GLOBAL RESOURCES OUTLOOK 2019[1]

CASE STUDIES

The case studies here presented demonstrate issues of concern and solutions for the sustainable management of natural resources across sectors, and the positive impacts policy and other interventions towards decoupling can achieve.

The case studies presented have not undergone an external scientific Peer Review, nor have they undergone professional editing.

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[1] The full report should be cited as IRP (2019). Global Resources Outlook 2019: Natural Resources for the Future We Want. Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H., Clement, J., and Cabernard, L., Che, N., Chen, D., Droz-Georget , H., Ekins, P., Fischer-Kowalski, M., Flörke, M., Frank, S., Froemelt , A., Geschke, A., Haupt , M., Havlik, P., Hüfner, R., Lenzen, M., Lieber, M., Liu, B., Lu, Y., Lutter, S., Mehr , J., Miatto, A., Newth, D., Oberschelp , C., Obersteiner, M., Pfister, S., Piccoli, E., Schaldach, R., Schüngel, J., Sonderegger, T., Sudheshwar, A., Tanikawa, H., van der Voet, E., Walker, C., West, J., Wang, Z., Zhu, B. A Report of the International Resource Panel. United Nations Environment Programme. Nairobi, Kenya. Available at: www.resourcepanel.org/reports/global-resources-outlook

International Resource Panel

Contents

1 The “Circular Transformation of Industrial Parks (CTIP)” Program in China

Authors: Bing Zhu (International Resource Panel), Dingjiang Chen, and Bomin Liu.

1.1 Introduction

As an important emerging economy and the second largest economy in the world, China pays strong attention to resource efficiency. Policies enacted at the national level display a commitment to developing a circular economy to improve the efficiency of resource use by the economic and social system, protect and improve the environment, and realize sustainable development. Building on life cycle considerations, the Chinese Government strives to promote resource efficiency by emphasizing the entire value chain, i.e. from production, circulation, consumption, to waste treatment. During the production stage, industrial parks (IPs) are regarded as a key to improving resource efficiency. Since 2011, China has been implementing the “Circular Transformation of Industrial Parks (CTIP)” Program to renovate and transform industrial parks based on circular economy principles so as to improve their resource efficiency, help achieve the UN Sustainable Development Goal 12 of “sustainable production and consumption” and promote China’s policy for an ‘ecological civilization’. The following case study reflects on this programme and its effectiveness over time. It is hoped that the experience of China’s IPs in implementing circular transformation will also be useful to other developing countries in their effort in promoting green development of IPs and achieving the United Nations Sustainable Development Goals.

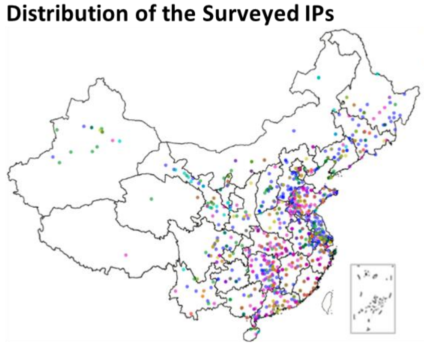
1.2 Potential of China’s industrial parks for resource efficiency improvement

Industrial parks are an important pillar of the Chinese economy. In China, industrial parks are an important vehicle for driving regional economic development and implementing regional development strategies and play a principal role in promoting scientific and technological innovation and developing high-tech industries. The Administrative Committee of an industrial park plays the role of a government department and serves as a public service provider and administrator. Industrial parks first appeared in China in 1984, and by 2018 there are already 2,543 industrial parks established with approval from the central or provincial governments, and it is estimated that there are more than 5,000 industrial parks established with approval from municipal or country-level governments. According to an estimate by a relevant association, more than 60% of China’s GDP is produced in various types of industrial parks.

Industrial parks are also venues with highly concentrated consumption of raw materials and energy, and highly concentrated generation of pollutants and greenhouse gases. In 2015, under the guidance and support of the National Development and Reform Commission

(NDRC), The Institute for Circular Economy of Tsinghua University carried out a survey of 1,656 national or provincial-level industrial parks regarding their economic, resource, and environmental situations. The result shows that in 2015, the aggregate GDP produced by the surveyed industrial parks was 26.4 trillion RMB. This accounts for 39% of China's national GDP. Total energy consumption of these industrial parks was 1.3 billion tons of coal equivalent, accounting for 42.4% of the total in China; their total area of developed land was 18,900 km^2, accounting for 37.8% of China's total area of land used for urban construction; their fresh water consumption was 9.65 billion tons, accounting for 7.1% of the total amount of industrial water use in China; their discharge of wastewater was 4.31 billion tons, accounting for 21.0% of the total industrial wastewater discharge of the country; their discharge of COD was 1,016,000 tons, accounting for 32.6% of the country's total industrial discharge; their discharge of SO_2 was 2,168,000 tons, accounting for 12.5% of the country's total industrial discharge; their discharge of nitrogen oxides was 1,561,000 tons, accounting for 11.1% of the country's total industrial discharge; and their discharge of industrial solid wastes was 970 million tons, accounting for 29.8% of the country's total industrial discharge.

Spatial Distribution of the Surveyed IPs



Categories of the Surveyed IPs

Categories	No. of IPs	Proportion
Machinery & equipment	288	17.4%
Chemical industry	218	13.2%
Metallurgy & nonferrous	133	8.0%
Construction materials	51	3.1%
Comprehensive industries	399	24.1%
High-tech	171	10.3%
Industry-agriculture composites	121	7.3%
Light industry	169	10.2%
Others	106	6.4%
total	**1,656**	

Figure 1 Spatial and categorical distribution of surveyed IPs

China's IPs have great potential for improving resource efficiency. The existing industrial parks initially focused on attracting investment. They have much room for improvement in terms of industrial and value chains, land use efficiency, and industrial agglomeration effect. Furthermore, it is a trend in China that industries are increasingly concentrated into industrial parks. In the future, more and more enterprises will move into industrial parks. Therefore, industrial parks will play an even more important role in China's economic development. Transforming industrial parks based on circular economy principles and improving their resource efficiency will contribute very positively to the realization of Sustainable Development Goals and the promotion of 'ecological civilization' in China.

1.3 Implementation of CTIP

The so-called "Circular Transformation of Industrial Parks" (CTIP) means that the existing industrial parks of various types will follow circular economy principles (i.e. "reduce", "reuse" and "recycle", with priority given to "reduce") to optimize spatial layout, adjust industrial structure, develop key technologies for linking various components of circular economy, extend the industrial chain appropriately and link its various parts into a circular loop, build infrastructure and public service platforms, and renovate organizational and administrative mechanisms, so as to realize efficient and circular utilization of resources and "zero discharge" of wastes in industrial parks, thereby continuously strengthen industrial parks' capacity for sustainable development. The implementation of CTIP was jointly organized by NDRC and the Ministry of Finance (MOF).

