INDIA EMPHASIZES EQUITY AND ENERGY ACCESS AT UN SUSTAINABILITY PANEL, PROPOSES SUSTAINABILITY INDICATORS

Helsinki, May 17 2011

India today made a strong call for equity and universal energy access by the year 2030 for all, at the meeting of the UN Secretary General's High Level Panel for Global Sustainability.

Participating at the meeting of the Panel at Helsinki, India's Minister of State (I/C), Environment and Forests, Mr Jairam Ramesh, put forward three detailed papers prepared by Indian experts with the Minister's inputs (see appendix for full papers). These were:

- "Equity in the context of Sustainable Development"
- "Universal Energy Access by 2030"
- "Sustainable Development: A Proposal for a New Indicator"

India's papers were widely appreciated by other Panel members and will form the basis for further discussion.

India also shared a presentation on its experiences with the "Rights-based Approach" which relies on giving legal entitlements to citizens as a means of empowerment and improved service delivery. The models of India's Right to Information (RTI) Act, the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA), the Right to Education Act and the Forest Rights Act, were keenly discussed and Panelists felt it was an approach that has important lessons for both developing and developed countries, many of whom are still striving for such an inclusive paradigm. A discussion of the Rights-based Approach will form a key component of the Panel's final report.

The UN High Level Panel on Global Sustainability was established in September 2010 by the UN Secretary General with the aim of developing a set of substantive recommendations for the world's sustainability agenda. The Panel is chaired by President Jacob Zuma of South Africa and President Tarja Hallonen of Finland and has 20 other members from across the world. India is represented by Minister Jairam Ramesh.

In his intervention at the meeting, Mr Ramesh highlighted the "international sclerosis" which has come to afflict global environmental issues, even as public awareness and domestic actions have expanded over the last two decades. He spoke of the need for an "economic anchor" to underlie international discussions on environmental issues, and the need to mainstream metrics like per capita income in the discussion, with increasing international obligations being linked to levels of and increments in per capita income. He also spoke of the need to mainstream biodiversity, especially marine biodiversity in sustainability discussions.

The UN Panel will continue its work over the next few months, and submit a final report to the UN Secretary General by November 2011.

Appendix 1: Text of Letter from Jairam Ramesh to the Co-Chairs of the UN Secretary General's High Level Panel on Global Sustainability

Your Excellencies,

Thank you for your letter of May 2, 2011, with your thoughts on our Panel's work and seeking our inputs. At the outset, let me thank you, the Panel Co-Chairs, as well as the Secretariat, for providing such good direction and support to the Panel's work so far. I would like to start by re-emphasising what I said at GSP1: that our panel needs to focus on a set of concrete recommendations, developed in substantial detail, if it has to create impact, and not be relegated to the footnotes of history. I therefore fully share the Co-Chairs view that the Report must focus on the "how", i.e., on specific options to consider and how to get there. Given this context, I take this opportunity to highlight some of the concrete areas where I think the Panel could focus:

- **Indicators/Goals:** As has been discussed, how to take forward the subject of Sustainability Indicators/Goals could be a unique 'value-addition' provided the Panel. Here we must go beyond merely suggesting the need for such Goals/Indicators (which would be merely re-stating what several expert panels / institutions have already stated), and provide as concrete a framework as possible. The championed paper "Sustainable Development: Proposal for a New Indicator", submitted by us (updated copy available at GSP3) discusses in detail one approach that can be taken, and could form the basis for discussion within this Panel. The paper provides possible elements of a multi-dimensional indicator that captures various aspects of sustainability and development, and proposes a methodology on how this can be taken forward. The Panel could use this as a basis for discussion and recommendation in its report.

- **Universal Access to Energy:** The question of energy access is at the heart of every discussion on sustainability, especially for developing countries, where a disturbingly large share of citizens do not have access to modern (and clean) sources of energy. Ensuring universal access to energy in an equitable, inclusive and cost-effective manner is a key moral imperative of our times. The challenge before us is to ensure that this access happens rapidly, while ensuring that the sustainability related constraints are not violated. This requires tremendous innovation in both technology and policy choices that we make. What are the realistic options before us, and how should we approach this gargantuan challenge? The Panel could do the groundwork for addressing this question, providing a clear roadmap for the global community, international organizations, nation-states, and sub-national units. The championed paper "Universal Energy Access by 2030", submitted by us (updated copy available at GSP3) provides a detailed assessment of various options before us, and could provide a good background for the Panel to present a roadmap in its final report.

- **Equity:** We all are agreed on the importance of equity in any discussion related to sustainable development, but have varying notions on what it really means. The Panel could take the discourse on the question of 'equity' forward, in particular, by clearly bringing out the links between equity and sustainable development. The championed paper "Equity in the Context of Sustainable Development", submitted by us (updated copy available at GSP3) provides a good starting point for this.

- **Innovative Paradigms**, e.g., the Rights-based Approach: There is much to learn from "good-practices" that have been attempted across the world. As has been suggested by the Co-Chairs, such practices and paradigms must be emphasized both in the main body of the Report, as well as in detailed appendices. India's Rights Based Approach in service delivery and citizen empowerment in the context of sustainable development (which was presented at the UN-GSP interaction with the International Trade Union Confederation in Madrid in April) provides one such paradigm that could be discussed in the Report.

I look forward to our discussions at GSP3.

Best regards,

Jairam Ramesh
Minister of Environment & Forests, India
15th May 2011

Appendix II: India's Submissions

EQUITY IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Note for UN-GSP

Version 2.0

PREPARED AT THE REQUEST OF
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1. INTRODUCTION

The introduction of the concept of Sustainable Development (SD) was seen as a profound paradigm-shift by many analysts, activists and policy-makers, as it brought environmental concerns to the centre-stage of development. The Brundtland Commission report is of course best known for its defining statement: `”Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs''. Equally important is the clarification that follows: “the concept of 'needs', [refers to] in particular the essential needs of the world's poor, to which overriding priority should be given”. The report, which provided a sense of global acceptability to the concept of SD, based its considerations on the argument that development was not possible in the long run without protecting the environment. It simultaneously recognized that environmental degradation was further impoverishing people (World Commission on Environment and Development, 1987). The conception of sustainable development in the report gave a high priority to poverty alleviation and to equitable development, arguing that “a world in which poverty and inequity are endemic will always be prone to ecological and other crises” (p.43) and that “long before these are reached, the world must ensure equitable access to the constrained resource” (p.45).

In spite of this originally broad-based formulation, , the deployment of the concept of SD in practice has been marked by significant weaknesses.

First, in the process of the further diffusion of the concept and its apparent general acceptance , the dimensions of equity and poverty alleviation tended to be de-emphasized (Lélé, 1991). Even in the final report itself, the original term “Sustainable and Equitable Development” (Jacobs *et al.*, 1987) which was current in the discourse, was truncatedto just sustainable development.

A second, related, weakness in the entry of SD into the mainstream discourse, was that several multilateral finance and development institutions, important bilateral aid agencies, as well as many national governments, continued to privilege economic growth in GDP terms as the focus of development. This trend continues despite the parallel and growing realisation that national income is only a partial measure of development that matters and that such growth can co-exist with a wide range of inequalities include widening income disparities, Subsequently, the Millennium Development Goals brought back some focus on issues other than economic growth, but they gave short shrift to environment itself (Drexhage and Murphy, 2010).[1]

Third, by using the term 'sustainable' as if it captured all aspects of 'environmental soundness', the mainstream conception of SD has perversely narrowed the basis of environmentalism itself. In the post-Brundtland era, the environment appears to matter because, and only to the extent, that it sustains certain set of economic processes or lifestyles. Thus, for instance, conservationists are now forced to emphasize the 'services' that biodiversity provides, because the intrinsic value of biodiversity is not easy to relate to the idea of development.

A fourth limitation is that by focusing on "sustaining" something, which by default becomes the 'current, already perilous state of the environment', developing countries and the poor within them are unconsciously condemned to remain where they are Sustainability is equated with 'no further transformations of the natural landscape', a frozen concept with no room for transformative social action on nature and society itself. However, poverty eradication across the developing world and sharp and rapid increase in human well-being, both fundamental aspects of equity, would require transformative action, on a large scale that is entirely non-equilibrium in character.

Even as the operationalisation of the SD concept has suffered from these weaknesses, another major shortcoming in practice has been the restriction of considerations of SD to developing countries. In the context of developed nations, sustainability has been limited to an aspirational goal, or limited strictly to local environmental considerations, or reduced to purely an individual lifestyle question. Sustainability as a global goal, for the developed as well as developing nations has been in the main ignored, and a key component of the issue, viz., the natural resource footprint of the developed nations, has been largely sidelined.

Some of this is undoubtedly due to the origins of the sustainability perspective (in a pure resource constraint sense) in the idea of the "limits to growth". In this perspective, that in any case downgrades equity concerns and whose conceptual signature is alarm at the prospects of the drive of the world's poor to achieve material well-being, clearly the onus is on the late-comer to make do with such resources as are available without little responsibility on those who consumed it in an earlier era.

[1] Environment has become only 1 of 8 goals, and the specific targets set under this goal are very weak, to say the least .

Thus, there is a clear need to re-iterate and clarify the links between equity and justice on the one hand and sustainability, SD, and environmentalism on the other. We argue in this paper that, firstly, equity and justice are an integral part of many kinds of environmentalist thinking, and need to become more so. Secondly, even with a broad commitment to SD and poverty alleviation, the question of sustainability cannot be engaged with meaningfully, without the clarification of issues related to distribution and access to resources. We begin by briefly defining equity and justice, then outline conceptually the links between equity and sustainability. We then examine these links in the specific context of common pool resources, first using Hardin's pasture as a simple local-level common-pool resource, and then examining the implications for a more complex global common-pool resource such as the climate system.

2. DEFINING EQUITY AND JUSTICE

The idea of equity is a complicated one and the discourse on equity is vast. The terms 'equity', 'fairness' and 'justice' are often used interchangeably (Konow, 2003), although they involve subtle differences. For the purposes of this paper, we use the term equity to encompass a range of ideas:

- At the very least, an equality of opportunity to achieve one's potential
- Equal share of benefits for relevant stakeholders in specific contexts (equity of outcomes)
- At the macro-level, reduced disparities in income and wealth.
- More generally, a 'fair' distribution of benefits and costs of a particular public policy, or a fair allocation of public funds, resources, spaces, including natural resources.
- Positive discrimination and redistribution to right historic wrongs or in favour of systematically disadvantaged groups, including disadvantages of economic, social, gender and other positions in society.
- Equity of process, i.e., empowerment to enable access to information, fair representation, meaningful participation in decision-making, bargaining and effective remedy
- Equity between nations, or international equity that operates in the realm of inter-societal relations
- Global equity on the basis of identities that transcend national boundaries, such as gender, membership of an indigenous community or the particularly vulnerabile in some form.

It is intuitively clear that a one-sided emphasis on any single one of these aspects considerably distorts the meaning of equity, though there is a significant literature that often privileges one of these aspects to the exclusion of the others. All of these dimensions come into play when we consider the links between equity/justice and sustainability/SD.

In general, an emphasis on equity highlights the importance of good governance, redistribution of income and wealth, empowerment, participation, transparency and accountability. Thus, while different groups will often have different ideas about what constitutes 'fairness' or 'justice', equity enables diverse groups to have their voices heard in these debates in specific contexts. Equity – of opportunity, outcome and process – therefore underpins the capacity of people (and especially marginalized groups) to gain control over resources and institutions that affect their lives,

3. RELATIONSHIP BETWEEN SUSTAINABILITY/SD AND EQUITY/JUSTICE

Conventionally, equity and justice are seen as 'social' issues, as 'red' issues, while the environment is characterised as distinct from these, as a 'green' issue, thereby suggesting that they are disconnected, separate realms. Even in the SD debate, the tendency is to introduce equity as an separate concern, as in talk about the "triple-bottom line" of the 'economic, social and environmental' or in terms of 'productivity, equity, sustainability' (see, e.g., PANNA, 2009; IWMI, 2005).

