Chapter 11
Industrial Ecology in Developing Countries

Megha Shenoy

Abstract Sustainable development is not a simple, singular and well-tested path. It needs an interdisciplinary examination of resource use patterns, ecological heritage, demographics and cultural values. Industrial ecology, owing to its emphasis on using a holistic approach, can provide a valuable platform to draw out sustainable strategies and policies for developing countries to implement. It can offer a paradigm within which IE methods and tools can inform responses to local development challenges. Within this paradigm, sustainable industrial, rural and urban development strategies and policies in developing countries should follow from IE research and analyses.

A SWOT analysis of IE in developing countries highlights strengths of high economic growth and threats from outdated policies and inadequate industrial ecology awareness in the policy making and governing spheres. Examination of the IPAT equation in the context of developing countries highlights the role that new technological hubs such as China and India can play, the significance of increasing affluence among "new consumers" in the developing world and the role of population in managing resources sustainably.

Research in IE since its introduction to the global south around the mid-1990s has primarily focused on two concepts of IE – cleaner production and eco-industrial parks – largely due to the impetus of development organizations. Other studies using the IE lens and tools have shown the potential of the IE paradigm in developing countries. These studies have highlighted the importance of focussing on scarce resources such as water, examining the possibilities of using well-tested technologies and evaluating the long-term maintenance of new technologies and practices before recommending their implementation. New policies in the developing world can gain from the IE community in terms of assistance in simplifying and downsizing data requirements, application of solutions to contemporary sustainability challenges and framing effective policies based on IE concepts.

M. Shenoy (✉)
Independent Sustainability Research Consultant,
SJ 102, Shriram Spandhana, Chalghatta, Bangalore 560037, India
e-mail: shenoymegha@gmail.com

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1 Introduction

1.1 Benefits of IE for Developing Countries

The topic 'industrial ecology (IE) in developing countries' is as vast as the ocean and I would not wish to attempt to raft through its entirety with this chapter. Using my field glasses, I attempt to provide an overview, highlight areas of industrial ecology that have been examined in developing countries and two-way streets for developing countries to benefit from IE and *vice versa.* Developing countries[1] can use the concepts and tools of IE to ensure that the improvements they make to the quality of life for their citizens is achieved in harmony with improving the health of ecological systems, while investing effort, time and resources into a resilient economy. Regions with higher population densities are also ones whose populations are most at risk due to climate change and other environmental disasters caused by unsustainable industrialization. Some of these countries (especially BRICS[2] countries) have high GDP growth rates, owing to relatively recent industrialization, and are at a point where they could redefine their "development" paradigm and vision towards embracing sustainable progress, rather than focusing on narrowly defined economic expansion (Fig. 11.1).

1.2 GDP Fixation

Despite the overwhelming focus on improving a developing country's GDP, its citizens have to realize, as renowned environmental and policy analyst Vaclav Smil (1996) reveals, that there is little worth of China's impressive 10 % GDP growth if the true cost of environmental damage caused by this GDP increase is about 15 % of its GDP. The out-dated practice of "pollute now, clean up later" will only degrade the country's environment and quality of life and increase economic expenditure on future remediation efforts (Erkman and Ramaswamy 2003; Chiu and Yong 2004). Moreover, once a country's development paradigm and infrastructure are built on a foundation of modern consumerism reliant on profligate use of fossil fuels, corrective action to move towards sustainability will be expensive, complex and challenging to navigate. Some of the reasons for the resistance in developed

[1] Defined as those with a lower Human Development Index (HDI) and lower standard of living relative to developed countries.

[2] "BRICS countries" refers to Brazil, Russia, India, China and South Africa.

