in the *politics* of indicators, and the *commitment* they engender. If the measures (at the national and local/urban levels) illustratively proposed in this paper were to be generated by a panel of experts, one might claim that the measures rested on rationality, experience, and theoretical knowledge. However, that might not result in acceptance of, and commitment to, the expertise-based indicators. The issue of rationality vs. dialectic in indicator design suggests the need for involving those most affected (Levette, 1998) constituting a caution that knowledge may not always confer power. Indicators developed in isolation and/or lacking clarity in responsibility are likely to founder (Scott, 2012).

As Dahl (2012), Scott (2012), and others have asserted, indicators ranging from individual to the planetary level would be invaluable in aiming for and reinforcing efforts in sustainability *across* multiple levels. For instance, if one of the national level measures was reducing material and energy usage, corporations would need to invest more in R&D activities toward this end, while regional/urban authorities could help by offering incentives to companies and local communities to achieve mutual complementarity of actions. In similar fashion, achieving reductions in vehicular carbon emissions would be facilitated by establishing national standards for emissions/mileage, corporate product research and innovative business models, and by urban governments making investments in the necessary infrastructure. Equally important would be ensuring a fit *within* levels. Corporations developing new technologies for more energy efficient products could invest in social programs enhancing educational capabilities in new technologies, commit themselves to employee reskilling, and encourage women to enter and succeed in technology-related fields. Urban authorities working to reduce food waste would also then emphasize locally grown foods, and provide support for organic/urban farms, and educational facilities focusing on sustainable foods. The measures exemplified in this paper could serve not only as standards and comparators (among countries, corporations, regions/cities) but also enable achieving a fit across and within levels of the *system* of indicators.

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