But this characterization is misleading in many ways. Environmental concerns overlap with equity and justice on both normative and instrumental grounds. Sustainability itself has a shade of justice, while environmentalism historically has had an even closer nexus with equity and justice than sustainability-ism (Lélé, 1994; Agyeman *et al.*, 2002).

The questions of equity and sustainability are closely linked in a number of ways.

a) If SD is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", then in effect it is a plea for inter-generational equity. (Pezzey, 1989; Howarth and Norgaard, 1993).

b) For many people, environmentalism also includes fair treatment or respecting the rights of non-human living organisms, those who are sentient but do not have a voice. These include not just the Deep Ecologists (Naess, 1973), but many other groups. While there is a tendency amongst some animal rights activists and deep ecologists to focus on the rights of non-humans at the cost of social justice (Guha, 1989), most would agree that fairness to non-humans follows fairness within humanity.

c) Most important and obvious, environmental issues include situations where the current actions of one actor negatively affect the current well-being of someone else. These are the typical 'externalities', or more specifically, unidirectional spatial externalities, of air or water pollution going downwind or downstream. The central issue is not the loss of some 'aggregate benefit' to society (inefficiency) as the economists would frame it (Fisher, 1981) or the inability to continue this activity into the future (unsustainability). The central issue here is the *unfairness* of such a situation — it is not *fair* that one person, even while pursuing a legitimate livelihood, should negatively affect the health of another person (Lélé, 1998;1994).[2] Many of the battles in developing countries today are over such negative externalities of developmental activities, whether it is mining, dams, or factories. While some of these protests are cast in 'sustainability' terms, such as the sustainability of a dam in the face of heavy soil erosion and siltation, and others highlight the likelihood of a net loss to society if a proper benefit-cost analysis is done, the core issue is still one of the fairness — how fairly are benefits and costs of such projects distributed.

d) This environmental (un)fairness also often overlaps with pre-existing socio-economic inequities. Very often, the polluters are better off than the pollutees: such as industries polluting rivers whose waters are consumed by poor farmers, or dams destroying livelihoods of poor fisherman downstream. In such situations, one would say that the social justice question overlaps with the environmental unfairness — instead of giving special consideration to poorer sections, the policy to go ahead with such projects would lead to a double disadvantage. The 'environmental justice' movement in the USA for instance has highlighted the double-disadvantage problem in the preferential siting of hazardous industries in the neighbourhoods where socially and economically marginalized groups reside. (Bullard, 1990).

e) Environmentalism also highlights the need for equitable access to natural resources and environmental sinks. This is an area in which environmental and social concerns overlap fully, because the equitable distribution of the socio-economic benefits from the use of natural resources depends critically on how initial rights to resource use are granted.[3] Equally efficient distributions of rights to resources may lead to very different outcomes in terms of equity.

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[2] And it really does not matter what the social positions of the polluter and pollutee are, although in practice it is often the case that the polluters are also from the socially and economically more powerful segments of society, which is why they are able to get away with the polluting activity.

[3] Note that equitable access may take different shapes and nuances depending upon the context. For a local resource such as a pasture, this might be equal access to all users, i.e., all graziers. But those with historical rights of use might claim precedence over those who came later. Those with more cows may say they "need" a larger area to graze in. In the case of water rights, many nations give rights as per prior beneficial use.

f) Environmental degradation aggravates poverty, and thereby accentuates inequity in society. Where the poor are directly dependent on natural resources such as forests for firewood, pastures for grazing or scarce water resources for survival, the degradation or destruction of these ecosystems hurts the poor the most. The rich are likely to have moved away from such direct dependence on ecosystems to the use of fossil fuels. The rich can also offer to purchase technologies or to access resources from further away (Pearce, 1988; Nadkarni, 2000).

g) Finally, in many cases, equity may enhance sustainable resource use. Several analysts have argued that a fair allocation of resource rights is more likely to result in individuals and communities cooperating in the collective management of the resource (e.g., Gadgil, 1987). More recent literature, however, suggests that this relationship may be more complex (Baland and Platteau, 2002); in some situations, inequality can still ensure collective action.

In short, the links between sustainability and equity are multi-dimensional and mutually reinforcing. Sustainability itself means justice to future generations. And it is impossible to imagine a situation where a case is made for inter-generational equity while underplaying intra-generational equity (Anand and Sen, 2000).

As we have noted earlier, environmental soundness or environmentalism as a concept is broader than sustainability, because it explicitly includes environmental fairness—both in distribution of impacts of resource use and in the access to resources, even if the dimension of inter-temporal equity had not always been explicitly incorporated. And of course there is the oft-highlighted practical dimension that a more equitable allocation of resource rights is more likely to generate the cooperation necessary for sustainable management of common pool resources.

Social justice and equity go one step beyond this concept—they explicitly demand additional attention for instance to historical inequities and the current socio-economic positions and abilities of both pollutees and polluters. In general, they demand attention to historical inequities and discrimination, and also to the initial allocation of resource rights and opportunities. Thus, bringing together sustainability and equity also infers the need for transformation of social relations, redistribution of rights and resources, and policy approaches which address social, economic and environmental concerns simultaneously and holistically

4. EQUITY, SUSTAINABILITY AND COMMON POOL RESOURCES

At the core of environmental problems lies the problem of externality: decisions taken with a narrow, short-term self-interest in mind have adverse consequences over space, time and sectors. A subset of such problems can be classified as "common pool resource" problems, where the externalities are symmetrical[4] and resources are can be depleted (Stevenson, 1991). Multiple actors can use a 'resource', each user affects others through such use, and unregulated self-interested use by each actor can lead to depletion for all.

Garrett Hardin highlighted this problem as the 'tragedy of the commons', subsequently more accurately characterised as the tragedy of open access to common pool resources. He used the example of a pasture and a group of shepherds who graze their sheep in the pasture, and pointed out that 'rational economic decisions' by each shepherd would lead to overgrazing of the pasture. While Hardin's solution was either privatization or state control, others have pointed out to the need for a more nuanced approach, given truly common-pool resources cannot be privatized. Collective agreement and enforcement by the resource users themselves through well-designed institutional arrangements could be another approach (Ostrom et al., 1999), leading to sustainable use (what economists call inter-temporal efficiency). In the pasture example, shepherds could agree to limit the number of sheep they graze to a level that represents a win-win for all.

But characterizing the pastoral commons simply as a common-pool sustainability problem hides several important dimensions of the problem. Knowing the 'carrying capacity' of the pasture in terms of the total number of sheep that can be sustainably grazed is only one dimension. Who should graze how many of these sheep, i.e., what should be the initial allocation of grazing rights across shepherds? Who qualifies as a user in the first place? What happens if a household not historically involved in grazing wants to start now? If overgrazing is occurring and cutbacks are required, who should cut back how much? Is past grazing and therefore past contribution to degradation relevant to how costs of pasture restoration should be allocated? Is the wealth of the shepherd relevant to this?

In most analyses of the commons that start with Hardin's formulation, there seems to be an implicit assumption that all shepherds are identical, all have equal flock sizes and each can contribute equally to degradation or restoration. Hardin's formulation also sidesteps the question of who is a legitimate rights-holder in the commons. The analytical focus is on efficiency, not equity. But given that the solution, even within this framework, involves the conversion of an open-

[4] When externalities are asymmetrical, they result in the standard 'pollution' problem, where upstream polluters affect downstream pollutees.

access resource into a common property resource, the initial assignment of rights becomes absolutely critical.

Moreover, in real-world situations, decisions about allocations of rights and responsibilities, of benefits and costs have to be taken at every step: who protects, who invests in technology to regenerate, how is heterogeneity in the resource (e.g., variations in quality of the pasture) to be addressed, etc. And clearly, initial disparities in wealth, power, and prestige of the users significantly influence the way the institutions of common pool resource management are structured and function.

The role that economic considerations exert in critically re-dimensioning concerns of equity in the context of sustainability, or more generally the environment, is worth remarking upon. Law, for instance, is not a powerful a force in diluting equity and if anything legal studies appear to offer greater purchase in pursuing equity (see, e.g., ILA, 2002).

5. THE CLIMATE COMMONS AND EQUITY

All these issues are relevant to climate change, that is in some sense a ``perfect storm'' in sustainable development. In many ways, climate change is the archetype of a global common-pool resource management problem. The global climate system is non-excludable because it is well-mixed and nobody can put up walls and protect 'their' atmosphere from being 'dirtied' by someone else's emissions. And it is depletable in that any CO_2 entering the atmosphere (or more precisely the atmosphere-oceans-land system) reduces its ability to absorb additional CO_2. 'Sustainability' in this context is defined as maintaining the total quantum of CO_2 in the atmosphere below some threshold, which in turn requires limiting the total global quantum of CO_2 emissions below a certain level. Equity here seems orthogonal to sustainability: whichever way one shares the permissible level of emissions across different countries or emitters, the total is what matters for sustainability. But closer examination reveals complexities.

Firstly, the impacts of crossing the sustainable climate threshold (or even approaching it) are not as evenly distributed, even if the greenhouse gases are well-mixed globally. Small island states will suffer devastation from sea-level rise, whereas larger nations might suffer relatively much less damage, and landlocked nations even less.

Secondly, there is a question of unequal present emissions, and subsistence versus luxury emissions. Thirdly, there is a question of who contributed to degrading the global commons by past emissions. Fourthly, there is a question of inequality in other endowments (technology, financial capital, infrastructure, institutions) and current stage of development. Not surprisingly then, the idea of equal cutbacks across all nations has hardly found favour.

Does this mean that equity is a necessary or sufficient condition for a sustainable climate treaty? In a purely environmental sense it may not seem so. After all, it is quite possible for better endowed players to use their power to impose an unequal treaty that is still climate effective. However it is evident that in a wider reading of sustainability, inclusive of political and economic considerations, such a climate regime would be unsustainable and is unlikely to be even effective.

It is also possible that an equitable treaty can be climate ineffective: an equitable sharing of the mitigation burden may be agreed upon, but the overall mitigation is simply inadequate to prevent CO_2 concentrations crossing the threshold.

But clearly, if one is committed to sustainable and equitable development, to poverty alleviation, and to fairness as a general principle, then from all these perspectives a fair allocation of the mitigation burden, of rights and responsibilities is essential. And it is possible that a fair treaty may lead to a broadly acceptable and enforceable treaty.

Note that in the case of climate change, full equity in the sense of a fair allocation of the global atmospheric commons cannot be attained at all, since the earlier degradation of the resource has rendered equity impossible to achieve without sacrificing sustainability. It is clearly important that the unfairness of this situation be acknowledged. Without this first step, it is unlikely that those who will suffer the consequences of this unfairness will be prepared to undertake any further action.

6. GLOBAL JUSTICE AND INTERNATIONAL EQUITY:

The climate question brings to the fore another dimension of equity that is the source of some tension even among those who are agreed in the significance of equity. And this tension emerges directly from the local aspect of sustainability that has dominated thinking on SD prior to the era of climate change. The equity and sustainability perspective undoubtedly contributes positively to the work on vulnerability and adaptation, especially in the way it draws attention to the rights of those who are not responsible for the problem but are nevertheless profoundly affected by it. It is also unexceptionable that such equity concerns are grounded in the specific analysis of the potential harm that is caused to communities in their specific ecological and socio-economic setting, and such analyses undoubtedly strengthen an important aspect of the equity-sustainability nexus.

However, a potential source of confusion arises when analogous concerns of equity are echoed by nations themselves in the pursuit of a fair international climate treaty. Where do the rights of individuals or collectives at the local level stand in relation to the rights of nations?