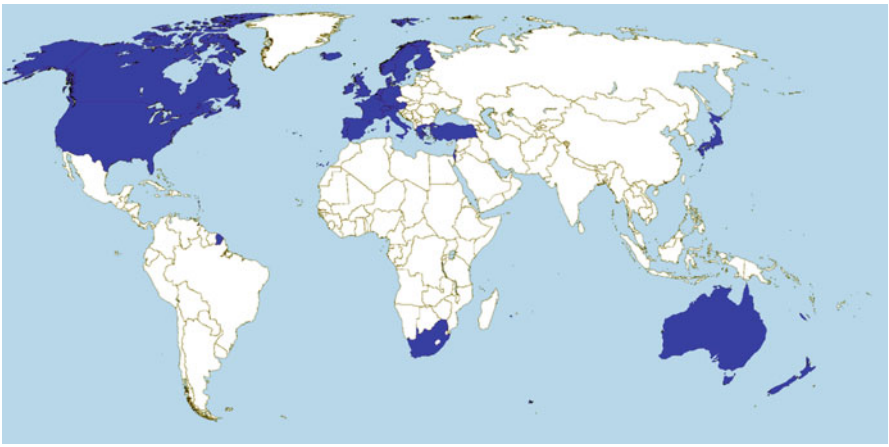

Fig. 11.1 Developed and developing countries (CIA 2013; Augusti 2008)

countries to redefine their development paradigms lie in their high accumulated debt and the enormous investments they have made in infrastructure that is not designed for sustainability (see Chaps. 6 and 7). When examined further, these aspects may reveal a potentially more optimistic picture for developing countries.

1.3 Previous Studies on IE in Developing Countries

Sustainable development is certainly not a simple, singular and well-tested path. Many different interest groups are in conflict over which environmental and social challenges to tackle first, as well as their solutions. As previous reviews on industrial ecology in developing countries suggest, IE offers an umbrella paradigm, a sort of panoramic vision within which individual local crises could be approached with pragmatic solutions. Industrial ecology based solutions offer the advantage of simultaneously addressing several other interlinked problems to yield concurrent benefits for all stakeholders (Chiu and Yong 2004; Lowe 2006). A SWOT analysis of IE in developing countries, based on a previous study that looked at IE in Asian developing countries (Chiu and Yong 2004), is presented in Table 11.1. Some strengths, such as rapid economic growth, can also be viewed as a weakness, opportunity and threat.

In the developing world context, characterized by immediate development challenges brought on by rapid industrialization and urbanization, Chertow (2008) suggests applying a narrower focus to the word "industry" in IE, rather than using it in its broad sense to cover a range of anthropogenic activities. This suggestion may hold well in contexts such as in Eco-Industrial Parks (EIPs) where resources are cycled between industrial firms and collective benefits are realized to reduce environmental and social impacts. However, even in these contexts it is important to realize that, in

Table 11.1 SWOT analysis for the potential of IE in developing countries (Adapted from Chiu and Yong 2004)

Strengths	Weaknesses
1. *Economic growth*: Most developing countries are growing fast with large foreign direct investments and domestic industrialization, especially in the BRICS countries. This situation can provide the economic impetus for funding industrial ecology research and implementation in policy and industrial innovation.	1. *Developing country specific IE based models and data*: Models specific for understanding flows of resources and their interaction with socio-economic groups in developing countries need to be developed, especially in the unorganized/informal sector. Specific metric and indicators more suited for developing countries should be identified. Background data especially that of life cycle inventories (LCIs) for life cycle assessments (LCAs) are lacking for most developing countries.
2. *Human resources*: Most developing countries have high population densities with demographics emphasizing youth populations, especially in countries like India.	2. *Scarcity in financial resources*: There is meager funding for research and development of IE in developing countries.
3. *Research*: In some developing countries, the research and academia have been exposed to industrial ecology, making this an ideal stage for the setting up IE research and education centres.	3. *Dearth of education programs*: There are very few specialized educational programs in IE in developing countries. Most of these programmes are in China
4. *Awareness*: People are aware about sustainability and are looking for methods and tools to implement solutions for it. This awareness is present amongst the corporates, citizens and the government.	4. *Inadequate clarity in the role of different governing bodies*: In several developing countries, there is a lack of clarity in the roles of governing bodies for resource management. In many cases, there are gaping gaps in governance and in some cases there is overlap in the responsibilities of public sector institutions. There is a lack of an integrated and collaborative approach to resource management.
5. *Role of government*: The government in some developing countries have shown interest in IE and implemented IE based policies, especially in China. Political cooperation can lead to growth of IE in groups of these countries such as South Asian Association for Regional Cooperation (SAARC), Commonwealth countries, etc.	5. *Insufficient data*: Data necessary to make content informed policy decisions are insufficient and at times unreliable. 6. *Scarcity of green tech*: Lack of innovation and access to green and clean industrial technologies. 7. *Insufficient enforcement*: Lack of enforcement of sustainable policies and for management of resources.
Opportunities	**Threats**
1. *Redefine sustainable development*: Have an opportunity to redefine their development paradigm and polices to maximize social welfare while limiting environmental impacts of development focused on consumerism.	1. *Strong focus on economic growth from rapid industrialization*: There is strong focus on industrialization and economic growth rather than increasing social welfare. This thrust has already damaged the ecological health of developing countries to a great extent.