1.4 Macro policies and administration by the central government

The central government attaches high importance to the program, provides consistent policies, and ensures wide coverage. In 2008, China promulgated *The Circular Economy Promotion Law*, which contains specific stipulations about the development of circular economy in industrial parks. In 2011, NDRC and MOF promulgated *Notice about Carrying out CTIP Demonstrations and Pilots First in Gansu and Qinghai Provinces*, which marked the formal launch of the CTIP program. In 2012, NDRC and MOF issued *Opinions regarding the Promotion of CTIP*, which made specific arrangements for CTIP. In 2013, the State Council's *Circular Economic Development Strategy and Near-term Action Plan* lists CTIP as one of 10 Big Demonstration Programs for Circular Economy. In 2017, NDRC and 13 other central departments issued *Guiding Actions for Circular Development*, which listed CTIP as the first among all Key Special Programs. During the 12th Five-year period, the central government provided financial support to 100 industrial parks for their circular transformation demonstration. During the 13th Five-year period, the central government will support another 100 industrial parks, among which 29 have already received support.

Figure 2 Spatial Distribution of China's Industrial Parks Participating in CTIP during 2011-2017

The program has a clearly defined objective, with a number of implementable key tasks. The objective of CTIP is that by 2020, circular transformation should be carried out in 75% of all national industrial parks and 50% of all provincial IPs. Their transformation is to be carried out through seven specific key tasks: rationalizing spatial layout, optimizing industrial structure, building circular industrial linkages, utilizing resources efficiently, centralizing pollution treatment, making infrastructure green, and standardizing operational management. In the meantime, the Program centers around important regional strategies of the country, focuses on key environmental problems such as air and water pollution, provides type-specific guidance to different industrial parks, and start with priorities.

The central government oversees the whole process, and there is wide participation from the government, the industry, and the academia. The Program first fosters national-level demonstration industrial parks, whose main approaches and lessons are then disseminated to other industrial parks across the country with the objective that most industrial parks in China will eventually carry out circular transformation. The central government oversees the entire process, including proposal solicitation and selection, regulatory control, mid-term appraisal, and final check and acceptance. During such a process, there is multi-stakeholder participation (including the central government, local governments, the administrative authorities of the industrial parks, enterprises within the industrial parks, research institutions, consulting firms, etc.) to ensure robust and orderly implementation.

In order to evaluate the performance of CTIP in a comprehensive way, the central government has established an evaluation indicator system that consists of various indicators in 6 categories: resource efficiency and economic output, resource consumption, comprehensive utilization of resources, discharge of wastes, so-called “other indicators”, and so-called “unique indicators”. These indicators include not only so-called “key” ones such as “resource productivity”, “comprehensive utilization rate of industrial solid waste” and “share of non-fossil energy in primary energy consumption”, but also so-called “unique” ones that each park can use based on its own, unique situation.

1.5 Approaches of CTIP

Each participating industrial park has developed an implementation plan in light of its own characteristics and according to circular economy principles. This is a very important step for CTIP. The Administrative Commission of a park typically entrusts a research institution or consulting firm to develop the implementation plan. Such a plan is based on an analysis of the park’s status quo and materials flow, takes into account in a comprehensive way such aspects as existing industrial and resource endowment advantages, regional development needs, the generation of side products and industrial wastes, and infrastructure, etc., and proposes a series of measures or projects for such purposes as renovating and upgrading traditional industries, fostering and developing strategic emerging industries, promoting cleaner production, building and upgrading centralized pollution treatment facilities, and constructing a park administration platform, etc. Based on such a plan, the Administrative Commission of the park will determine key construction projects, establish safeguarding measures, and implement the plan with the support of diverse economic instruments.

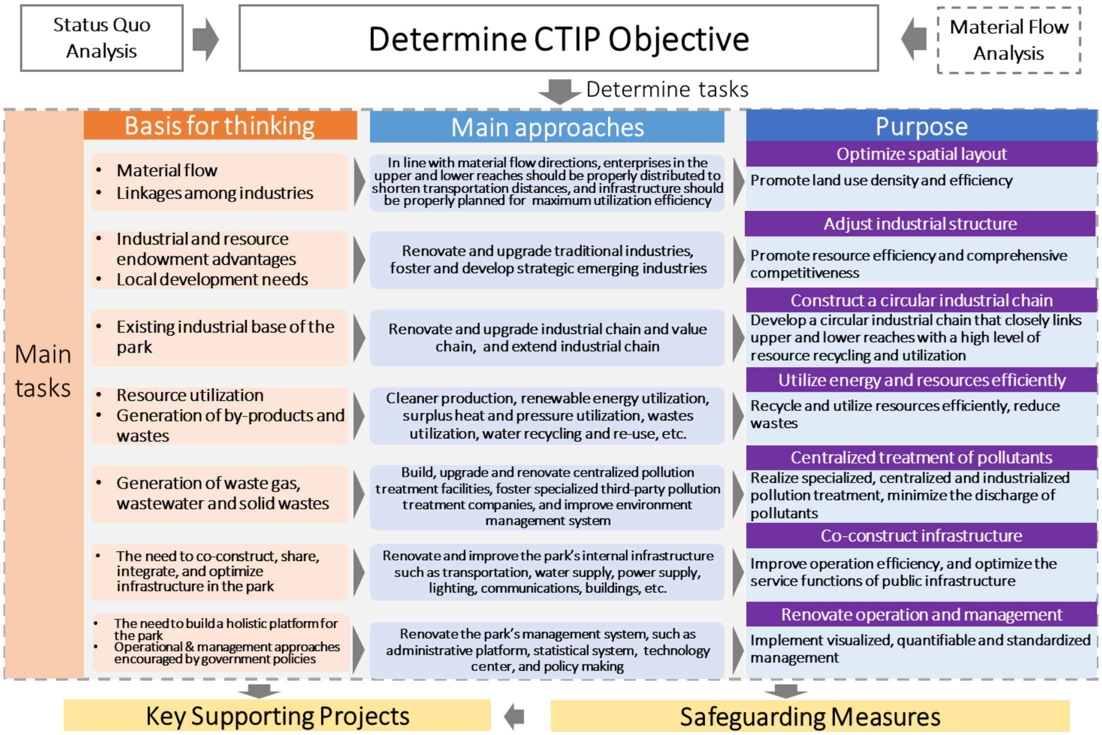


Figure 3 Conceptual Framework of a CTIP Implementation Plan

Key projects are identified for each park. Typically the following three types of projects receive special support: 1) infrastructure renovation and upgrading projects, such as centralized pollution treatment, reuse of treated wastewater, tiered utilization of energy, comprehensive corridor for pipelines, and centralized supply of heat, water and materials; 2) public service platform projects, such as a) park management platform for energy, resources and environment, and b) center for circular economy technology R&D and incubation; and 3) key linkage projects that can support the dominant industrial chain of the park and can significantly promote resource efficiency and environmental performance.

Safeguarding measures are in place to ensure that key projects are carried out and the CTIP objective and tasks accomplished. Such measures include: organizational support system, policy support system, technology support system, public service platform, statistical and evaluation system, supervision and management system for pollution prevention and control, risk sharing and safeguarding system for industrial chain linkages, public participation, information dissemination, and public education and exchange.

There are also supportive economic measures to ensure funding for CTIP. First, the central government provides financial support to the administrative committees of IPs for their implementation of CTIP. Second, participating enterprises have access to multiple channels for financing, and are supported to issue special corporate bonds. Third, the IPs are encouraged to establish special funds for CTIP, to attract social capital and support key projects.