To many it may look as if climate change would require, as in an earlier era when the nuclear issue was growing into the world's most intractable political issue, limiting national sovereignty so as to ensure justice to those vulnerable to climate change. In this view, global justice trumps the issue of justice at the inter-societal level. Superficially, it appears that all societies have carbon profligates as well as those whose emissions are limited and who are not responsible for the problem, though the exact proportions of the two may vary.

At the same time, equity between nations is undeniably an issue. There is a clear divide between those whose responsibility (even in purely physical terms) is far greater than those whose responsibility is far less and the divide is precisely on the basis of nation states. The number of those

The implicit tension between global justice and international equity is also evident in the process aspect. International equity is clearly privileged since by the very nature of the negotiating process nations have a key role to play, Yet increasingly as the weight of the climate issue bears down, global equity must also be addressed. No nation can afford to ignore either, but nor are the two in any way entirely fungible.

Global justice and international equity are distinct (see Sen 1999 for an illuminating discussion) and it is clear that on the climate question both aspects have their own distinctive roles to play. Not the least of the reasons is that global action for climate change mitigation and adaptation will be inseparable from national action on climate change, and that both national institutions as well as institutions that cut across national boundaries need to be involved to successfully tackle the problem.

7. CONCLUSION

It is the argument of this note that in the context of the human-environment nexus the relationship between equity and sustainability is inseparable from the individual nature of either of the two. Historically it is the relationship with equity, justice and fairness that has driven the undoubted appeal of the slogan of environmental protection and later sustainable development.

And yet in practice there has been a weakening of resolve in keeping equity at the centre of considerations of the environment. Sustainable development has been in danger of lapsing into a slogan for all seasons while in operational terms there has been a narrowing of vision in the substantive content of sustainability, precisely by displacing or conflating equity criteria with other narrower views of efficiency or feasibility.

Almost twenty-five years after the first invitation to consider the fashioning of our common future in our common home, the issue of climate change in particular, and other such global challenges, offer another opportunity to renew this vision. The melding of equity and sustainability needs to be an integral part of this renewal.

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UNIVERSAL ENERGY ACCESS BY 2030:

TECHNOLOGY, ECONOMICS, POLICY

***NOTE* FOR GSP**
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PREPARED ON BEHALF OF

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Objective

Ensure that the poorest sections of population have access to clean and modern energy sources.

Introduction

There are estimates that more than 2 Billion people lack access to clean and modern energy sources. In China, 423 Million people rely on conventional biomass for cooking applications. The corresponding number in India and Africa is 855 and 657 Million respectively[i]. Similarly, almost 400 million Indians lack access to electricity. The per capita electricity consumption of India is a measly 600 kWh as against over 12,000 for the US[ii]. Providing clean and cheap energy access is a major challenge, especially in the developing countries.

The question arises, how much energy is essential? If India were to achieve a reasonable level of economic prosperity, a simple calculation suggests that India's electricity generation would have to increase from the present 700 Billion kWh to 5,000 Billion kWh. Or, the installed generation capacity will have to increase to almost 925,000 MW! At that point, India and China combined would be emitting in excess of 10,000 Million Tons of $CO2$ per annum from coal alone. Likewise, there would be a large replacement of biomass by alternate cooking fuels such as natural gas, kerosene or LPG. On the other hand, with aggressive energy efficiency like Denmark or Japan (which are relatively compact nations, of course), the energy requirements for comparable economic prosperity would be much lower. Even this requires enormous growth in the energy supply.

Nobel Laureate Richard Smalley coined the phrase "The Terawatt challenge" to refer to the global objective of ensuring equitable access to clean energy supply, especially to the 2 – 3 Billion population which presently lacks access[iii].

Some of the key questions that emerge are:

- Can this be accomplished in an inclusive sustainable manner?
- What are the fuel and technology options?
- What is the impact on green house gas emissions, in particular CO_2?
- What are the required investments and mechanisms for financing these?
- And, what regulatory framework is required for this transition to occur?

This report will examine the implications of "universal energy access" at the global level. We also periodically provide some illustrations from Indian scenario.

Global Energy Resource Availability

We first ask the question: Are there enough energy resources in the world to cater to large scale increase in energy demand, in particular in developing countries? The table below shows the global resources of various energy resources. The present global energy supply is about 14 Terawatt hours per year. Keeping this in mind, the world has enough energy resources to last for centuries. Coal and nuclear can sustain the world energy for over four centuries. Therefore, there is no global energy crisis.

Figure 1: Availability of global energy resources [iv]

Energy Resource	Energy Potential (Tera Watt year)
Oil and gas (Conventional)	1,000
Oil and gas (Un conventional)	2,000
Coal	5,000
Methane Clatherates	20,000
Oil shale	30,000
Uranium (Conventional)	370
Uranium (Breeder)	7,400
Sunlight on land	30,000 per year
Wind	2,000 per year
Fusion (if successful)	250,000,000,000!!

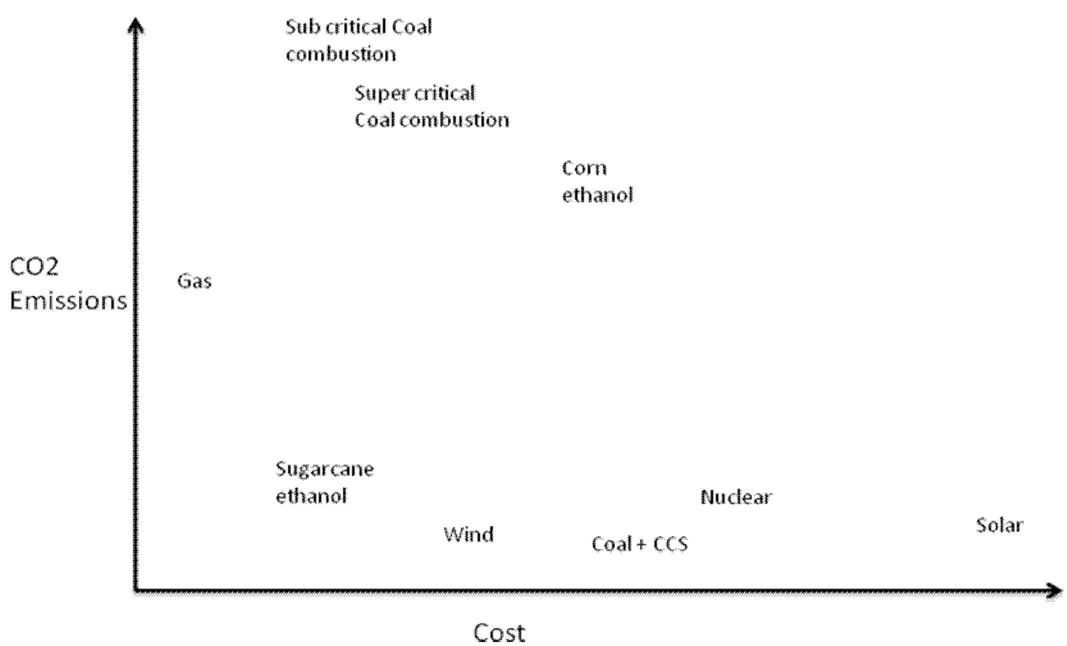
The main issue is of harnessing these resources in an efficient and environmentally friendly manner and distributing these with the appropriate regulatory framework to all sections of the society. The table below shows the lifetime CO2 emissions (grams per kWh) from different energy resources.

Figure 2: Lifetime CO2 emissions associated with various energy resources [iv]

Energy Resource	Life Cycle CO2 Emissions (kg per kWh)
Sub Critical Coal	0.95
Super critical coal	0.84
Oil	0.80
Natural Gas	0.45
Solar	0.01 – 0.73
Wind	0.07 – 0.12
Nuclear	0.02 – 0.06

Clearly, we are attempting to satisfy three simultaneous criteria: energy security, economics and environmental compatibility. At the moment, there are few options which satisfy all the three. Coal, for instance, is presently the cheapest energy option and there is abundant supply. However, it is severely damaging the environment. If India and China decide to go with building large coal power plants, it would have a disastrous impact on the environment, both from global warming as well as local air pollution perspectives. Nuclear is a proven source of clean energy. However, the recent incident in Japan has once again brought back the issue of safety of reactors to the forefront. It is likely to delay if not stop the building of new reactors till this concern is adequately addressed. Solar is abundant and can sustain the world indefinitely. However, the cost is prohibitively high and it integration with grid increases the overall energy cost and that further increases the vulnerability of poorer sections. Biomass and biofuels are in theory “net zero” carbon options. However, in most developing countries, biomass is used for various applications such as cooking, heating and in agricultural processing. It is not clear how much biomass is available for energy generation and the opportunity cost would be high. Moreover, using land for making fuels is fraught with danger given the concerns about food security.

Figure 3: Cost and environmental tradeoffs between several energy generation options. The relative positions on the scales is only representative.



Low Carbon Options: Centralized Generation

We first discuss the potential of several low carbon fuel and technology options.

Advanced Coal Combustion

Coal presently accounts for majority of the global primary energy supply. The developing countries including India and China rely on cheap coal reserves for meeting their energy aspirations. It is therefore reasonable to assume that coal will continue to remain a major part of the world energy mix under any scenarios in the near future. Therefore, it is important to consider technology options which could reduce CO_2 emissions.

Most sub critical power plants operate at about 35% efficiency and generate 0.93 to 1 kg CO_2 per kWh of electricity (net). The efficiency of coal power plants increases with the increase in combustion temperature. In super critical coal power plants, the steam is generated under super critical conditions and these can operate at almost 40% efficiency. As a result, the CO_2 emissions reduce to about 0.85 kg per kWh. It is possible to increase the temperature further (Ultra super critical combustion); however that places stringent material challenges.

Government of India has already taken a lead in this regard by constituting the mission on Clean Coal (Carbon) Technologies as one of the National Mission under the National Action Plan on Climate Change. As part of this, it has been decided that most of the new coal power plants in the coming decade will be super critical technology. Further, the government has placed high priority on the development of Advanced Ultra Supercritical (Adv-USC) Technology for Power Plants as part of the above proposed National Mission. The government recently came up with a document titled "Mission 2017 - Advanced Ultra Super Critical Technology Demonstration", which envisages the implementation of indigenously developed advanced ultra super critical technology in an 800MWe Adv-USC plant, which would have steam cycle pressure of 300 kg/cm2 and 700 degree C steam temperature. So far, the existing power plants have achieved peak pressure and temperatures of 247 kg/cm2 and 565 degree C / 593 degree C. With these parameters, the efficiency of the proposed indigenous Adv – USC plant is expected to be over 45%. It will therefore, emit much lower CO_2 than a typical sub critical power plant.

It is important to note that this is entirely an indigenous effort and the parameters targeted have not been adopted and commercialized anywhere in the world so far.

Coal gasification is also considered an attractive option for high efficiency coal utilization. It generates a partially combustible gas, which can be utilized for power generation and also for production of synthetic transportation fuels and also hydrogen. Coal gasification is also more amenable for CO_2 capture as compared with conventional coal combustion. However, technical and commercial viability of coal gasification is yet to be proven, especially for high ash Indian coals. For the moment, super critical and ultra super critical coal combustion appear to be more cost effective than coal gasification.

Underground coal gasification (UCG) is yet another promising technology option, which could be used to recover coal reserves that cannot be economically mined and are located in ecologically fragile regions. UCG also provides the opportunity for in situ carbon capture in the existing mine. However, UCG is site specific, and depends on several geological variables UCG could be an important technology to consider for developing countries given that coal mining comes into direct conflict with environmental degradation.

Given that coal will continue to be an important source of energy in the near future, it is vital that all new coal power plants are of the efficient super critical technology. There should be close coordination of global research in coal technologies to achieve this objective.