(continued)

Table 11.1 (continued)

Opportunities	Threats
2. *International co-operation*: Several international institutions are collaborating with partners in developing countries to investigate systems using IE concepts and tools.	2. *Inadequate industrial ecology awareness*: Especially in the policy making and governing spheres and the public domain.
3. *Development of new models and tools*: Can contribute to the development of new models and tools in IE.	3. *Insufficient data*: Lack of sufficient macro and micro level data to inform policies on sustainable management of resources.
4. *Global political arena*: Several developing countries are allying with one another to further their negotiations in global agreements such as those regarding climate change. They can use these political collaborations to cross collaborate on IE based policies and strategies.	4. *Focus on remediation*: Stuck in the "industrialization – pollution – remediation" running wheel to further development. Lack insights into how to transition towards sustainable policy development and enforcement. IE may therefore be viewed merely as a technical "add on" or "fix" to remediate pollution, caused by inefficient management of resources and insufficient lack of enforcement of environmental policies.
	5. *Outdated policies*: Policies in some cases prevent effective IE implementation. For example "Zero discharge policy" in India disallows water cascading among industries. In some countries laws inhibits the formation of waste exchange networks and industrial symbiosis.
	6. *High externalities of industrialization*: In several countries, the externalities associated with industries are tremendous as proper working conditions, environmental protection and social benefits to affected communities are not included in the cost of production.

the absence of an overarching sustainable development paradigm, industrial residues that are expensive for industries to recycle will be disposed of in the cheapest and most often not the cleanest of ways. Moreover, polluting industries such as coal fired power plants in EIPs may be further locked-in in industrial networks, making it difficult to replace them with cleaner technologies such as plants based on renewable resources. On the policy front, it is important for developing countries to be aware of these interlinked complications and think of ways to avoid net long-term damage to their ecological, social and economic health, as explored in Chap. 6.

1.4 IE in the Policy Context

Around the world, national policies for environmental protection have evolved from a perception of industrial processes as linear chains, rather than viewing them as cyclic ones. These policies, therefore, are aimed at cleaning up pollution at the end

of a chain, rather than avoiding its creation. Furthermore, policies have been artificially compartmentalized for protection of naturally interconnected systems of air, water, forests, agricultural lands and urban settlements via separate air, water and waste acts. More than 30 years after its initiation, industrial ecology has evolved to inform progressive sustainable policies in the developed world. These policies include embedding life-cycle thinking in the European Union's legislation and intelligent design of infrastructure (Chertow et al. 2015). Learning from these significant initiatives, developing countries need to progress towards this next generation of sustainable policymaking whose overarching vision should be to initiate, support and enforce sustainable conditions.

IE provides an overarching framework for individual polices and schemes that support sustainable urban, industrial and rural development while ensuring weeding out, rather than locking in, of polluting technologies. Periodic monitoring of these policies will ensure that progress is not made in a fragmented and unsystematic fashion. For instance policies that focus on improving fuel efficiency of automobiles may be blind to the requirements of increasing the amount of land utilized for road transportation, the huge investment required for this infrastructure and the way it locks development into favouring road transport and ownership of automobiles. Such short-sighted policies may yield some benefits to the quality of life in the short term but harm it in the long run.

Considering what has been achieved by industrial ecology in the developed world and learning from experience is important to avoid reinventing the wheel and losing out on one of our most precious resources – time. However, this is not the only direction for learning to take place; this chapter highlights the fact that developing countries not only offer valuable, relatively uncharted landscapes for enriching our understanding of how industrial ecology can inform sustainable development but also help uncover unexplored practices and technologies that can provide a similar level of social welfare by using far less resources.