1.6 Achievements of CTIP

In 2016, NDRC conducted a mid-term evaluation on 30 industrial parks in the first two batches of CTIP demonstration pilots. **The evaluation result showed that CTIP had been very effective.** With the program, most industrial parks had increased their resource productivity by more than 16%, and increased the comprehensive utilization rate of industrial solid wastes to more than 90% and the reuse rate of industrial water to more than 85%. Significant progress was observed in such aspects as tiered utilization of energy, water recycling and reuse, materials exchange and utilization, and wastes recycling and reuse. In aggregate, the 30 industrial parks utilized 23 million tons of solid wastes, reduced energy consumption by 33 million t.c.e., saved water resources by 27 million tons, reduced the discharge of main pollutants (SO_2, NO_x, COD and ammonia nitrogen) by 1.6 million tons and carbon emissions by approximately 30 million tons.

The main practices and typical lessons of the national-level industrial parks participating in CTIP have been studied and summarized by a consulting firm commissioned by NDRC. **The following aspects have been identified as important success factors and have been disseminated to other industrial parks across the country**.

- Optimize the park's spatial layout for more efficient land use
- Promote investment tender based on industrial chains or the mending of chains (rather than for individual projects only), to realize the circularity of industrial chains
- Share infrastructure, make more efficient use of and thereby save resources, and centralize the treatment of pollution
- Construct an "internet + public service" information platform, to upgrade the park's management
- Provide innovative support for investment and financing, to promote the implementation of key projects
- Establish a risk sharing and safeguarding system for industrial linkages, to strengthen risk prevention capability

1.7 Next steps and international cooperation

CTIP is a key program for promoting circular economy in China and represents an important approach for accelerating the transformation of economic growth patterns, promoting green, low-carbon and circular development, and upgrading resource efficiency. In the future, China will continue to carry out in-depth circular transformation of existing industrial parks, so as to construct circular industrial chains, promote the linkages and circularity of industries, and refine materials flow management and environmental management. In the meantime, new industrial parks are required to follow the principles of CTIP in formulating special plans for circular economic development, in promoting and selecting investment in the development of industrial chain, value chain, and ecological chain, and in optimizing spatial layout. Efforts will also be made to promote organic linkages among the "small cycle" within an enterprise, the "medium cycle" within a park and the "big cycle" of the society, connect the production system with the household system, renovate the organizational aspects of regional economy and of industries based on the concept of circular economy, thereby promote resource efficiency from a holistic perspective.

The Chinese Government has been attaching high importance to international exchange and cooperation, as it requires the joint effort of the entire world to promote global resource efficiency and achieve UN Sustainable Development Goals. China has been a beneficiary of international cooperation. Since the time when industrial parks were first established in China, they have been receiving valuable support from other countries. One such example is Suzhou Industrial Park, which was established in 1994 and has been a flagship project of cooperation between the governments of China and Singapore. With more than twenty years of development, the park has by now become a high-tech industrial park that is competitive internationally. In 2017, the park realized a total production value of $36.8 billion, and was ranked No. 1 among all industrial parks in China in overall performance evaluation. In today's world, it is a common challenge for developing countries to improve resource efficiency and protect the environment during rapid industrialization. In the process of developing, upgrading and transforming industrial parks over many years, China has learned some valuable lessons. It is hoped that China's experience with CTIP would be of value to other developing countries in pursuing green development of industrial parks and promoting the realization of UN Sustainable Development Goals.

2 Towards Zero Pollution Cities: Human health, climate, and natural resource co-benefits from circular economy strategies in areas as shown in a case study of 637 Chinese cities

Author: Anu Ramaswami (International Resource Panel); Director, Sustainable Healthy Cities Network; Professor, Public Affairs and Engineering, University of Minnesota

2.1 Overview

Air pollution is a global killer and predominantly an urban one, responsible for about 7 million premature deaths worldwide each year. Air pollution by particulate matter (PM) in cities can be reduced through system-based approaches focusing on better use of natural resources and better design of urban infrastructures and industries. This case study applies a systems approach to demonstrate the potential economic benefits, resource-savings, reductions in greenhouse gases (GHG) and PM emissions, air quality improvements and associated health co-benefits achievable by implementing key circular economy strategies in 637 cities in Chinese mainland (Ramaswami et al. 2017). The drivers resulting in air pollution in China include both population growth and urbanization in conjunction with industrialization. These drivers generate pressures which are seen in the form of high air pollution levels, which in turn create direct public health impacts, particularly for large populations in close proximity to pollution sources in and around urban areas. Infrastructure transitions, particularly those employing circular economy concepts can represent an effective response to air pollution challenges, as shown in this case study.

Circular economy strategies focus on material and energy exchange across urban infrastructure and industries, a process also known as urban-industrial symbiosis (Van Berkel et al., 2009). Multiple cross-sectoral urban infrastructure interactions can leverage the sharing of locations, land, activities and material energy flows in ways that can foster more resource-efficient urban metabolic configurations. The exchange and reutilization of 'waste energy' (in particular in the form of heat, to generate heat and cooling) and waste materials across infrastructures within cities opens up significant opportunities for resource efficiency.

Such strategies are broadly relevant to China and other rapidly urbanizing and industrializing world regions, such as Asia and Africa where future urbanization and industrialization are expected to occur together. This will create large infrastructure drivers for buildings, roads, energy supply and water for urban residents in cities, as well as substantial water and energy requirements for industries.

China is now the world's largest user of fossil fuels globally, and about 80% of fossil fuel use in China occurs in the industry sector, creating a source of unused waste heat that can displace fossil fuel use in individual stoves and boilers in homes/businesses (which are difficult to regulate and are large contributors of PM pollution). Material use in cement, steel and construction sectors is also high resulting in resource depletion and air pollution. The material footprint of Asian cities, such as Singapore, Tianjin, Xiamen and Shanghai shows the construction sector contributes more than 40% of all material usage on a life cycle basis in final consumption in cities. Reducing demand for new construction materials through material exchange and reuse can reduce resource use and pollution associated with producing these materials. This case study models energy-, resource- and monetary-savings, as well as health and carbon co-benefits of applying key circular economy strategies beyond current practice in all 637 cities of China.

2.2 Key Cross-Sector Circular Economy Strategies Modeled: Heat exchange and material reuse

Two broad categories of circular economy strategies for urban industrial symbiosis are modeled in this case study: 1) heat exchange and 2) material reuse. Within each of these categories, there are different types of feasible infrastructure actions and technology interventions. The actions within each category, and their relevance to the Chinese context are described in more detail below**.**

Heat Exchange- Infrastructure design in new cities incorporates high-rise buildings with shared heating/cooling systems that reutilize industrial waste heat in urban district energy systems. These strategies can take shape in a variety of ways, and require varying levels of proximity to be effective.

1. High-grade industrial waste heat is reused for electricity generation, i.e. mobilized as a form of combined heat and power generation (CHP), also known as co-generation.
2. Medium-grade industrial waste heat is reused in conventional urban district energy systems using steam and hot water for other nearby industries co-located in eco-industrial parks. This strategy requires the sites on either side of the exchange are located in close proximity to one another.
3. Low-grade waste heat, not readily reused in industries, is used in advanced 4th generation district energy systems to cost effectively heat/cool buildings up to 30 km away, e.g. from an industrial facility on the outskirts of a city to a dense urban core.