Nuclear Power

Nuclear power is an important component of any future low carbon energy mix. Nuclear power is poised for expansion with several countries including India and China announcing plans to build several reactors in the coming years. The recent earthquake and tsunami in Japan leading to the nuclear accident in Fukushima has raised concerns about the safety of nuclear reactors. It is premature to speculate on its impact on the nuclear power programs. It could possibly slow down the capacity addition plans until public concerns on safety are adequately addressed. However, it is unlikely to stall the nuclear programs.

Nuclear power reactors of most countries, including US, France and Japan are based on the once – through cycle, in which the spent fuel is permanently stored after sufficient cooling. However, the spent fuel contains small quantities of plutonium, which is a fissile material, and could be used for starting new nuclear reactors. India is the only country pursuing this option and is building a 500 MW Fast Breeder reactor. There is considerable debate on the economics of reprocessing spent fuel vs. direct disposal. The international evidence seems to suggest that direct disposal is cheaper[v]. However, we believe that plutonium is too precious an energy resource to be disposed along with the nuclear waste. This is particularly true in case of India, which relies on thorium for its long term energy security. However, thorium is not a fissile material and has to be converted to a fissile isotope of Uranium (233) in a reactor using plutonium. Therefore, harnessing the country's large thorium reserves requires a sufficient stock of plutonium fuel.

India has indigenous research programs for both Fast Breeder and Thorium reactor technologies. However, it could immensely benefit from international cooperation in technology, and nuclear material. This will help accelerate the nuclear power program in the country. At present, nuclear fuel, technology and equipment are tightly controlled by a select group of countries (the Nuclear Suppliers Group) and under the International Atomic Energy Agency (IAEA). Most of these regulations were framed in the cold war era and were guided by restricting access of nuclear material to other countries. However, now that many countries such as India and China have large nuclear power programs, it is opportune to revisit these provisions. We propose to discuss a new international regulatory framework which facilitates development of nuclear power as a safe, and low carbon source of power while addressing the concerns of proliferation.

Solar

In theory, solar provides limitless potential for meeting global energy needs. One hour of sunshine falling on the Earth's surface could potentially meet the entire world's energy needs for an entire year (around 14 TW·year). Nevertheless, solar energy currently provides less than 0.1% of the world's energy supply. Unfortunately, the flux of solar radiation is low (less than 1000 W/ m^2 at the noon peak) and intermittent, and conversion technologies are inefficient and expensive as compared to conventional fossil fuels.

India has recently announced a major initiative "National Solar Mission", which targets 20,000 MW of solar capacity by 2022. The government provided attractive feed in tariffs to incentivize solar projects. The initial signs are encouraging as many solar plants are being commissioned. The next few years would therefore provide an opportunity for considerable learning from these projects. It will also help India develop an indigenous base for manufacturing of solar technologies.

However, building several utility scale grid connected solar farms requires large tracks of land and water (in case of solar thermal technologies). This may not be easy, particularly in densely populated country like India. Hence decentralized generation options should be closely pursued. For village or community level energy needs, a combination of wind, mini-hydel, solar and biomass can provide a solution. However, for the household level, perhaps solar is unique; as it can be scaled down even to light a single bulb. The challenges of decentralized generation are discussed in a subsequent section.

Universal Energy Access

Millions in India do not have access to clean energy for the most basic needs - lighting and cooking. 16% of the 600,000 villages in India are not electrified and due to last mile connectivity challenges, roughly around 60 million rural households depend on kerosene that is polluting and has several ill-effects and remains subsidized. Around 75% of the rural households and 18% of the urban households use traditional biomass for cooking and heating. Modern energy for lighting, health care needs and cooking can provide substantial socio-economic and health benefits to the community overall and to individual households. However, this has proven to be an enduring challenge, given the vast terrain and geographical diversity of the country and economic disparity among the citizens.

In the case of cooking, the fuel choice is often based on availability of modern alternatives, culinary habits, and affordability. The number of households using modern fuel sources such as kerosene and LPG in rural India constitute less than 10%. Given that biomass will continue to remain the mainstay for cooking in the near term, the design and increased dissemination of efficient cook stoves can help in reducing indoor smoke as well as reduce the dependence on traditional biomass which has several ill-effects.

In the case of electrification, given the demand-supply gap and high transmission and distribution losses in the country it is unclear that just extending the grid to remote areas alone can usher in good quality reliable electricity to the remote villages. Even with significant capacity addition, the availability of quality and reliable power supply will be a challenge in the near future. Hence it is important to look into decentralized generation options which are affordable, economically and environmentally sustainable. Alongside, innovative financing, and institutional mechanisms have be in place to increase the adoption in a sustainable manner.

Decentralized Generation

Decentralized power generation using locally available resources is thus considered an attractive option. The optimal solution is very location specific depending the availability of local resources and demand. Solar, wind, mini-hydel and biomass could provide interesting possibilities for local energy supply. Decentralized generation can be at the individual level or at the community level (micro-grid).

There is considerable experience in the country in decentralized generation, particularly, biomass and solar. Several pilot projects have been attempted; however, these experiences have not scaled up. The learning from the initial global experiences highlights the following challenges:

- Institutional mechanisms
    - Ownership and operations
    - Price and availability of resources, particularly in the case of biomass as the opportunity cost of biomass is high as it is used for cattle feeding, cooking, heating, hut making etc.
    - Revenue model for pricing of energy given the subsidized tariffs in rural area, particular for irrigation. The energy tariff policies in India provide virtually free power supply to the irrigation sector. This is a disincentive for the decentralized generation model and also encourages inefficient water usage.
- Lack of adequate service and maintenance.
- Upfront capital cost particularly in the case of solar and lack of adequate financing mechanisms.

Among the decentralized options, solar energy has played an important role in the country. Globally, a large range of applications and institutional mechanisms have evolved in the dissemination of solar technologies. This has made solar based applications flexible to meet the rural household’s need. As a source of distributed energy, solar photovoltaic technologies can be used to electrify all the way from individual homes to communities. The significant penetration of solar home lighting systems requires the presence of a well-functioning market of suppliers, maintenance service providers and of course competitive pricing.

Solar home lighting systems have seen a wide adoption across the developing world and several different service models have been used. For example, while Sri Lanka and Bangladesh relied on microfinance[vi], Latin America (Honduras and Nicaragua)[vii], and in certain regions in Africa[viii], the leasing or micro-leasing approach was prominent. In Argentina franchisees are chosen based on competitive bidding and are given the responsibility of service providers. There are several merits and demerits with each of these models.

However, India is unique in having an extensive banking network, and rural regional banks have played an important role in the solar technology dissemination. A UNEP solar loan program in 2003 was one of the first instances of the Indian mainstream banks financing solar lighting systems[ix]. In this case, the UNEP extended an interest rate subsidy. Market based dissemination models with interest subsidies, orchestrated by rural regional banks in India is likely to help increased adoption. This is an integral part of the national solar mission.

To support broader development needs of rural India, a comprehensive rural electrification program that takes into account a range of technologies, financial solutions and institutional mechanisms need to be planned. Low interest loans are a must to ease the periodic cash requirement to pay back the loan. However, the upfront down payment requirement by the banks from the customers is often the major barrier faced by end-users and hence innovative financing schemes keeping in mind the end-users' cash flow is critical.

To increase the penetration of solar energy solutions India's extensive network of banking institutions can be utilized. While it is unclear CDM benefits alone could help with large scale adoptions, earmarking funds towards subsidized loans targeting decentralized generation from renewable sources could prove to be beneficial. In addition, help with capacity building, policy and regulatory framework and affordable financing mechanisms are some of the other critical factors to increase the uptake of decentralized generation from renewable sources.

Biomass and Bio – Fuels

Biofuels have come into increasing prominence because of the perceived scarcity (and distributional concentration in selected areas) of petroleum resources and the volatility in their price and supply. As oil prices reached record highs in recent years, several countries announced biofuels targets. For example, the US has an ambitious target of producing 36 billion gal (1.4×10^{11} l = 1.4×10^{8} m^3) of biofuels per year by 2020.

However, the benefit of bio – fuels to energy security and environment should be examined on a life cycle basis. For instance, corn ethanol has a net energy balance of around 1.34, which implies that the energy contained in a liter of corn based ethanol is only marginally (34%) more than the fossil fuel energy consumed in the process[x]. As a result, corn ethanol doesn't provide either energy security or environmental benefits. In contrast, ethanol from sugarcane molasses has a net energy balance of 8 – 10.

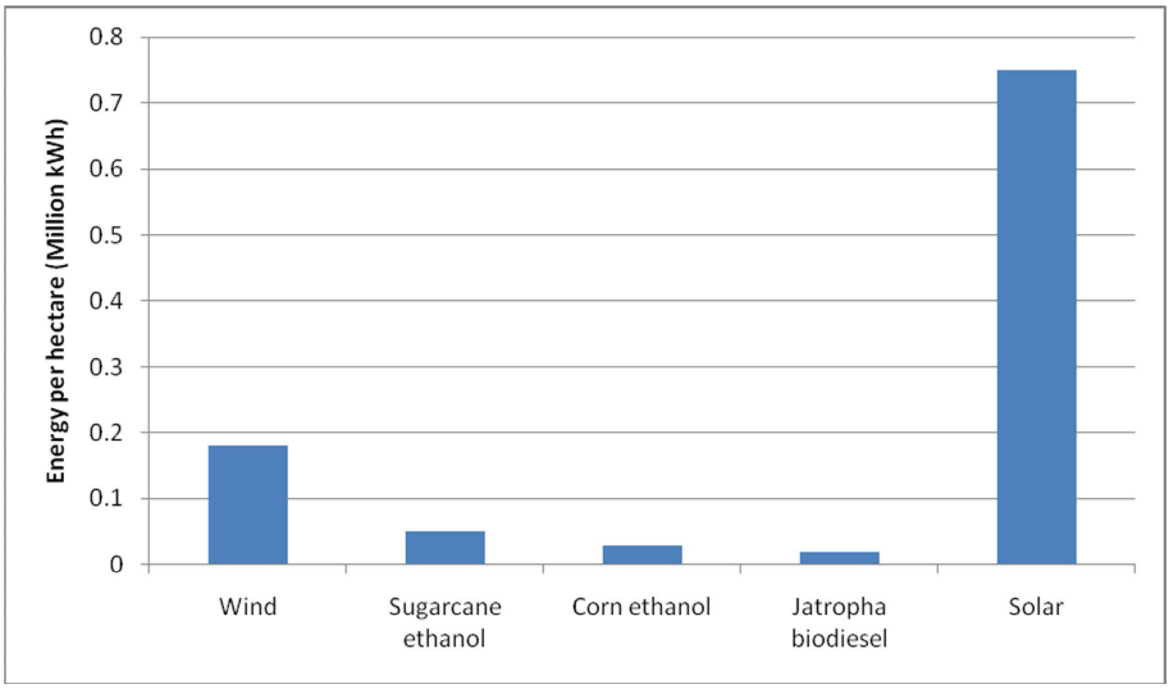
Large scale bio – fuel production often comes in direct conflict with food production. A recent World Bank study reported that large-scale production of biofuels in the US and Europe and the related consequences of low grain stocks, speculative activity, and export bans accounted for almost 75% of the total food price rise[xi]. The report also mentioned that Brazil's sugarcane-based ethanol did not have an appreciable impact on food prices. It also argued that the presence of subsidies and tariffs on imports added to the price rise and that, without such policies, the price increase would have been much lower. Another study determined that the current biofuel support policies in the European Union and United States would reduce greenhouse gas emissions from transport fuel by no more than 0.8% by 2015, but that Brazilian ethanol from sugarcane would reduce greenhouse gas emissions by at least 80% compared to fossil fuels[xii].