2 What Has Been Achieved by IE in the Global South?

Taking the glass is half full" approach, let us begin examining what the glass contains with a brief history of IE in developing countries. Industrial ecology was first systematically introduced into developing countries in 1995, when Erkman and Ramaswamy initiated a collaboration to disseminate and experiment on applying IE in the Indian context (ROI 2010). This collaboration resulted in the publication of case studies (Erkman and Ramaswamy 2003) and the establishment of the Resource Optimization Initiative (ROI). In 1999, an Industrial Ecology conference was organized at the Indian Institute of Management, Ahmedabad (Erkman 2015, Origins of industrial ecology in developing countries. Personal Communication via Email). Around the same time, in 1997, the faculty of the Dalian University of Technology (DUT) began its IE work in China.

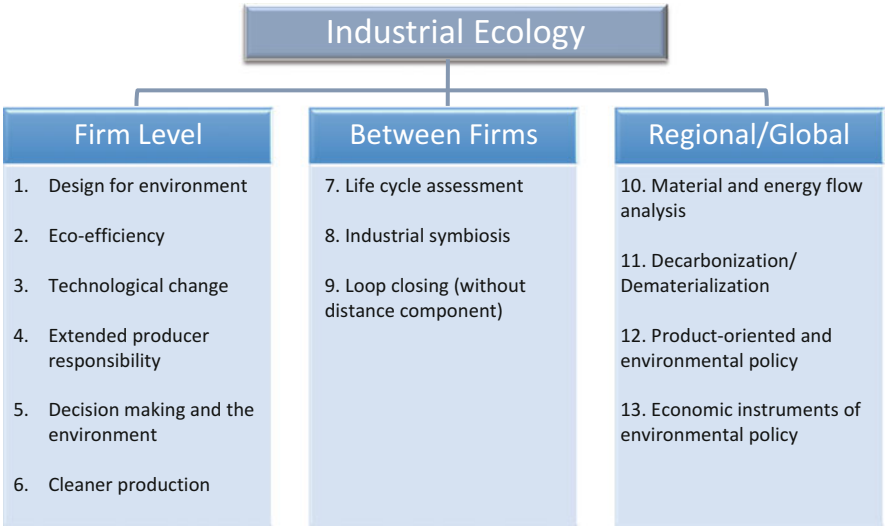

Fig. 11.2 Industrial ecology concepts and tools at the firm level, between firm and regional/global level (Adapted from Lifset and Graedel 2002)

2.1 Hotspots of IE in the Global South

Available research papers and reports highlight the main streams of IE that have been researched and implemented in developing countries. Analysing 131 documents (comprising 83 peer-reviewed journal articles, 27 books and book chapters and 21 reports from development organizations, institutions and companies) that examined various concepts and tools of IE (see Fig. 11.2) in the Indian context from 1997 to 2009 (Shenoy and Chertow 2009) revealed that Cleaner Production was a "hot spot" being explored in a majority of cases (see Fig. 11.3).

Examination of industrial ecology in other countries has revealed that almost two decades since its first introduction in developing countries, IE has developed in two relatively large branches: (1) Cleaner Production and (2) Eco-Industrial Development. Apart from these two areas, several cases that use Material Flow Analysis, Life Cycle Assessment, Extended Producer Responsibility and dematerialization have been examined in diverse developing world contexts.

2.2 Cleaner Production

Cleaner production (CP) is an IE strategy that has been implemented in several developing countries since the early 1990s. The Chinese National Cleaner Production Centre (CNCPC) was established in December 1994 (UNIDO/UNEP n.d.). In 1995, the world-wide UNIDO/UNEP National Cleaner Production Centre