Heat Exchange Chinese Context- Centralized heating already serves about 70 percent of urban residents in China (Zhang et al., 2015b), but could be more efficient and use cleaner burning fuels if upgraded to a fourth generation district heating system. In the twelfth FYP, about 800 million m2 of district heating floor area from CHP and renewable sources was to be added by 2015. Fourth generation district energy systems use low temperature hot water rather than steam, and there is only 5 percent heat loss in the network compared with 30–50 percent in current high-temperature district heating systems. This can yield an 80–90 percent saving of fuel used for residential and commercial heating purposes.
Material Reuse- Beneficial exchange and reuse of materials occurs across energy and construction sectors focusing on two key material exchanges:

1. Reuse of fly ash from power plants in lieu of cement (beyond current reuse levels) in the construction sector.
2. Reutilization of steel slag in a new technology that enables both heat recovery and material substitution of cement.

Material Reuse Chinese Context- Material exchange/substitution: Cement and power plants are key industries supporting urban infrastructure. Symbiotic exchange of materials among these large industries can significantly contribute to resource efficiency. Recent studies show that by using the dry slag granulation process, steel slag that is normally wasted can be reutilized in a 1:1 ratio, replacing up to 25 percent of cement production (Slag Cement Association, 2006). Fly ash reutilization from power plants in cement and brick production is already occurring in many provinces in China. The Beijing MCC Equipment Research & Design Corporation (MCCE) has recently signed an agreement with CSIRO Australia to pilot and commercialize a new dry slag granulation technology. China produces about 60 percent of the world's slag and more than 50 percent of the world's supply of cement.

2.3 Results from 637 Chinese Cities: Multiple co-benefits spanning air pollution, GHG mitigation, and resource use

A unique opportunity exists in China, arising from the fact that industrial location strategies and spatial urbanization patterns have resulted in many industries being co-located in special economic zones (SEZs) that include highly dense urban areas. The co-location of residential and commercial buildings in China's SEZs makes large-scale resource sharing possible. Further, there is also great potential to significantly enhance the energy efficiency of material use in the construction sector by impacting the production-side of steel and cement through industrial symbiosis.

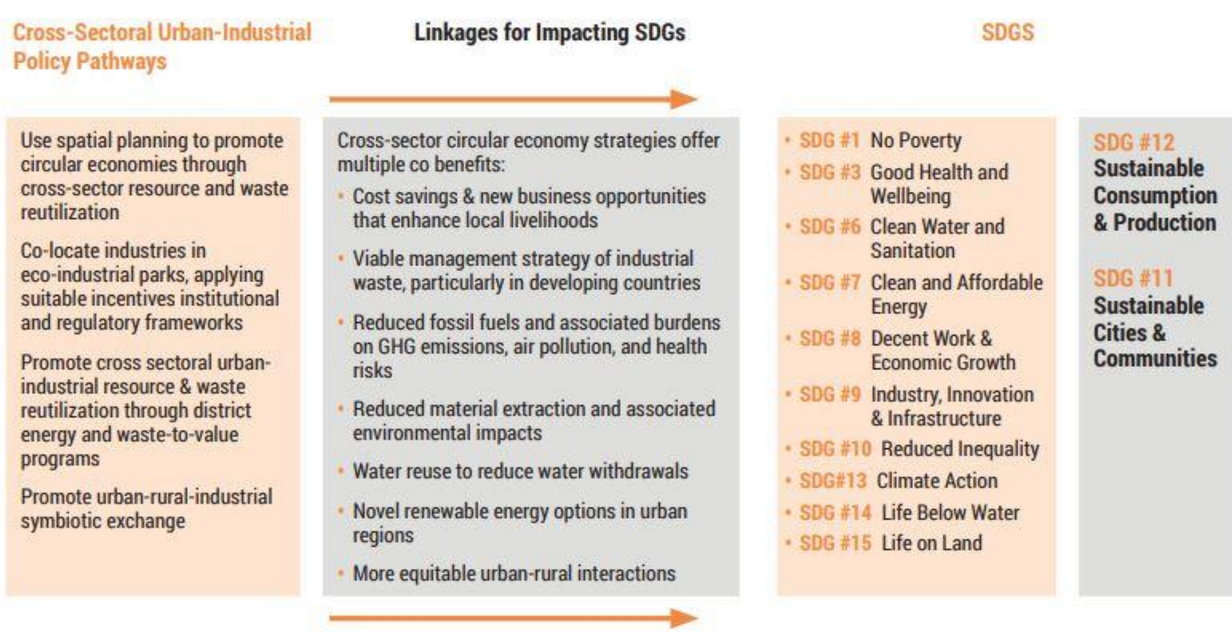
Drawing on diverse data sources, researchers modeled the colocation of industries with homes and commercial establishments in cities, to explore the potential for urban industrial symbiosis, i.e. the exchange of materials and reutilization of waste heat in 637 Chinese cities.

These key cross-sectoral material and energy exchange strategies are found to generate significant co-benefits. These co-benefits are compared to the impact of single sector efficiencies (buildings, industries and power plants) noted in China's five-year plan, where cross-sectoral material and energy savings are computed beyond existing levels of implementation in China. Multiple SDGs are benefited with significant economic savings as seen below (Figure 1).

Results show that approximately 47,000 annual premature deaths associated with PM2.5 air pollution exposure could be avoided (using the globally integrated health risk assessment provided by Burnett et al (2014) and considering meteorological effects on pollutant concentrations for exposure). From a greenhouse gas standpoint, the urban-industrial symbiosis strategies provide an additional reduction of about 15-35 per cent in greenhouse gas emission compared to single-sector strategies alone. (Ramaswami et al. 2017, Tong et al 2017).

Figure 1- Co-benefits of district heating and cooling strategies and linkages to UN Sustainable Development Goals (SDGs) (IRP, 2018)

Figure 1- Linking Circular Economy and Industrial Symbiosis Strategies to Multiple UN Sustainable Development Goals (IRP, 2018).



2.4 Policy Response: Enabling frameworks for circular economy and urban industrial symbiosis strategies

A National Policy Framework for Eco-Industrial Parks- In China, over 1,500 industrial parks at national and provincial levels are in existence, contributing to both the substantial growth in national GDP as well as rising environmental and human health pressures, affecting air quality, climate change, water quality, and so on (Tian et al 2014). In response to the increasing environmental and human health pressures caused by relatively unregulated industrial processing, the Chinese government in 2001 mandated the establishment of a national eco-industrial park demonstration programme, which, by 2017, resulted in 48 accredited eco-industrial parks, with another 45 listed as trials. The widespread success of Chinese eco-industrial parks in reducing environmental impacts while increasing economic value are thought to be a result of the combination of both top-down regulatory policies requiring compliance within minimum performance standards, as well as facilitation strategies which help expand knowledge about and incentives for symbiotic material and energy inter-industrial exchanges (Yu et al. 2014).

Performance Standards and Waste Disclosure Requirements- Policies requiring conformance with minimum environmental performance standards and disclosures of wastes and emission using a variety of enforcement mechanisms (e.g. fees, quotas, deprivation of preferential policies and stock market listing penalties) paired with policies providing economic incentives through pricing mechanisms (e.g. grants, subsidies, tax incentives, market access , etc.) can further facilitate exchange of waste materials and energy (Yu et al. 2014).

Educating Market Players- Concerted knowledge diffusion and coordination via a centralized organization that can help facilitate matchmaking workshops and trainings to help identify material/energy flows ripe for collaborative exchange (Yu et al. 2014).