Another unanticipated impact of biofuels policy is the indirect land use change. Specifically, the bio – fuel targets announced in the European Union led to the large-scale clearing of forest and peat lands in Indonesia and Malaysia for cultivation of biofuel crops. Land clearing results in a large initial release of CO_2 to the atmosphere and it could take a few decades for this to be recovered by the annual biofuel cycle[xiii]. In fact, deforestation significantly increased Indonesia's CO_2 emissions and made the country among the world's leading emitters.

Therefore, bio – fuels should be pursued with caution. There are interesting options with Next Generation bio – fuels, in particular cellulosic ethanol and algae based ethanol. These do not conflict with the food chain. However, these technologies have to be technically and economically proven.

However, this is a model that should be pursued with appropriate financial and regulatory support as this alone will ensure development of the villages in short to medium run. There is also the issue that any energy option requires land. The figure shows that solar is the most efficient option for producing energy from an acre of land as compared to bio – fuels and even wind. This is because efficiency of photosynthesis is less than 1%.

Figure 4: Energy generation from various sources per hectare of land.

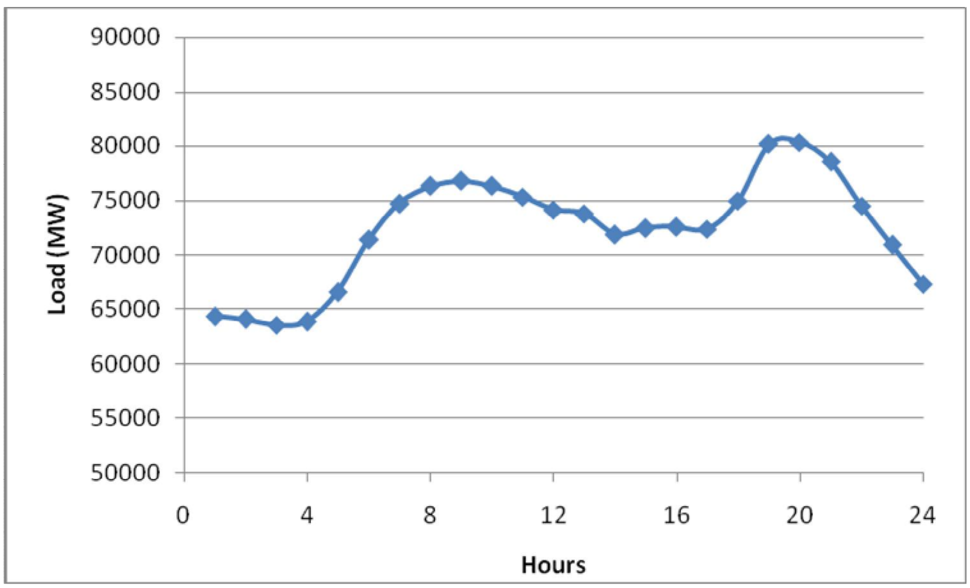


Smart Electricity Distribution Options

Any large – scale transition to a renewable based power generation is contingent on a parallel revamp of the transmission and distribution grid. The power grid of today looks essentially the same as that built a century ago and cannot handle the integration of intermittent renewable sources. However, recent advances in telecommunication technologies has led to an exciting new paradigm in what is called the "Smart Grid", which aims to use digital communications and control technologies to make the electricity supply system more robust, efficient, cost-effective, and amenable to renewables.

In the envisioned smart system, one would know exactly what power was going where and when and be able to act in response to conditions, either through direct control mechanisms or through economic signaling (changing the price). For example, today's retail consumers have mostly enjoyed flat-rate tariffs for electricity, even though power at 5 PM is typically more expensive to supply than that at 5 AM. Figure 5 shows India's load curve on a typical summer day. As the load reaches the peak, the utilities resort to large – scale load shedding to meet the peak power demand. The utilities are driven by commercial concerns and try to ensure supply to large cities, which have paying customers. The villages get hit as a result. Smart metering provides the opportunity for better peak management to ensure near uninterrupted supply.

Figure 5: India's load curve on a typical summer day[xiv]



At base, it would mean that consumers would be paying for the electricity they use, ideally at prices that directly reflect costs. It is just such microeconomic efficiency that has proponents excited. Conversely, fears have been raised about the complexity of such a system, about the undue financial burden it could place on those least prepared to respond to dynamic prices (e.g., senior citizens), and about the potential it could pose for invasion of privacy and risk to consumer data. Government of India has embarked on a major program for reform of the electricity power transmission and distribution network with an outlay exceeding $ 10 Billion. As part of this program, it is undertaking the deployment of a few pilot smart grid projects in various parts of the country.

Next Steps: International Policy and regulatory framework

The above sections highlight the global challenge of ensuring universal energy access to the 2 – 3 Billion which presently lack access to modern energy. This is a daunting task in its own right and it is further complicated by the constraint of reducing global CO_2 emissions. We have discussed the potential of a few select fuel and technology options, which is by no means exhaustive. However, a global transition to a radically different energy mix requires a concerted international effort covering three key aspects: Innovation and technology transfer, Funding and Policy and regulatory framework. We briefly flag these issues in this interim report. The final report will discuss these in more detail and also come up with clear policy recommendations.

Innovation and Technology transfer

It is clear that we need to pursue innovation and research and development of a portfolio of low carbon technologies. However, technology alone is not sufficient. Its success or failure depends on the over arching context of the country or region under consideration. For instance, India is pursuing research in the Fast Breeder and Thorium reactor technologies. China and India have undertaken major research programs in advanced coal technologies. Solar technology is presently tightly controlled by a few leading manufacturers in the US and Europe. Even the raw materials such as Silicon are available only in a few select countries thus providing them with an economic advantage in the cell manufacturing process.

Innovation and technology development should be undertaken in countries/regions which have a comparative advantage in the specific sector. Further, there should be significantly higher collaboration and mechanisms required for technology transfer. We will examine a few such illustrations in the final version of this paper.

Funding

Global transition to low carbon technologies is inherently an expensive option. For instance, most renewable sources are expensive as compared with conventional technologies. Wind is now almost cost competitive, but solar power is very expensive; almost four times that of coal based power generation. Developing countries would be unable to undertake such a transition in the absence of a global funding initiative to incentivize a large – scale deployment of renewable power. The present mechanisms such as CDM and World Bank/GEF funded projects have only gone so far and are not adequate for large scale adoption of renewable sources in developing countries.

We have to think out of the box for innovative options. One option is a Global support (such as Feed in Tariff). The underlying principle is to subsidize renewable sources using a tax imposed on very high energy consumers in the developed countries. The key questions to examine are:

- Is such a system workable?
- How much funding could it generate?
- And what is the international regulatory environment required?
- Else, what are the other funding mechanisms?

We will examine the viability of such possibility in the final version of the paper.

Policy and regulation

The international policy and regulatory framework should facilitate the global adoption of low carbon technologies. For instance, the nuclear regulatory framework was constituted in the backdrop of the cold war era. This may require a change as nuclear power is poised for expansion in countries such as India and China and they would require access to nuclear technology, material and equipment. Similar analogies can be drawn in other cases also such as solar power. The report will articulate clear policy recommendations which could be enacted under an international framework.

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Sustainable Development: Proposal for a New Indicator

Note for UN-GSP
version 2.0

Prepared at the request of

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by

CSTEP INDIA

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Contents

Objective

Develop a new globally useful metric and indicator for sustainable development that combines sustainability with human development.

Summary of Proposed Metric

More important than the details of the metric proposed are the guiding principles and building blocks of the metric, which are explained below:

1) The metric will necessarily be composite given the multiple dimensions that need to be capture, but that does not imply that it would be a single number. In fact, a multi-dimensional measure may provide greater value than a single number or score.

2) Human Development is a key goal, and sustainability is a part of *how* that is to be achieved. One could discount or correct "development" for lack of sustainability, or treat development as development per se (e.g., HDI) and correct for unsustainable practices in the sustainability analysis. We propose a hybrid approach, in the manner detailed subsequently.

3) There should be targets for selected sub-components of the metric, especially on the sustainability dimension. While for many components more (or less, depending on the metric) is better, without proper targets it becomes meaningless to just show large gaps between developed vs. developing countries. Different targets can reflect not only the state of development and legacy issues but differences in geography, climate, etc.

4) What the targets should be is likely to be a rather contentious issue. We propose the development of cohorts (similar countries) to help set targets instead of creating individual targets per country. This is for both simplicity reasons and because of a proposed computational (machine learning) based mechanism for setting targets.

5) One mechanism for dealing with the targets is the concept of gaps. This is a mechanism for estimating the value of not meeting the targets, and applies to both development and sustainability.

The net output for this metric aims to be an understandable, actionable, and comparison-friendly metric.

Introduction

Metrics are a useful mechanism to both judge where one is and also establish targets. Here, one has to be very careful of the "Fallacy of Misplaced Concreteness",[5] whereby one associates different

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[5] "For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future", Daly and Cobb (1994), 2nd Edition, Beacon Press.

meanings or relevance to an indirect (if not different) measure. For example, while GDP (Gross Domestic Product) is universally acceptable as one metric, it is also recognised that it shouldn't be the sole measure, and it certainly shouldn't make claims of well-being. The Human Development Index (HDI) was created[6] precisely to measure development above and beyond economics, that too a narrow slice of economics (viz., GDP = consumption + (capital) investment + exports − imports [final goods and services only]).

HDI itself has many limitations well articulated in the discussion paper "Alternative Indicators of sustainable development and well-being: A discussion paper for the High-level Panel on Global Sustainability" (author unknown), and this note begins the process of additional or alternative metrics for sustainable development. Like all metrics, there are challenges and trade-offs, ranging from data availability, complexity, etc. to subjectivity of selected parameters.

The twin concepts of sustainability and human development each have a history of metrics and indicators, many of which are in widespread use. However, there are few metrics that combine both of these concepts. A part of this is due to the difficult nature of measuring sustainability in a transparent, neutral, and globally accepted manner.

Considering the two dimensions of sustainable development (sustainability and human development), human development has received more focus, perhaps because the metrics have been easier. It is also possible that development has received a greater policy focus since some believe sustainability can be "added on" subsequently (ala Kuznets).[7]

Human Development Index (HDI) is a composite measure that goes beyond economic development (typically measured by Gross Domestic Product, GDP) to add in dimensions such as education and health (in its current iteration). In addition, there are developing country-centric metrics such as the Millennium Development Goals, which have targets along various dimensions of development, mostly quantitative, but some less rigorously defined.

Sustainability on the other hand has found far less widespread acceptance, rather uptake, despite several metrics in literature such as Green GDP/NNP (net national product), which factors in depletion of resources, ecological footprint, etc. A very detailed set of metrics is available via the briefing papers for the "Beyond GDP" efforts by the EU.

As there is no single measure that will suffice for the complex needs of capturing sustainable development, any indicator chosen will likely be a composite measure. In addition, the proposed indicator should be easy to operationalise (gather data for) and thus be amenable to periodic updates. It should also allow for meaningful comparisons, both cross-geographically and cross-

[6] Pakistani economist Mahboob Al Haq developed HDI for UNDP.

[7] If one follows Kuznet's model for development, now vs. sustainability, this would lead to the model where lesser developed countries first become less sustainable as the develop, and only after they reach a fair level of development does sustainability grow faster than development. Of course, his analysis was not prescriptive, and, in fact, didn't factor in time series data for measures of development.

temporally. Any indicator should also, ideally, limit its use of subjective measures since these can both be contentious and hard to gather data for.

It will never be easy to come up with a universally acceptable (rather, desirable) measure, especially not without extensive multi-stakeholder discussions. Nonetheless, this note is an attempt at capturing both existing literature and ideas as well as proposing something slightly different. All attempts have been made to be transparent with the reasoning and implications, e.g., how a particular formulation impacts selected nations or citizens.