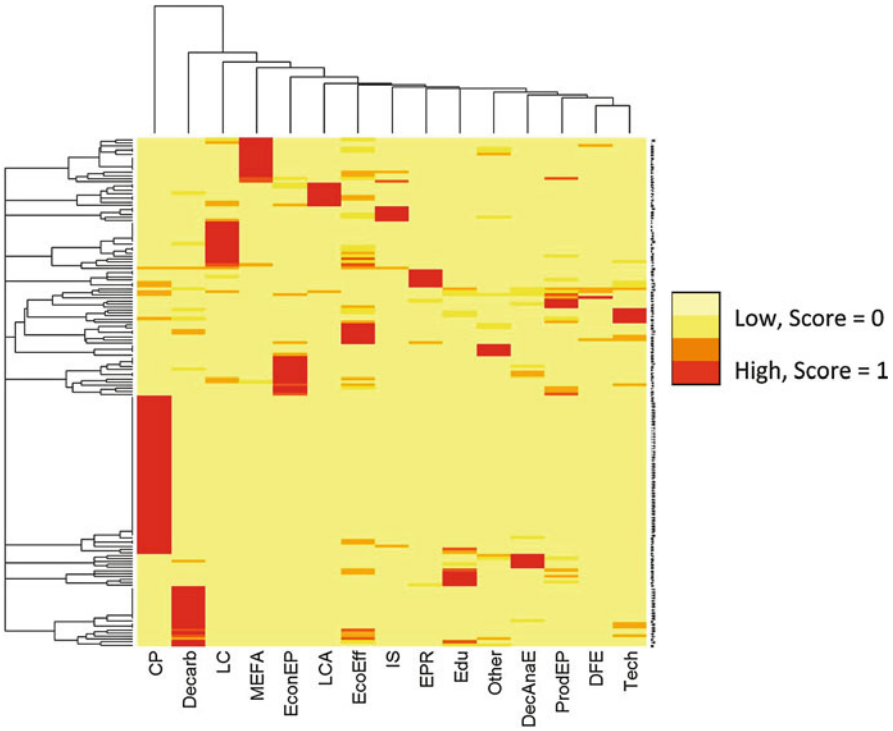

Fig. 11.3 "Heat map" of 131 documents that examined various concepts and tools of IE in India (*CP* cleaner production, *Decarb* decarbonisation, *LC* loop closing (without distance component), *MEFA* material and energy flow analysis, *EPR* extended producer responsibility, *IS* industrial symbiosis, *LCA* life cycle assessment, *EcoEff* eco-efficiency, *Other* includes IE related topics, such as social network analysis, social capital, ecological economics, sustainability modelling, scenario analysis, international environmental agreements and treaties, etc., *DecAnaE* decision making and the environment, *Tech* technology interventions for sustainability, *DFE* design for environment, *ProdEP* product oriented environmental policy)

(NCPC) programme included the CNCPC and established NCPCs in Brazil, India, Mexico, Tanzania, Tunisia and Zimbabwe (Nishikawa 2009). Since then the programme has expanded to include 47 developing and transition countries (UNIDO/UNEP 2010). In each of these countries, training programmes on CP have been conducted and in-plant CP assessments have been completed (UNIDO/UNEP 2010). In the 1990s, the World Bank sponsored a project focused on "Environmental Management Capacity Building" that resulted in CP promotion efforts in India (Rathi 2003).

In 2002, CP was included in policy in the Cleaner Production Promotion Law that was passed by the Chinese government in 2002. This law defines and sets goals and targets for clean industry, clearly specifies implementation responsibilities and outlines ways to measure successful implementation of CP in industries (Mol and Liu 2005). Other developing countries are yet to frame policies to support and facil-

itate CP. Currently, the lack of specific policies to facilitate and sustain CP, funding and capacity for implementation, lax enforcement of regulations and insufficient external social pressure demanding change are some of the significant barriers to CP implementation and expansion (Muduli et al. 2013).

2.3 Eco-Industrial Development

Applying the concept of CP at the scale of an industrial area gives rise to eco-industrial networks that exchange materials and realize collective sustainable benefits (see Chap. 5). In the broadest sense, industrial areas that are either designed or remodelled for this purpose are called Eco-Industrial Parks – EIPs. The first EIP in the developing world was set up in 2000 by the Chinese Research Academy on Environmental Science, an affiliated institution of the China State Environmental Protection Administration (Chiu and Yong 2004). Currently as many as 60 parks have been approved under the national pilot EIP programme in China (Zhang et al. 2010). In 2009, China framed and enforced the Circular Economy Promotion Law that supports the development of EIPs, via specific regulations and schemes to raise resource recycling rates in production, circulation and consumption cycles (WB 2009). In India and in most other developing countries, national or regional policies that facilitate EIPs are lacking (Ashton and Shenoy 2015). In India, over the past few years, the German development agency, GIZ, has been involved in the establishment of EIPs in a few states in India (GIZ n.d.).