Mixed-Use Compact City Policies- Urban spatial planning strategies that support mixed use and dense urban development can allow for energy and material exchanges to more easily take place. The analysis of industrial symbiosis infrastructure interventions assumes that they are taking place within a sufficiently dense urban fabric where proximity enables the interactions to be implemented.

2.5 Implementation Barriers and Financing

Barriers to adoption of these proposed circular economy infrastructure interventions include cost and penetration of CHP for thermal power generation. However, although the capital investment may be higher, case studies such as the new CHP system for the Pudong International Airport in Shanghai have shown a payback period of less than six years (IEA, 2008). In looking at the cost of potentially retrofitting an existing heating network, a case study in Anshan identified the costs and payback period of retrofitting a centralized city heating network with capital cost recovery occurring in less than three years (UNEP, 2015).

Another common barrier to implementation is the cost associated with replacing existing centralized heating networks. However, while the existing centralized heating networks in northern Chinese cities may be inefficient, the infrastructure already in place can be upgraded to create more advanced district heating systems that can utilize waste heat. These upgrades can take place without needing to fully replace the existing infrastructure.

Generally, the material and heat exchange technology interventions modeled in this case study exhibited a payback period between 1 and 4 years (Ramaswami et al. 2017, Tong et al 2017).

3 Marine resources and their management in Areas Beyond National Jurisdiction

Author: Steven Fletcher (International Resource Panel)

The relationship between stressors and coastal and marine resources was assessed using a targeted literature review of 340 papers. Each stressor was scored as “high impact”, “medium impact” or “small impact” based on its impact and the size, quality and consistency of the body of evidence. The stressors with the highest influence on marine resources were found to be: sedimentation, turbidity and currents and salinity, whilst plastic and other marine debris, dissolved oxygen, phosphorus and marine invasive species had the lowest influence. The resources most impacted were biodiversity, fisheries resources and habitat condition and extent, whilst coastal minerals, aggregates and deep-sea minerals and oil and gas are least impacted. Due to the limited studies on stressors impacting abiotic resources the scores and rankings provided are general indicators rather than definitive trends. The relationship between stressors and the state of resources are often complex and have non-linearities and thresholds. This creates complex relationships between land and sea that require cross-sectoral and transboundary governance responses.

Due to these impacts, an international solution is needed.

Areas Beyond National Jurisdiction (ABNJ) occupy more than 60% of the surface of the global ocean (UN Environment, 2006; Rogers et al., 2014) and 95% of its volume (Katona, 2014). Natural processes within ABNJ provide essential contributions to global marine ecosystem function and human health (Thurber, et al. 2014), and generate resources of significant ecological, socioeconomic and cultural importance to society (Vierros et al. 2016). For example, more than 10% of annual world fish catches by weight are caught in ABNJ (Rogers et al., 2014; Sumalia et al., 2015). Deep-sea mining activities for metals (including manganese nodules on abyssal plains, massive polymetallic sulphide deposits at hydrothermal vent sites and cobalt-rich crusts on seamounts) are already being considered (Ramirez-Llodra et al. 2011). Indeed, as of May 2018, the International Seabed Authority has already entered into fifteen year contracts for exploration with twenty-nine contractors (ISA, 2018a).

Where the continental shelf break plunges to depths greater than 2000 metres below sea level, extreme pressure, temperature and light conditions host a wide range of biodiverse deep-sea ecosystems, such as hydrothermal vent and cold seep communities and deep-sea coral reefs (Rogers et al., 2015). These deep-sea communities, including, inter alia, deep-sea macro-invertebrates, sponges and bacteria, are of great interest to the bioprospecting sector, looking for novel marine natural products for use in pharmaceuticals and cosmetics (Thurber et al. 2014). However, as a consequence of extreme environmental conditions, deep-sea species are highly adapted and can often be slow growing, making them particularly vulnerable to habitat disturbance (Norse et al. 2012; Ramirez-Llodra et al. 2011).

Table 1. The strength of impact of potential stressors upon abiotic and biotic resources

			Sedimentation	Turbidity	Nitrogen	Phosphorous	Temperature	Salinity	Current	Dissolved oxygen	Persistent toxins	Plastic & other debris	Invasive species	Average weight of resource
			Potential stressors											
			Natural								Non-natural			
Resources	Abiotic	Salt		Medium				High	Medium		High	Low	Medium	**1.2**
		Aggregates	High						Medium					**0.5**
		Coastal minerals						No impact found						**0.0**
		Deep-sea minerals					Medium	Medium	Medium					**0.5**
		Oil and gas	Medium	Medium			High		Medium					**0.8**
		Marine renewables	Medium		Medium		Medium	Medium	High		Medium	Low		**1.3**
	Biotic	Fisheries resources	High	High	High	High	High	High	High	High	High	Medium	High	**2.9**
		Primary production	Medium	High	High	High	Medium	Medium	Medium	Low	Medium	Low	Medium	**2.1**
		Habitat condition and/or extent	High	High	High	High	High	Medium	Low	Medium	High	High	Medium	**2.5**
		Biodiversity	High	High	High	High	High	High	High	High	High	High	High	**3.0**
		Marine genetic resources	High				High	Medium		Medium			Medium	**1.1**
		Water quality	Medium	High	High	Medium				High	High	High	Medium	**1.9**
Average weight of stressor			**2**	**1.6**	**1.4**	**1.2**	**1.8**	**1.5**	**1.6**	**1.2**	**1.5**	**1.1**	**1.3**	

Key		
	Strength of impact	Allocated weight
(red)	High	**3**
(yellow)	Medium	**2**
(green)	Low	**1**
(grey)	No impact found	**0**
(white)	No studies found	**0**

Until the mid-20th Century, the remoteness and challenging conditions in ABNJ provided deep-sea ecosystems, associated biodiversity and natural resources, some degree of protection from human activities. However, technological innovations enabling easier access to the deep ocean, and increasing demand for marine resources, including fisheries resources and deep-sea minerals, have driven increased human activities within these areas (Ramirez-Llodra et al., 2011; Merrie et al., 2014). In conjunction with the growing threat from climate change and ocean acidification, increasing occurrence and intensity of human activities is likely to substantially increase pressures on marine ecosystems and biodiversity within ABNJ. One such pressure, particularly on deep-sea ecosystems, is pollution from land-based activities. An example of this is plastic pollution, the majority of which originates on land, which has recently been found in the world's deepest ocean trench, the Mariana Trench at 10,898 m deep (Chiba et al. 2018).

Currently, ABNJ are governed under the UN Convention on the Law of the Sea (1982) and a number of sectoral governance regimes established under the its framework to manage specific activities and pressure. For example, the International Maritime Organization governs shipping in the High Seas and implements the International Convention for the Prevention of Pollution from Ships to prevent pollution from shipping. The International Seabed Authority is the competent organisation through which States Parties can organise and control activities occurring in 'the Area' (the seabed beyond 200 nautical miles and beyond extended continental shelf submissions), and implements environmental management measures to reduce the potential impacts of deep-sea mining. Regional Fishery Management Organisations/Arrangements (RFMO/As) have a management role in governing fisheries in ABNJ.