Desired qualities of a new metric

Before we discuss the proposed metric, we begin with some observations (more descriptive than prescriptive) about current metrics and issues that would be worth considering in the new metric. Please note that this is not an exhaustive list, nor in any particular order.

1. Capturing variance and comparison: One should capture variance to compare across or within countries. Eg: Gini Coefficient. In addition, the indicator should allow for cross-temporal comparisons within a country or across countries. If we consider equity to be a component of sustainability (with environment and economics) then variance is a justifiable component of a proposed indicator.
2. Granularity of data: One should pick indicators that are simple to measure and compare, which has a bearing on the granularity of data considered. For instance, are we measuring at a household-level versus neighbourhood-level versus regional versus national-level?
3. Rate of change of the metric: For measures like GDP, the rate of change is a useful and often prized metric. It is unlikely a composite measure would display meaningful variations on an annual basis, in which case sub-components may be required to help guide and recognize short and medium term policies that are societally beneficial.
4. What isn't measured: What isn't measured has to be clarified. For instance, leisure time, unpaid work, etc is not captured in the GDP. There are updates or corrections to GDP such as Genuine Progress that reflect some of these.
5. Limiting what is "desirable": Realistically, you have to limit sustainability instead of attempting to capture everything that is "desirable", such as the notion of happiness. Examples of other desirable qualities that may be difficult to measure, subjective, or even very contentious include openness of the society, level of democracy and rights, and the ability for an individual to be successful independent of their parents or family (social mobility).
6. Absolute versus relative indicator: A country that has already invested heavily in infrastructure creation, even though it consumed resources, should be reflected differently than a country where certain infrastructure is missing. Above and beyond indicators like with the millennium development goals, this has implications for expected or future expenditures/effort. Externalities and depletion/consumption of resources should be properly accounted for in flows and transactions. Hence, the indicator has to accommodate where a country is in the path of development.

7. Choosing weights in a composite measure: How do we choose the weights in a composite measure? Is it meant to be descriptive or prescriptive? A dynamic descriptive process would almost be something fed heavily by data.
8. Timescales: What are the timescales considered? For instance, local air pollution impacts the population acutely. Taking the long-term view, you may consider carbon or climate change. What would then be the balance between these?
9. Targets: Can there be targets for sustainable development like the MDGs? If one does not develop sustainably, one faces a penalty.
10. Kuznet's curve: Do we accept Kuznet's curve as inevitable for development? If so, this has implications for what different countries should be doing. In particular, this would place greater burden on the developed world to be more sustainable. The flip side of this is to lose the opportunity to "do it right the first time" in developing regions, who are yet to undergo much of the energy and economic growth expected in the coming decades. A practical problem (unlikely to be captured into a metric) deals with the who (where) sustainability should expand the most first, is a challenge of NIMBY (Not In My Back Yard), where people are willing to embrace a development goal or target in principle but not for themselves.
11. Separating production and consumption: This is a known challenge for economic measures, whereby consumption could be a better indicator of welfare and also externalities than production, especially given cross-border transfers. For instance, given the shift of manufacturing to China, its environmental impacts and carbon footprint appear very bad. But the overwhelming majority of that production may be slated for, say, US consumption. Extending that, one can consider a number of developing countries who exploit an available natural resource and export it. Ecological footprint attempts to capture some of these issues.
12. Can/should we distinguish between types of production/expenses? This can be called input versus output side metrics. Just because a country spends more money, if they are not getting more bang for buck then that should not be counted as positively. For example, when the US spends 1/6 of its GDP on healthcare, it has infant mortality rankings somewhere close to 40 or 50th in the world, can that be reflected? Or, is this sufficiently captured in infant mortality and GDP corrections?
13. Accounting for varied and moving targets: For instance, if one takes minimum earnings levels to provide for a certain number of calories, it would depend on the culturally acceptable and available diet. What should be the mode for and level of updates?

The main focus areas for any proposed Sustainable Development Indicator (SDI) would ideally address many of the challenges listed above:

First, sustainability has different dimensions: economic, environmental, and equitable. This is also known as the triple bottom line: profits, people, and planet. These need to be expounded individually and the tradeoffs have to be detailed too.

Second, there is a need to capture variance instead of just a single average or a total number. This is often articulated as a Gini Index, but even that concept has its limitations.

The last area would be a serious examination of a mechanism to capture both absolute and relative sustainable development that factors in where a country is on the path to development. This is important since one cannot expect a one-size-fits all solution to sustainable development. In addition, to what extent is utilisation of resources or even growth a zero-sum game, i.e., one country (or sub-group therein) is more advanced precisely because others are less so?

Proposed metric: Sustainable Development Indicator (SDI)

Introduction

One could always be more sustainable by reducing consumption, but this would, in today's economy, affect human development, and is unlikely to find societal acceptance. An oft-quoted statement providing an analogy is that the only truly secure computer is one that is not on the Internet. The next best alternative is to undertake the effort to make it secure, by design and by operations. Similarly, consumption could be encouraged if it were sustainable. This impacts not only the quantum of resources but also their type (with factors like choice of product, their "localness", etc.). Countries (rather individuals) should be free to choose how they achieve the balance.

In the proposed measure, there is a desire to minimize the non-sustainable aspect of consumption of energy of materials. Here, we should remove the penalty for consumption of fully sustainable energy (ideally, factoring life-cycle costs and externalities, e.g., the production of a solar panel), and also reward not only the use of sustainable materials (natural, replenishable materials) but also recycling and re-use.

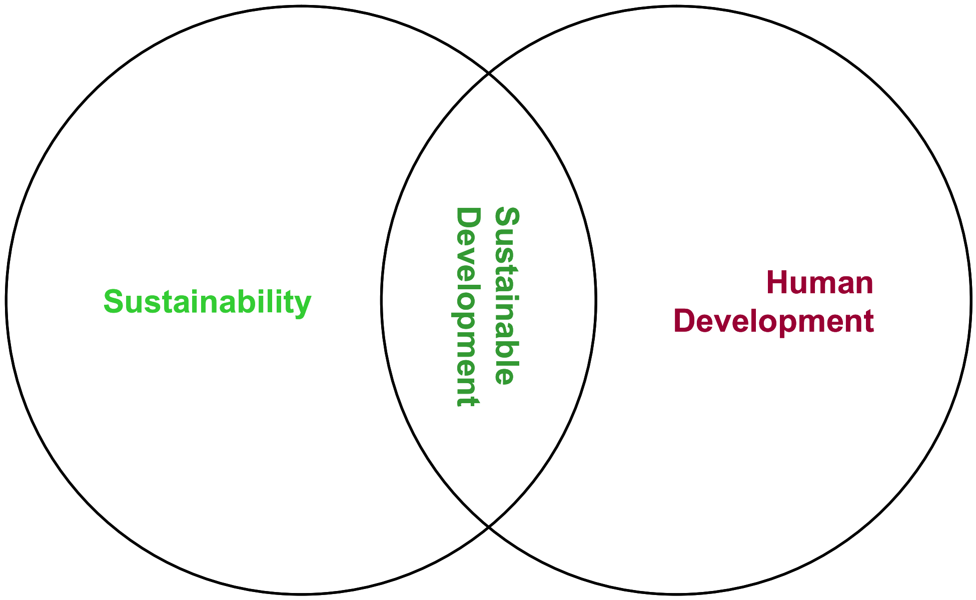

Figure: Sustainable Development

Composition of the metric:

The primary starting point for the SDI metric is that each dimension (sustainability) and human development has sub-metrics and even targets. Their composite (with additions detailed below) leads to the SDI.

Drilling down, the targets themselves have absolute components, and failure to reach said targets or levels indicates room for improvement. For instance, 100 per cent literacy for youth between ages of 8-14.

Another aspect of the SDI is that the targets, where possible, are output side. This means that expenditure on healthcare isn't the goal, healthcare outcomes is the goal. This implies poverty is measured not as the dollars needed for calories, but actual calories consumed per capita. In addition, there is a factor for variance, which implies that there is a minimum target, and a penalty for falling below the target.[8]

Categories of the composite development metric

The details of the components can be debated (based on data, availability, its impact, etc.). One can even start with MDGs as part of the target, or one can develop updated targets such as below. The below table is a *tentative* list of the categories which will be part of the composite development metric (details under preparation).

[8] Experts indicate that calories alone are not an appropriate measure, since raw calories have improved in some countries, but *nutrition* is poor. Nutrition factors in quality of calories as well (protein, vitamins, micronutrients (e.g., iodine), etc. The proposed calorie indicator could be enhanced with a composite metric for nutrition.

While most measures are normalized, the details of normalization vary with each sub-category. For development, the measures are absolute, in that the goals are not cohort based. Thus, something like life expectancy normalizes similar to HDI (2010 version) as below:

(Value – lowest value) / (highest value – lowest value).

This yields a range between 0 and 1.

Variance adds a factor captured by the Gini Coefficient, which is also between 0 and 1 (but needs to be inverted as [1- Gini] since a Gini of 1 is not the ideal but the worst condition, absolute inequality.

The development components, all normalized between 0 – 1, are then combined via a geometric mean (n^{th} root of the product of n variables).

Metric	**Sub-Metrics**	**Details**	**Discussion**
Economic	Genuine Savings (as per World Bank Definition)	PPP adjusted	Normalized as above
	Variance	Per capita Income Gini coefficient	[1-Gini] is a multiplier to income; given a Gini of 0 is nearly impossible, this is also normalized
Food	Calories	Fraction malnourished	[1-% malnourished]
	Other nutrition	Protein, micro-nutrients	Iodine is a good micronutrient as a proxy; others can be used
Water/Sanitation	Clean drinking water	% of population with home/immediately nearby access	
	Improved Sanitation	% of population with modern sanitation available	
Health	Longevity	Years	Normalized as above
	Infant mortality	Per 1,000	Either U1 or U5 mortality; again

			normalized as above
	Polluting (inefficient) biomass cooking stoves	Fraction using polluting stoves	[1-% of homes using polluting stoves]
Education	8-14 age-group literacy	%	
	Total literacy	%	
	Variance (8-14 age group)	Gender gap; percentage difference divided by girls' literacy	[1 – gender gap]
Energy	Households lacking electricity	%	[1 - %]

Notes: *Infant mortality was removed from HDI, but we suggest it has enormous value since it ties closely to short/medium-term policies.*

Biomass cookstoves per se are not penalized; only inefficient cookstoves using non-sustainable biomass are penalized.

Categories of the composite sustainability metric:

When we consider sustainability, the components of a composite measure are more challenging.

Metric	**Sub-Metrics**	**Details/Discussion**
Energy	Fraction Renewable	This is based on consumption, not generation This is normalized at a cohort level
	Energy intensity (energy per GDP)	[1-normalized value at a cohort level]
Materials	Total material consumption by sub-categories corrected by environmental factors (see below)	Cement, steel, and petrochemicals. The impacts of the materials are normalized by their environmental impact during production, but the accounting is for the consuming nation. Thus, "green cement" (e.g., which utilizes some recycled components, like fly ash) would have a lower value. This is net (post recycling). [1- normalized at a cohort level]
Environment	CO_2 per capita	[1-normalized at a cohort level]

	SO2, NOx, etc.	Local and regional pollutants Use healthcare driven models to set targets[9]

It is important to capture emissions and other environmental impacts on a consumption basis only. Thus, a country extracting raw material shouldn't be the "loser" in the metric, rather the consuming nation.

Consumption is a useful measure since this ends the challenge of national accounting norms and borders. E.g., many nations in Europe have an interconnected grid. Thus, they may themselves avoid any coal plants but may import coal (or nuclear, or another locally absent) power. As an example, let us consider a Country A consuming 1,000,000 tonnes of cement. Some fraction is domestic, while the remainder comes from countries B and C. Each country producing cement has a total (weighted average) metric for its environmental impact, which is based mainly on technology and operating performance. Thus, Country A's account for the cement would be normalised based on the environmental impact of the respective cement(s) used.[10] Operationalizing this, one would first start with average numbers only.