Examination of industrial symbiosis in India has revealed high potential for spontaneously evolved waste exchange networks (Bain et al. 2010). This observation reveals potential for a bottom-up approach to develop EIPs such as that carried out by the UK National Industrial Symbiosis Program (NISP) (Boons et al. 2011), further facilitated by policies and financial assistance that encourage industries to implement recycling strategies (especially for materials that do not have established markets). In addition, there is a significant need to (1) develop new methods to quantify material flows in the large informal sector, and (2) examine power relationships and negotiating authority between partners involved in residue exchanges, especially between large well-established companies and informal players such as farmers' co-operatives, individual farmers and waste recyclers. Such findings were revealed when uncovering the residue exchanges involving ash granted by large-scale companies to individual small land-holding farmers in south India (Bain et al. 2010).

In other developing countries, including Cambodia, Vietnam, Egypt, Namibia, South Africa, Colombia and Peru (UNIDO in prep.; Chertow et al. 2008), eco-industrial development is at varying stages of development. Most studies that report and examine EIPs in developing countries have focused on the physical flows of matter and energy. However, there is a need for a deeper understanding of crucial aspects of EIPs such as (1) systems for inter-organizational networking opportunities, (2) stakeholder participation and (3) measurement of life cycle environmental

and social impacts of EIPs for their long term sustainability (Eckelman and Chertow 2013; Ashton and Shenoy 2015).

Other than CP and EIPs, case studies that examine resource flows in systems in India have highlighted that in the developing world context it is important to (1) focus on scarce resources, such as water, including mapping its distribution over many sources and users, a majority of which are unorganized or informal; (2) redefine the pollution problems to highlight scarcity and imbalanced use of these resources; (3) examine the possibilities of using well tested, off-the-shelf technologies that are used for other purposes before exploring new technologies and (4) evaluate possibilities and solutions for the long-term maintenance of new technologies and practices before recommending their implementation (Erkman and Ramaswamy 2000, 2003; ROI 2005; Shenoy et al. 2010).

3 Current Issues

Continuing with the approach of 'the glass is half full' and asking 'with what?', we now examine the current situation: how and with what to fill the rest of the glass. For IE to yield truly sustainable initiatives in the developing world, we need to view the current environmental crises as symptoms of a particular development paradigm (Prins et al. 2010), founded on profligate use of fossil fuels and consumerist attitudes with exorbitant embedded energy and resource demands. Developing countries need to realize the value of this perspective and not follow the same development pathway (Shenoy 2010). A new development paradigm which places sustainability above economic growth has been pioneered by Bhutan in its concept of Gross National Happiness (GNH) (Ura et al. 2012). In 2011, the UN adopted the Gross National Happiness (GNH) and is now examining ways to measure this index in countries around the world (Kelly 2012). However, most developing countries place economic gains above sustainability in their development, owing to which they have undergone tremendous environmental damage in the recent past (GFW 2012).

3.1 Impact of Technology

Industrial ecology offers insights on ways to measure and manage impacts (environmental and social) so as to track progress on a sustainable development pathway. In the IPAT equation,

$$\text{Total Environmental Impact} = \text{Population} \times \frac{\text{GDP}}{\text{Person}} \times \frac{\text{Environmental impact}}{\text{Unit of per capita GDP}}$$

Ehrlich and Holdren (1971) define the third term – the technology term – as "a measure of how much each unit of production or consumption pollutes". Graedel and

Allenby (1995) optimistically place the responsibility of sustainable development on this technology term to encourage sustainable technological innovation by individual companies and corporates. Given that developing countries such as China and India are now emerging as leading technology hubs, technological innovation can contribute significantly to our sustainable development. Several companies from developing countries, members of the World Business Council for Sustainable Development (WBCSD), Global Reporting Initiative, Greening of Industry Network (GIN) and Asia Pacific Roundtable for Cleaner Production (APRCP), are including sustainability and the triple bottom line in their growth strategies. Some of the IE-based technology solutions that these companies can adopt are explored in other chapters in this book. They include (1) greening of the supply chain, (2) extending producer responsibility, (3) environmental certification and (4) dematerializing the economy. Despite the acceptance of these approaches, it would be naïve to entrust corporates entirely with the responsibility for sustainable development. Although technology and corporates can play a significant role, there is a definite need for the presence of overarching policies and government funding to facilitate sustainable technology development.