It has been argued that the current sectoral framework leaves legal, governance and geographical gaps in management of activities within ABNJ and is insufficient to address the cumulative impacts of the wide range of sectoral activities (Gjerde et al, 2008; Inniss et al., 2016; Ringbom & Henriksen, 2017). However, efforts to reduce such gaps have been undertaken in recent years, such as the establishment of three new deep-sea Regional Fisheries Management Organisations: the South Indian Ocean Fisheries Agreement in 2012, the South Pacific Regional Fisheries Management Organisation in 2012, and the North Pacific Fisheries Commission in 2015.

In recognition of remaining gaps in the existing governance frameworks, and in light of growing pressures, the necessity for cross-sectoral coordination and management of current and, importantly, future activities in ABNJ is being increasingly realised. For over a decade, issues surrounding the conservation of marine biodiversity in ABNJ have been a topic of extensive discussion. In 2004, the United Nations General Assembly (UNGA) established a "Biodiversity Beyond National Jurisdiction (BBNJ) Working Group" to explore these issues. In 2015, the working group provided recommendations to the UNGA to develop a new legally-binding instrument for the conservation and sustainable use of marine biological diversity in ABNJ, with a particular focus on four overarching issues:

- Marine Genetic Resources (including issues of benefit sharing);
- Area-Based Management Tools (including Marine Protected Areas);
- Environmental Impact Assessments; and
- Capacity building and the transfer of marine technology.

In the same year, and in recognition of increasing pressures in ABNJ, the UN General Assembly considered the recommendations of the BBNJ Working Group and decided to develop an international legally-binding instrument in Resolution 69/292 . Since 2015, four Preparatory Committee meetings have been held to explore and provide recommendations to the UN General Assembly on the elements of a draft text for a new instrument. On 24th December 2017, the UN General Assembly adopted Resolution 72/249 , which includes the decision to convene an intergovernmental conference to "consider the recommendations of the Preparatory Committee and to elaborate the text of an international legally binding instrument" under the UN Convention on the Law of the Sea. The conference will occur over four sessions between 2018 and 2020.

4 Artisanal and Small-Scale Mining (ASM) in Ghana – Creating value or destroying value: The search for a way forward

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[Source: UNU-INRA/UNECA Policy Brief (forthcoming 2018)]

4.1 Introduction

Artisanal and small-scale mining (ASM) is a crucial source of livelihood for many local communities world-wide, in general and particularly in Ghana. In recent years, there has been a widespread shift by poor households from agrarian to informal mining activities. The unsustainability and poor productivity of the agricultural sector have been the key drivers for the shift to the sector.

Although ASM is gaining more importance, it represents governance challenges. ASM causes significant environmental degradation. Many ASM activities coincide with the global commons of forested lands in critical ecosystems that were not used before (Duřan *et al*., 2013). The environmental impacts range from deforestation (Hirons, 2014), biodiversity loss (Butler, 2006), soil and water pollution, to extreme dust, and air pollution. Other impacts include changes in river regimes, surface or underground fires (in the case of coal mining), frequent landslides in areas of steep gradient, and noise pollution. Illegality is another serious challenge in ASM. More crucially ASM activities can fuel conflicts. Many of minerals driven conflicts are mainly driven by ASM produced conflict minerals[2]. From the perspective of large-scale mining companies, ASM poses potential financial liabilities and reputational risks, given its "illegal" nature, poor health and safety practices, use of child labour, and environmental impacts that may be mistakenly attributed to the large-scale company's activities (ICMM, 2009).

This case study connects with both the 'drivers' and 'pressures' components of the DPSIR framework.

Artisanal gold mining has a long history in Ghana and hence the colonial name of Ghana - The Gold Coast. Between 1493 and 1600, Ghana was the largest gold producer in the world, accounting for about 36% of world output, an enviable feat achieved with the support of a vibrant ASM sector (GOG 2014), underscoring the prowess of the sector and the special place gold has played in Ghana life.

Though formal gold mining has now come to dominate gold mining in Ghana, a significant part of gold output comes from artisanal and small-scale mining (ASM). The sector's contribution to national gold production has increased steadily from 2.2% in 1989 to about 34% in 2014 (Ghana

[2] The key ASM conflict minerals gold, diamonds, 3Ts (Tunsgten, Tin and Tantalum), and cobalt

Chamber of Mines, 2014)[3]. The contribution of ASM to employment, however, dwarfs that of the formal sector. As a whole, while less that 20,000 are employed in the formal sector, estimates indicate that there are over 1 million people in the ASM sector and close to 4.4 million people in Ghana are also dependents of these people (McQuilken and Hilson, 2016). Indeed, the Africa Mining Vision (AMV) points to the "the potential of ASM to improve rural livelihoods, to stimulate entrepreneurship in a socially-responsible manner, to promote local and integrated national development as well as regional cooperation."

4.2 Challenges of ASM

While ASM is key employer and many people depend on it for their livelihoods, ASM is plagued by many challenges. There are significant externalities that emanate from ASM activities and these are borne by other people not necessarily connected with ASM. The main challenge of ASM is environmental degradation which negatively impacts agricultural productivity and pollution that poses health risks to communities. Illegal ASM adds a new layer of challenge. The miners invade lands of people and also concessions of large-scale miners, creating conflicts that have led to deaths. They are also linked to wider society and globally through patronage networks for protection and investment. Illegal mining comes with significant security threats in addition to traditional challenges of ASM.

In the desire to improve outcomes from ASM, the government of Ghana has recently promulgated the Ghana's ASM policy framework to guide the development of the ASM sector (Minerals Commission, 2015). Though the objective of the policy is to help ASM support sustainable development through supporting the sector to upgrade, the pathway for this is not very clear. Some proposals are discussed below.

4.3 ASM and Sustainable Development – The Search for Potential Pathways

4.3.1 Agriculture Vs. ASM – the search for symbiosis

The traditional relationship between subsistence agriculture and ASM has broken down, meaning that ASM is not complementing agriculture, and indeed it is destroying agriculture since ASM is highly profitable compared to subsistence agriculture. Gold prices are cyclical, and like those of any other commodity, after a boom a bust does come. Also, gold runs out, leaving ghost towns in its wake. Therefore, the question of sustainability is crucial and requires careful thought. While agricultural-driven rural transformation provides a sustainable path to rural transformation, this can take a long time. On the other hand, ASM provides money immediately and thus people are unlikely to leave ASM for a better (potential) future agriculture promises. A middle of the road strategy that can strike a balance between ASM and agriculture is needed. This requires a mechanism to couple the two sectors again so that one complements the other in enabling rural transformation. Short-term benefits from mining will need to be invested in longer term benefits

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[3] This equalled the total contribution of three large multinational companies. Anglogold contributed 6%, Newmont had 13% , and Goldfields Tarkwa 15%,(Ghana Chamber of Mines, 2014)

of improved agriculture through investment in improved seeds, mechanization, irrigation, and skills.

4.3.2 Local value addition – Can ASM lay the foundation?

Ghana largely exports its minerals with little value addition opportunities, thus it missing many opportunities that gold, its key export, can bring[4]. More value addition has been an objective of the Government. However, local value addition efforts are likely to face significant challenges.