When we extend this to ecological footprint (embedded in the sustainability components), it is consumption and not production that is of value. Else, nations like Australia would be free to do almost anything they want, but a nation like Singapore (where exports and imports are greater than the GDP) would be rather limited. In fact, accounting for transportation hubs like Singapore should be done at the consumer side, since if we chose to dismantle a hub like Singapore on the grounds of local carrying capacity, that economic and environmental activity would simply shift elsewhere. If this were more dispersed, it might have employment implications for developing regions, but the efficiency gains from hubs like Singapore, Rotterdam, etc. likely compensate on a materials and energy point of view.

Ideally, one would want an accurate lifecycle, supply-chain based metric of consumption and its sustainability implications, e.g., an input-output matrix based measure. However, input output tables, above and beyond being very data intensive, have limitations of granularity (in practice) and

[9] If one applies risk-based targets, one could justifiably argue for a cohort model. Using cost-benefit style calculations, $/life saved from environmental factors indicates what the cost is for any particular regulation or policy. One tool has been to use "value of life" estimates to set the guidelines. But from a developing region, opportunity costs may be more appropriate, since there are lower hanging fruit still remaining to be done, e.g., fire and earthquake codes, before worrying about particulates at sizes of 2.5 microns versus 10 versus 50, i.e., PM 2.5 vs PM 10 vs PM 50. Note that only the most developed of regions even measure particulates at the smallest size today.

[10] In theory, one could do plant level accounting, but this becomes intractable. Even this formulation may require some simplification as it entails pair-wise accounting of supplier nations (for the factors) and consumer nations (to whose account the impact is booked).

dynamics. Thus, we have chosen to limit measures of consumption from a development perspective.

Is it worth looking at direct linkages between development and sustainability or should those be let at an aggregate level? If we consider something like agriculture, a critical component of the global economy from an employment perspective though less and less so from a GDP perspective, then development can easily be measured by yield (productivity). The highest yields are often from Western Europe, by almost an order of magnitude more than in some of the lesser developed regions. But, on the sustainability side, such productivity is highly energy and fertilizer intensive, and thus would lose points for its energy and other inputs. From a metrics point of view, aggregate is likely superior, since how much (and what type) of agriculture a country pursues is a decision driven by local needs, culture, etc. It is only when we are examining sector-specific policies would the more disaggregated data like above be appropriate. In an ideal world, the macro could be built up from a sum of all the micro, but that appears to be a long term goal.

If we come back to the issue of sustainability within development or sustainability as a separate dimension, examining the current methodologies we find there is value to keeping them separate at the least (though it can be embedded as well – a "hybrid" approach so to speak). GDP, even with corrections, tends to drown out many other factors. E.g., Genuine Savings, as reported by the World Bank, including corrections for depletion of resources, environmental impact (though right now measured as Carbon only), etc. indicates that developing regions are worse off than developed from a "weak sustainability" measure. Similarly, energy intensity (energy required per GDP) is misleading since almost all developed regions have better energy intensity than developing, despite consuming far more energy, simply because the GDP is disproportionately high (a combination of productivity, structural issues, i.e., more services, and what is captured in GDP).

Are we considering weak Sustainability vs. strong Sustainability? The former allows for innovated or engineering (manufactured) substitutes for a natural resource. The latter does not, in part because the true value of a natural resource (e.g., a forest, the ozone layer, etc.) is hard to quantify. While the indirect resource value may be difficult, there are cases where substitution of resources through innovation is not only equivalent, but perhaps superior. E.g., the primary fuel for lighting during parts of the 1800s was blubber (whale oil). This was gradually replaced by kerosene and then electric lighting. Similarly, innovation and materials substitution can be a net positive, but here the change is not because of depletion of the earlier natural resource but because of the superiority of the substitute. It may be appropriate to consider strong sustainability only at a global level but weak sustainability only at a national level.

Sustainability Targets and Cohorts:

It is unreasonable to believe that developing countries will approach the level of development as highly developed nations in the near term. Is the same naturally true for sustainability? What does sustainability mean when the environmental impact is low precisely because of low development? And, ala Kuznets, as they develop, they become less and less sustainable (at least under today's Business As Usual models).

This issue comes up when we consider targets – should they be absolute or relative? We propose development targets be absolute but sustainability be relative, but periodically updated. The reason for this is because there are likely few highly sustainable nations that are not highly developed (the data remains to be put through the model). Thus, developing regions are given a temporarily slightly lower target for sustainability as they strive to develop.

Extending this, the target for sustainability is modified based not only on the level of development of a nation but also other factors such as climate (which impacts heating/cooling needs, etc., geography, population density, etc.) The idea is to use Machine Learning (computational) tools to determine the most "similar" countries to form a handful or two of cohort nations. Appendix 2 has details on such tools. While the details of this are to be worked out, the fundamental (and new) idea is that instead of a priori knowing the targets, cohort nations are chosen, and then the best performances within the cohort are used to set the target. In essence, the data speaks to the model, instead of vice versa.

Does such a model diminish the pressure on developing regions? I.e., since they start lower, they only need to target "a certain amount" higher? E.g., carbon emissions from developing regions. The use of Machine Learning (ML) for determining cohorts and targets removes political values from the targets. It is possible that the targets may still not be aggressive enough, but it is premature to say so. Also, from a highly practical point of view, a cohort based target (which can still be aspirationally high) is much more meaningful than an obvious gap in sustainability. It is infeasible to imagine a developing city like Dhaka can become developed AND environmentally clean like, say, Zurich, in a short period of time (and one can extend the analogy to nations, where developing countries fare even worse because of rural/urban divides along many dimensions).

Sustainable Development and gaps:

Once targets are created as above, is there a meaningful manner to create comparisons? This extends to both sustainability and development. One mechanism for this is to apply the concept of *gaps.* This examines where a country is in meeting the targets, and then adds an economic penalty based on the cost required to develop or clean up.

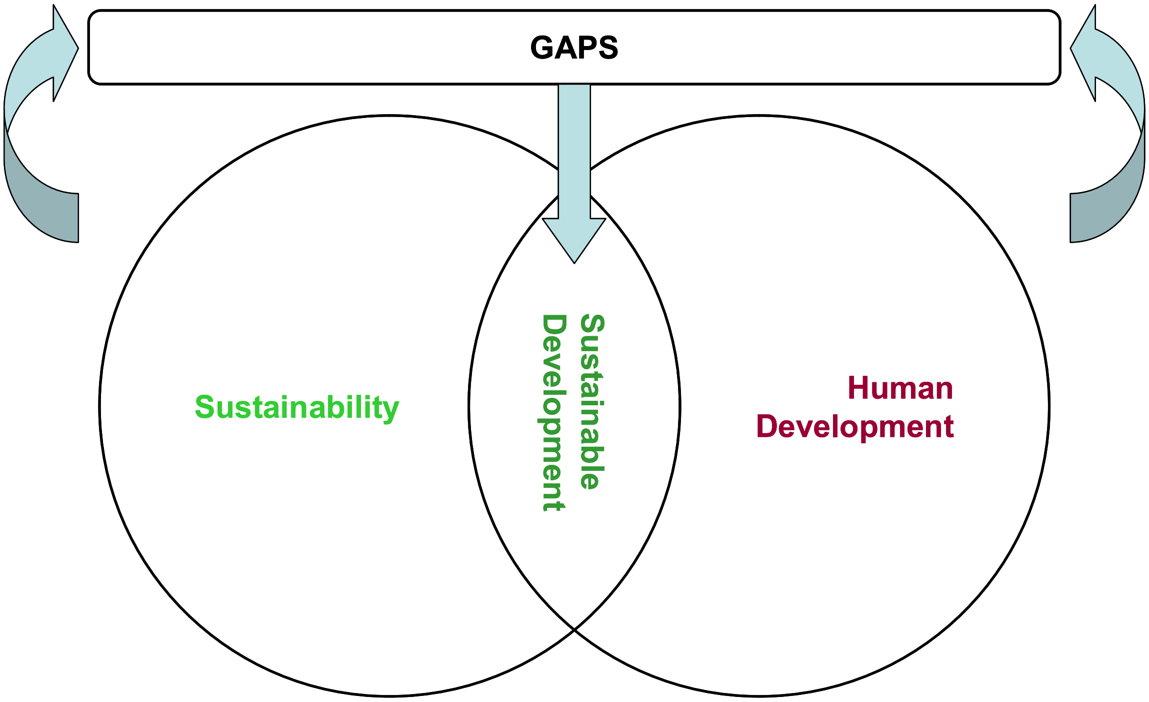

Figure: Sustainability gaps

One of the thoughts behind the "gap" mechanism is the Kaldor-Hicks criteria for dealing with social efficiency via welfare transfers. To simplify, something is worthwhile if it leaves society better off, even with winners and losers, since the winners could always pay off the losers for their losses. This says nothing about how or whether this is actually done, and isn't a prescriptive policy, but one that is in contrast to a Pareto Optimal solution where the equilibrium cannot be disturbed as some may disagree (Pareto Optimal solutions have no further improvements possible without someone being worse off).

One useful analogy for this is to consider a coal-fired power plant. It is estimated that some 25-30 per cent of the costs of a coal-based power in the US are for meeting environmental standards.[11] Thus, if one were to remove environmental constraints (which, today, don't factor in carbon emissions), then one could theoretically obtain cheaper power. Thus, a nation without commensurate emissions either has paid the costs of removing such emissions or it simply doesn't have such a power plant. The latter ranges from fuel substitution (which, ultimately, could move to renewables) all the way to simply not having such any equivalent power plant in the first place. Ignoring importing energy, this could be because of energy efficiency or because of lower demand stemming from lower development. In the proposed SDI, development that has inappropriate emissions is penalized.

[11] Integrated Environmental Control Model (IECM) analysis, Carnegie Mellon University (http://www.cmu.edu/epp/iecm/)

As we consider development and sustainability, there are links, and either one or both parts of the SDI capture any positive or negative development. In fact, the creation of goals for development reduces the burden of accuracy of input side measures. E.g., if we consider cooking, many developing regions use biomass for cooking. In theory, biomass could be a good fuel for cooking compared to non-renewable fossil fuels, but it has several major drawbacks. First, it is often not replenished, i.e., citizens cut down any available biomass, without replanting. Second, the health impacts on citizens (indoor air pollution) are very high, combined with the very low efficiency of traditional cooking stoves. If a country is using "modern" cooking stoves, it benefits from lower penalties for inefficient cooking stoves but has a negative for sustainability due to use of fossil fuels. If it uses replenishable biomass in efficient cooking stoves, its SDI would reflect that positively (since replenishment would help forest cover whose loss would otherwise show up in the Genuine Savings metric).

Let's examine one example of gaps in some detail, sanitation. As per MDG literature, this is a more expensive proposition (and harder target) than drinking water. Primary surveys in rural India at CSTEP indicate a very low proportion of rural homes have individual (household level) sanitation (toilets). The cost to build one in a rural setting is estimated to be Rs. 15,000. This includes a septic tank – a lower figure sometimes quoted excludes waste disposal/management. If we estimate 130 million homes requiring such infrastructure, the total capital costs come to an estimated $50 billion only.[12] Assuming this is built out over 5 years (to be aggressive), that still comes to only about 1% of the GDP of India. Personal conversations with development scholars indicate that the benefits (e.g., healthcare, productivity, etc.) would be far greater than 1% of the GDP annually.