3.2 Impact of Population and Affluence

From the perspective of a developing country with the world's highest population density, it is apparent that the two other terms in the IPAT equation – GDP/person (also called the Affluence term) and Population – need to take on equal and sometimes even larger responsibility in shaping a sustainable future. The environmental impact of the rich and affluent and rural to urban migration in developing countries can be very significant. For example, in 1990 in India, the collective CO_2 emissions of "new consumers" was found to be 15 times greater than that of the rest of the population (Myers and Kent 2004). Analysing the environmental impact of a person's lifestyle with respect to their personal (disposable) income would also be extremely important for developing countries, to measure and limit the impacts of increasing affluence and population.

3.3 Policy Development and Funding

Learning from studies that have examined ways for IE to inform policy development, developing countries need to defragment environmental policies across supply chains and across artificially compartmentalized environmental areas. For example, policies that focus on environmental protection of water more than land can lead to treatment of waste water only to end up with hazardous sludge that will continue to contaminate landfills and eventually leach into ground water. In addition, developing countries require an approach of not simply applying or adapting

IE concepts and tools but new ways of framing their problems and hence finding solutions (Erkman and Ramaswamy 2000).

If resources are cycled efficiently, as advocated by the IE paradigm, then we can expect to devote progressively less financial resources into future remediation. This argument provides a strong case for the financial value of IE, supporting the allocation of public funding for (1) industrial ecology research and education; (2) providing financial assistance to micro-, small-scale and cottage-scale industries to invest in efficient, clean technologies (Erkman and Ramaswamy 2000) and (3) monitoring environmental parameters and measures of human development, a task which is made more complex by the significance of the unorganized sector (Erkman and Ramaswamy 2003).

4 What Can IE Give to the Global South?

Although there is some financial impetus for developing countries to adopt IE, this need not be the only motivation for adopting IE. Recent research has found that high levels of human development can be achieved at moderate energy consumption levels and, more importantly, that increasing energy consumption does not necessarily contribute to higher living standards (Fig. 11.2) (Steinberger and Roberts 2010) (Fig. 11.4).

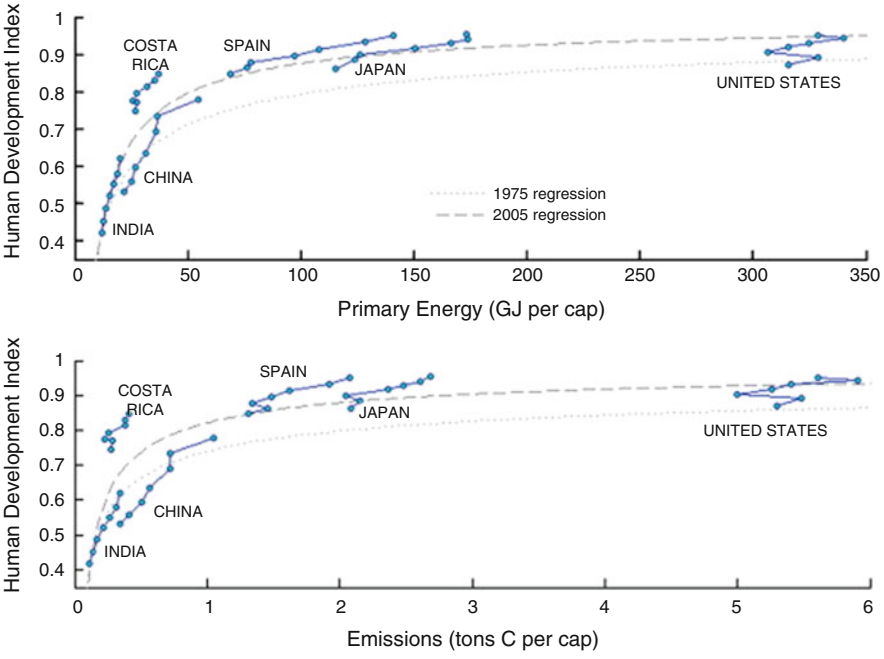

Fig. 11.4 Human development Index for specific countries vs. energy and carbon emissions from 1975 to 2005. Regression curves for 1975 and 2005 are shown for reference (From Steinberger and Roberts 2010)

4.1 Challenges, Metrics and Models

This motivation to improve human development standards comes with significant challenges specific to developing countries, due to limited data availability. The IE community can provide significant assistance to developing countries by simplifying and downsizing data requirements to a point which yields sufficiently accurate results to inform policy. It would indeed be counterproductive if developing countries were to wait for economic growth to fuel complex data gathering operations that can in turn inform their sustainable development policies. Some of the relatively simple metrics developed in IE that can be used to inform specific policies are ratios of different materials to measure resource efficiency. These ratios along with the caveats that need to be kept in mind while incorporating them into policies are in Table 11.2.