Value addition, like all aspects of minerals value chains, is very capital intensive and requires firms with skills and needed resources. It is unlikely that local entrepreneurs have the needed resources. This is also a highly consolidated sector with well-established global centres. Van Gelder and Smit (2015) points that two key nodes of the gold value chain, trading hubs and refining hubs, are located between the producing and consuming countries. These hubs include for example Switzerland, Dubai (United Arab Emirates), Singapore, Shanghai, and Miami (United States). By far Switzerland has the largest capacity refining of an estimated 70% of world gold refining capacity in 2012[5]. Creating new hubs will require a lot in attracting investments and building competencies to compete with these well-established hubs. Thus, local value addition may mean significant incentives to attract the needed investments, and these incentives can erode any benefits that come with increased local value addition as has been the case with generous incentives given to cocoa processing, which have delivered few benefits[6].

Ghana can leverage the ASM sector to exploit niche markets opening up with the growth of creative industries in the region. The rapidly developing local fashion industry is a regional trend setter and can support new jewelry value chain that are more amenable to local value addition efforts. The vibrant film and music industries provide yet another opportunity. This niche market can help build the competencies needed and with time produce world class designers. At the moment there is no mention in the ASM policy of how to leverage other creative industries to develop local jewelry value chains.

4.4 Way Forward

4.4.1 Rethink ASM Governance - Decentralize

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[4] Globally, the key applications of gold include: production of jewelry (48%); investment demand for gold bullion (36%); Central bank purchases where gold bullion is kept as a reserve asset (8%); Another 8% of global gold consumption is accounted for by industrial applications (mainly electronics and telecommunication equipment); Dental and medical applications took a 1% share of global gold consumption in 2013 (Van Gelder and Smit, 2015)

[5] The supremacy of Switzerland is being challenged by Dubai which has been adding significant capacity in recent years including the world largest gold refinery (van Gelder and Smit, 2015)

[6] Ghana has used generous incentives to entice global cocoa processors to do more processing locally. The processors get cocoa at discounted price of 80% of the world market price (the export value). They are also located in Free Zones which have many incentives including generous tax holidays, import duties exemptions, fast track services with customs, good infrastructure and easy access to ports. Though local processing of cocoa has increased dramatically as a result, this been mainly in low value and low employment grinding operations. Many have complained that the cost of the incentives is not worth the benefits (ACET 2017).

ASM in Ghana is governed much like formal mining with the Mineral Commission responsible for much of the oversight. Yet the structure of this sector is fairly different from formal mining. It competes directly with agriculture for land and for labor. Agriculture bears much of the brunt of the environmental challenges caused by ASM. Both sectors are in competition for land which is largely controlled by the traditional authorities.

Governance of ASM should thus be completely decentralized to traditional authorities. Artisanal mining and agriculture should be seen as alternative sources of livelihood for people who live on the land and the traditional authorities should be left to weigh the costs and benefits of adopting either livelihood approach and guide the development of both sectors. Indeed, traditional authorities played an important role in regulating mining activities, protecting communal water sources and settling disputes between miners (Wilson et al., 2015). Formal central government agencies' roles should be confined to backstopping traditional authorities e.g. providing technical advice on issues like surveying, environmental impact assessments, physical planning and so on.

4.4.2 Incentives should drive formalization of ASM

While formalization pays for government in terms of more taxes (and less externalities) it does not pay for ASM unless it is accompanied by incentives to make it worth-the-while for ASM operators. To make formalization attractive to ASM, some of the incentives that can be provided include: linking technical support and capacity building; linking access to credit to formalization; linking miners to formal markets that pay a higher price than the informal markets they usually use; demarcation of areas for ASM; provision of geological data (Collins and Lawson's (2014).

Ghana seems to be on the right path. To entice formalization and in the process facilitate collection of taxes, the Ghana Minerals Commission strategy is to geologically explore areas for small-scale miners, organize them into associations, and license the areas for them. Minerals Commission (2015) righty argues that by so doing, it will be easier to tax them appropriately. Development partners are also seeking to support formalization of the sector. The Global Opportunities for the Long-term Development of the Artisanal and Small-Scale Gold Mining Sector (GEF-GOLD) programme, is led by UN Environment and jointly implemented with Conservation International, UNDP and UNIDO is helping countries including Ghana to formalize the ASM as one of the actions required under the Minamata Convention on mercury reduction in target ASM sectors across the world.

4.4.2.1 *From focus on taxes and royalties to employment creation*

Governments are generally unsupportive of ASM due to the fact that it is harder to collect taxes from them as opposed to formal industrial mining or Large Scale Mining (LSM.) However, the reason for government to collect taxes is to create opportunities for citizens and drive transformation (both of which are critical to poverty reduction). ASM has already helped in one way through jobs and can also drive rural transformation if properly directed. It is time the Ghana government re-examines its role when ASM is concerned and focus more on creating an enabling environment for rural transformation through increased consumption that can come from inflows from ASM. Rather than try to capture direct taxes from ASM (which is difficult) it can focus on capturing taxes from consumption generated by in-flows from ASM if monies generated from ASM activities are spent locally. This is feasible if more goods and services are provided in areas where ASM occurs and the minerals also are purchased on those localities.

4.4.2.2 *More realistic legislation that conforms to reality on the ground*

Crawford et al. (2014) argue for a more realistic legislation that recognizes the reality on the ground. They point to a current situation where many local ASM operators, both registered and unregistered, are working with foreign partners irrespective of the law stating that small-scale mining is reserved for Ghanaian citizens only. Partnerships with Chinese have been particularly strong[7]. They point that this appears to be the *de facto* situation and one that is unlikely to change any time soon. And there is a simple logic to it. Local operators benefit from the capital investment, machinery and expertise that foreign miners bring. Indeed this arrangement is bringing capital and expertise that the government's new ASM mining policy seeks to bring to the ASM sector (Minerals Commission, 2015).

The Government may therefore consider changes in legislation in the ASM sector to come to terms with what is happening on the ground and indeed take advantage of this to accomplish its mission of upgrading the sector. It may be necessary to amend the small-scale mining legislation to formally allow foreign miners to work with registered Ghanaian concession holders. This will then create the space to set clear guidelines on the nature of partnerships, financing regulations, service provision, subcontracting rules, and ensure effective reporting and tracking of the gold produced and the revenues that accrue (Crawford et al., 2015).

4.4.3 Conclusion

ASM is an important source of livelihood for many people and it has been for some time. However, ASM has many externalities that come with it and is rapidly destroying agriculture, a key factor for sustainability. Without serious rethinking of how to steer this sector the externalities are likely to dominate the benefits that can be derived from ASM.

Yet ASM does still hold the promise of driving rural transformation and economic transformation in general. Significant inflows are generated from ASM activities and if they are redirected to rural areas they can help boost consumption and also provide investment resources to support transformation. Also by developing regional niche markets, ASM can support the growth of industries for local value addition. For this to happen, there is need to rethink the governance of the ASM sector and how it is organized and incentivized. ASM should be seen as separate from LSM and its governance should be fully decentralized and indeed transferred to traditional authorities who historically managed it. They are the best placed to manage and balance the benefits and externalities of ASM. Traditionally, the ASM was a way to diversify livelihoods with farming being the main activity. This relationship needs to be restored. In this complementary role, externalities of ASM could be controlled as the farmer-miner could weigh the benefits and payoff

[7] Some locals simply acquire lands directly from community landowners or chiefs, and sell these to the Chinese to undertake the mining. Others go through the legal concession acquisition process and then form a partnership with the Chinese, taking between 10-15 per cent of the gold produced while the Chinese who finance the entire mining operations take 85-90 per cent (Crawford et. al. 2015).

and chose an optimal level of ASM activity that provides resources to invest in agriculture with destroying the basis of this other important livelihood. Thus support of the sector should be towards driving it to sustainable practices and this could guide support efforts by development partners and others.