The exact modalities of gaps are under development. The two choices are to use relative measures or absolute measures. Relative measures (e.g., across countries) become a moving target, and thus comparisons over time become challenging. An absolute target is proposed, but the absolute target itself becomes updateable periodically. E.g., the fraction of energy that is renewable. In the short or even medium run, 100 per cent renewables are unlikely, except for the rare nation blessed with high hydropower potential. In fact, most present power grids finds themselves struggling to incorporate more than, perhaps, 20 per cent intermittent renewables such as wind and solar. Thus, the target is set at a reasonable best feasible, independent of what the global average is, but over time, the target should be updated, perhaps every 10 years. However, once we do have a target, using an estimated premium or incremental cost for, say, making "x" percent of energy carbon neutral (leaving the details to the country of how it is to be done), this helps compare gaps across countries using a common framework. In fact, one potential off-shoot of this may be the concept of gaps as a percent of nominal GDP.

[12] This estimate excludes urban toilet needs, which are lower in absolute number, and where, other than unauthorized developments (slums), is part of cost of building a house. One alternative discussed is community toilets. While cheaper, institutional challenges make this untenable, in contrast to community handpumps where the maintenance needs are far lower. The Andhra Pradesh State Government in India has a reimbursement scheme, "Indiramma" for rural/poorer households building a toilet, and this provides an estimated Rs. 5,000-8,000 depending on criteria, but there are not many takers. The Rs. 15,000 estimate for true costs is based on CSTEP primary survey data. [Note the scheme focuses on housing and not sanitation per se].

Comparing SDIs

A single number is easy and makes it easy to compare nations, but the value and insights (and predictive power for policy linkages) becomes inaccessible. We believe listing separate Development, Sustainability, and Gaps will be useful. If any nation does wish to have simplified comparators, Gaps can be useful. Given the non-absolute nature of these (cohort driven), a single number is problematic. A qualified Gap score may be more insightful, similar to how a golf score is based on a handicap. Thus, the Gap could be cohort linked.

If we consider energy per GDP (energy intensity), it is a useful measure that tells us about sustainability more than development since two nations with similar energy intensity could have very different development based on the overall energy (or GDP). Similarly, while SDI is chosen as a composite measure, a visualization of both the development and the sustainability of a nation, along two axes in a graph, would be a useful comparator. The numeric calculation of SDI is where the concepts of gaps would come in.

The hypothetical graph of the dimensions of sustainable development shows how different countries could be placed. The size of the circle represents the total population of the country, signifying scale, while shading (light to dark) could help visualize the Gaps. Intuitively, especially given a Kuznet type of model of development, one would expect more countries to the lower right than the upper left of the diagonal.

While we currently have not applied this new indicator to the countries across the world, we find there are four quadrants amongst which countries could find themselves, considering the dual dimensions of sustainability and human development. High vs. low development; high vs. low sustainability. Ideally, a country should aspire to high sustainability with high development. Given a large number of countries have low development, the main challenge would be to find pathways for increasing development while simultaneously maintaining, rather, improving sustainability.

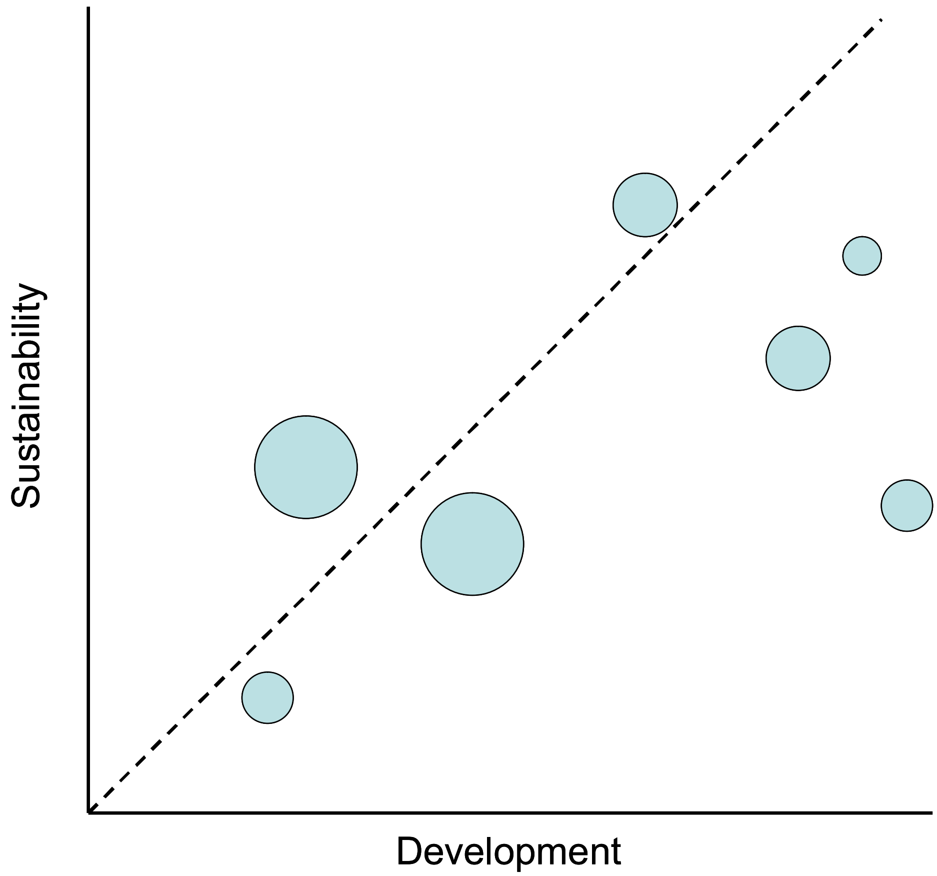

Figure: A hypothetical graph with sustainability and development as dimensions illustrating how different countries could be placed in it. Shading (light-to-dark) could also signify the Gaps (as defined previously).

Limitations:

One major drawback of this methodology, with targets revised every 10 years, and different targets for different nations by cohort is that comparisons become difficult. Temporal comparison limitations are easier to justify since so many things are a moving target. 10 years is considered a medium-term, which allows for policy efforts to take shape and bear fruit, and revisions become justified as technologies, structural set-ups (e.g., financial flows via globalization in a highly service economy), aspirations, household patterns, etc. can all change substantively in 10 years. Instantaneous comparisons with such an indicator are harder, but the underlying data should allow further comparisons on a case by case basis. As stated before, can two countries with, say, identical carbon emissions per capita be compared if their GDPs are more than an order of magnitude apart?

There are other limitations we recognize up front, but those are ones that can be corrected for with refinements (and checking whether appropriate data are readily available). First, it does not handle population growth explicitly. It is an embedded characteristic. Same goes for innovation, but the use of cohorts and of 10 year resets should help that. Lastly, it doesn't handle temporal issues explicitly, especially inter-generational. Only in the sustainability metrics could strong sustainability be potentially applied for global non-replenishable natural resources.

Further discussion:

The attempt in this note is to come up with a useful metric that corrects for several of the drawbacks of existing or popular metrics. No claim is made that this resolves all the issues, but it might offer new insights and guidance. In that sense, it may not be a replacement, but another indicator. E.g., many consumer goods now list "carbon footprint", even though carbon is not the only indicator of sustainability. But it remains one that is nonetheless useful, and one welcomed by many consumers and decision-makers.

This framework is still under development, and ready for stakeholder discussion before discussing specifics and values, and CSTEP welcomes comments on the overall concept and outline note (tongia@cstep.in).

Appendix 1: Discussion on Existing Metrics

Below are a few general framings for sustainability and economics.

- GDP = consumption + (capital) investment + exports − imports [final goods and services only]
- GNP = includes net income from abroad
- NNP = GNP - Depreciation of Capital
- Green NNP = GNP - Depreciation of Produced Assets - Depletion of Natural Resources
- Genuine Savings = Production - Consumption + value of education [knowledge capital]- Depreciation of Produced Assets - Depletion of Natural Assets

  (Also takes out net borrowings)

Genuine Savings is already a well-recognized (but not necessarily perfect[13]) metric, and statistics on this are published by the World Bank.

[13] One of the major criticisms of this indicator ("The World Bank's "genuine savings" measure and sustainability", J. Ram Pillarisetti, *Ecological Economics* 55 (2005) 599– 609) is its lack of additional predictive power compared to direct use of underlying components. In addition, GDP dominates many factors, e.g., CO2 emissions. The absolute emissions of the US may be ~25% of global emissions but the penalty is relatively small.

Appendix 2: Machine Learning and Computation tools for Development

A traditional approach to modeling and analysis has been what can be considered an engineer's (or economist's) approach. One has a model, and then examines the data to see the fit, including values for parameters or coefficients. As an example, a common tool is a regression analysis.

Recently, the growth of "machine learning" (ML)—which is sometimes considered a variant of artificial intelligence)—and advanced computational tools have offered a new alternative, whereby the data itself is used to come up with the best (most predictive) model, including relationship and weightage between variables. What this allows for could be far greater predictive power, as well as new insights that might have been hidden using conventional means. It also offers the advantage of being relatively neutral, and is now being applied for human development. The latter has matured as can be evidenced by the presentations at the AAAI Artificial Intelligence for Development Spring Symposium in 2010.

In attempting to produce cohorts and their targets, ML can help us identify the best groupings in terms of similar countries, and then we can set targets as the best practices within that cohort. Now, similar need not just be "large", Latin American, or natural-resource rich, etc. It can be the appropriate groupings of these. Whether we end up with 5 or 10 or however many cohorts can also be driven by the data. Just like a greater fit in regression analysis (R-squared) is possible with more independent variables, the adjusted R-squared may not always improve (which penalizes for complexity based on adding variables). Similarly, 20 or 30 groupings may be feasible in theory, but an adjusted fit may help us identify the balance between number of and predictive power of the groupings.

As an example, such techniques have been applied to healthcare in developing regions in the paper "Determinants of National Diarrheal, Disease Burden" by S. T. Green and colleagues.[14] To simplify the value of the mechanisms, above and beyond the analytic value of the findings, using such techniques, we can better group countries together instead of traditional measures like geography, HDI position, GDP, etc. Thus, Brazil may have more in common with S. Africa than its neighbors. For the SDI, this lets one add atypical but likely important factors like land-locked vs. not land-locked, annual rainfall, etc. Classification and Regression Tree, or CARTmay be a useful tool for the analysis, which is one of several candidates within ML techniques.

[14] "Determinants of National Diarrheal Disease Burden" S. T. Green., M. Small, E Casman, *Environmental Science and Technology*, Vol 43, No. 4 (2009).

Appendix 3: About CSTEP

The Center for Study of Science, Technology, and Policy (CSTEP) is a private, not-for-profit research institution with a vision to undertake research in engineering, science, and technology where it is relevant to Indian (and global) economic and human development. Work at CSTEP is interdisciplinary, and spans subjects such as energy, infrastructure, materials science, information and communications technologies, and security.

CSTEP Research

Energy
India faces tremendous challenges generating sufficient energy to propel its growth in an environmentally and economically sustainable manner. CSTEP is working on projects related to climate change, solar thermal energy, electricity market reform, smart grids, and energy games.

Information & Communications Technology
Information and communication technologies present great opportunities for countries such as India that are in the process of rapid economic development to create the groundwork for shared growth. CSTEP has worked on both general and specific issues related to ICT for development in an Indian and international context.

Infrastructure
CSTEP operates a Next Generation Infrastructure Laboratory (NGIL) to study design and policy-related infrastructure questions with both innovative and conventional tools. One major project is to create simulation-based games for policy analysis.

Security
India faces security challenges of all types: internal, external, economic, political, social, environmental and CSTEP performs evidence-based analysis, some classified, of these challenges.

New Materials
New materials are key to improvements in human welfare. CSTEP's focus is on new material development in the energy area, with an emphasis on batteries. This has implications for energy conservation and efficiency, disposal of waste and environmental sustainability, and innovations for new methods of energy use and storage.

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