In addition, IE research has developed frameworks and models that capture the complexity of real systems by integrating several IE-based tools, for example the social-ecological-infrastructural systems (SEIS) framework and LCA analysis in EIPs (Ramaswami et al. 2012; Eckelman and Chertow 2013). An example of the socio-economic metabolism approach is advocated in Chap. 6. The SEIS framework is currently being used to assess environmental impacts of emerging cities in USA, China and India (Ramaswami et al. 2015). A similar framework is the Integrative Regional Action Planning (IRAP) framework that integrates planning across undeveloped land, rural and urban regions (Jaderi et al. 2014; Van Zeijl-Rozema and Martens 2011; Huynen et al. 2004; Lowe 2006). Such integrative frameworks call for cooperation between various stakeholders and institutions for a comprehensive understanding of regions, their impacts and solutions. These inte-

Table 11.2 Metrics, policy guidance and caveats for some ratios for understanding ways to optimize of resource flows

Metrics	Policy guidance and caveats
$\frac{\text{Virgin Materials}}{\text{Recycled Materials}}$	Incentivize companies to pursue closing of loops rather than disposal of industrial residues. Policies need to clearly define virgin, recycled materials and by-products to avoid misrepresentation
$\frac{\text{Actual Recycled Materials}}{\text{Potential Recycled Materials}}$	Industrial cluster level, city level and state level metrics to favour those that recycle more
$\frac{\text{Renewable Fuel Sources}}{\text{Fossil Fuel Sources}}$	Individual companies, city and state level metrics to favour renewable energy sources. Although, in most cases a higher ratio would indicate lower environmental impacts, this may not always be the case. For e.g. biodiesel from palm oil extracted from plantations grown on destroyed forest land can have much higher life cycle impacts compared to fossil fuels (Crutzen et al. 2008; Fargione et al. 2008)
$\frac{\text{Economic Output}}{\text{Material Input}}$	This measure can be used to improve resource efficiency

grative frameworks may need to be adapted to suit developing country contexts and, in some cases, new models will need to be developed. For example, while smart cities developed in the global North may be commendable in their ability to capture complex impacts and employ ecological design, they may not address the economic and social constraints and challenges in the developing world.

The IE community can also offer solutions to contemporary challenges, including how to address the problems of rebound that arises from improving energy efficiency (Gillingham et al. 2013) and avoiding "lock-in" of polluting technologies in eco-industrial networks (Boons et al. 2011; Shi et al. 2010). Analyses on how to include these effects into policy are needed, not only in countries that already have energy efficiency and EIP policies in place but also those that are developing new policies.

5 How Can the Global South Contribute to IE?

Industrial ecology concepts and tools have developed primarily in the developed world. However, owing to their low energy and material consumption patterns, developing countries can provide unexamined contexts for the developed world to learn from. Some of these contexts where the IE lens has provided valuable insights are (1) informal recycling by the unorganized sector in several developing countries (Medina 1997; Wilson et al. 2006); (2) provisioning of fresh vegetables and fruits on a regular basis to reduce food wastage due to inefficient management of household food inventories (Sahakian et.al. in press); and (3) water balance of cities in India (Eckelman et al. 2010).

In some cases, historic management of resources in developing countries has been postulated as more sustainable than the way resources are currently managed around the world; examples are flood management along the Brahmaputra in West Bengal (Rasid and Paul 1987) and community-based construction and maintenance of water tanks in the pre-British era in various regions in India (Mosse 1997). IE can offer qualitative and quantitative measures to understand and monitor such initiatives.

6 Conclusions

Some developing countries have realized the benefits of IE approaches and have used its concepts for sustainable growth of communities; others are yet to realize the value of this approach. The benefits of IE for developing countries include strategy elaboration and policy framing for sustainable development. Developing countries need to re-examine their development strategies and make important decisions to improve social welfare and build healthy economies, while protecting their ecological heritage. Redefining a country's development pathway is a complex process that

needs an interdisciplinary examination of cultural values, ecological heritage, resource use patterns and demographics. Due to its emphasis on a holistic approach, industrial ecology can provide a valuable platform to draw out this redefinition in ways that can be implemented.

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