Also, the government should accept the reality on the ground and note that foreigners are working in the ASM sectors in close partnerships with local ASM operators. They are helping upgrade ASM through capital investment and transfer of skills. Rather than try to fight the reality, efforts should be made to formalize these partnerships. However, there is need to ensure the foreign operators form proper and beneficial partnerships. One way is to develop model contracts for joint ventures that can be implemented by local authorities, especially traditional chiefs. The traditional authorities should also be part of the joint ventures. This will ensure foreigners do not bribe local chiefs and get away with illegal or dangerous activities as chiefs have a stake in the ASM that goes beyond just allocating land.

5 Impact of sand mining on environment

Authors: Pascal Peduzzi and Janyl Moldalieva, United Nations Environment Programme

5.1 Our society is literally built on sand (drivers & pressures)

With growing population and infrastructure, the need for sand and gravel (thereafter aggregates) has never been so high. Aggregates are needed to create concrete for roads, building, dams, dikes, bridges and other infrastructures. It is needed for gas extraction using hydraulic fracturing (also called “fracking”), flattening topology filling gaps and underneath roads. We use sand for sea reclamation to increase land availability in dense urban areas. It is also use for beach nourishment to fight against coastal erosion or for creating touristic infrastructures. Sand is also used for generating glass, specific sand is used in electronics, as fertilizers, and even in some cosmetic.

Sand and gravels are the unknown heroes, pillars of our economy and development. Without them, there will be no concrete, no asphalt, no glass. Impossible to build the necessary schools, hospitals, roads, solar panels and other necessary infrastructures to achieve the Sustainable goals. Our dependency to sand and gravels is colossal.

So far sand and gravels were thought to be infinite. However, sand is being produced through erosive processes, following a geological time scale. Like the fishes in the ocean or the timber in our forests, even when it is available in vast quantity, you cannot use any resource at a rate exceeding its renewing rate, without, at one stage, running out of it.

We are no yet running out of sand, however there are some locations where sand is getting rare and there is a need to be much smarter in the way we are using this resource.

5.2 Current status and trends

Sand and gravels account for the largest volume of solid material extracted globally (second in volume after water). Despite the absence of global statistics on the amount of sand extracted world-wide, its use is estimated to be between 40 and 50 billion metric tonnes per year. This is the equivalent of about 18 kg per day for each individual on the planet, or, placed in another way, this is enough to build a wall of 27m high by 27m wide all around the equator every year.

This raises three major concerns. Firstly, we cannot extract such volume of material without inducing large impacts on the environment. Secondly, given this extraordinary dependency, how come most governments, decisions makers are not more aware about this issue?
Sand and gravels are considered to be so common, that no one seems to worry about it, despite our life being so dependent on it.

The trend is exponential. If we look at the amount of cement as a proxy (given that global cement production is reported by countries since 1990), statistics show that our use of cement increased three-folds in the last two decades. China increased its used by 540% in the last 20 years, exceeding the use of all the other countries combined in 2008 (see graph below).

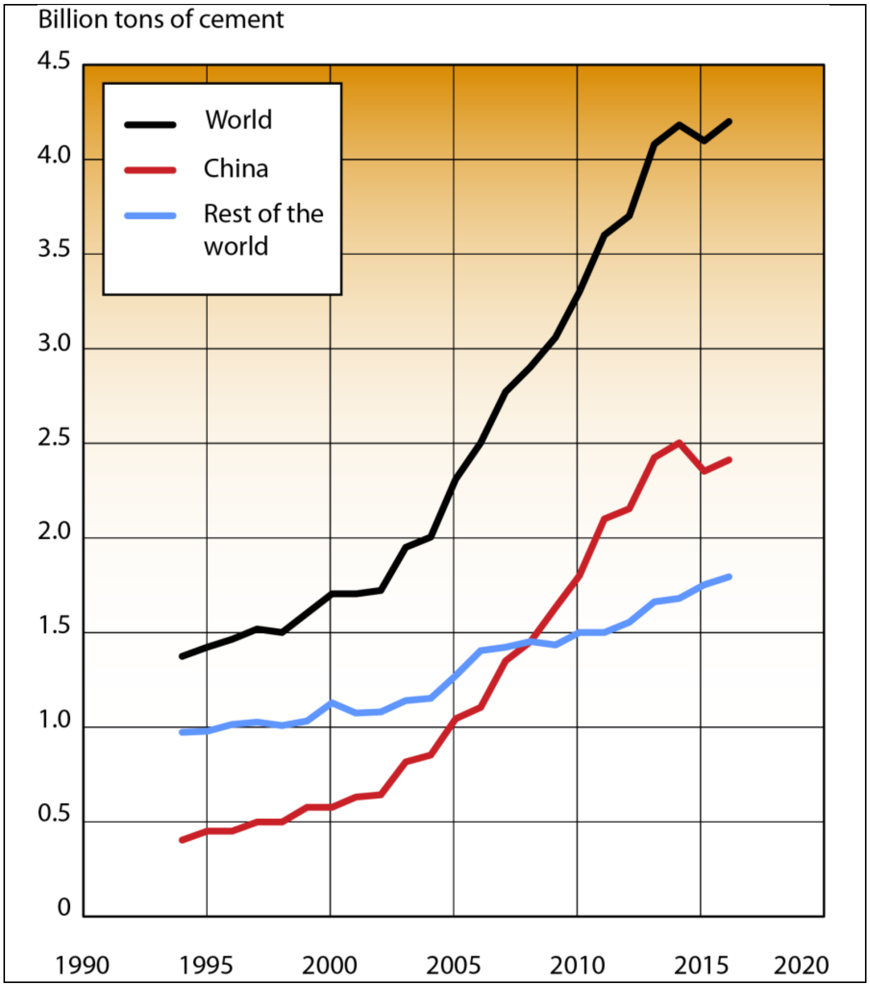

Figure 1 Evolution of the cement production in China and the rest of the world since 1994 (unit: billion tons)

In absence of global monitoring, it is difficult to estimate the total amount of sand. However there are countries, which do produce statistics on both sand and cement. For example, in the United States of America, the apparent annual use was 900 million tons of sand and gravel for the construction sector in 2017[8], while the use of cement was 86.3 million tons in 2017[9].

And in the USA there is a 96% correlation between the use of aggregates and cement, with an average of about 10 tons of sand for 1 ton of cement (10.3). Aggregates also contribute to 90% of asphalt pavements and 80% of concrete roads (Robinson and Brown, 2002).

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[8] Sources USGS : https://minerals.usgs.gov/minerals/pubs/commodity/sand_&_gravel_construction/mcs-2018-sandc.pdf

[9] Sources USGS: https://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2018-cemen.pdf

So using cement as a proxy, it is possible to estimate the total amount of aggregates use. USGS is reporting 4,1 billions tons of cement production for 2017, meaning that the estimated use of sand and gravels is probably exceeding 40 billions tons only for the construction sector.

Added to this are all the aggregates used in land reclamation, shoreline developments, beach nourishment (for which the global statistics are unavailable), plus the 210 million tonnes of sand used in industry (USGS, 2017)[10].

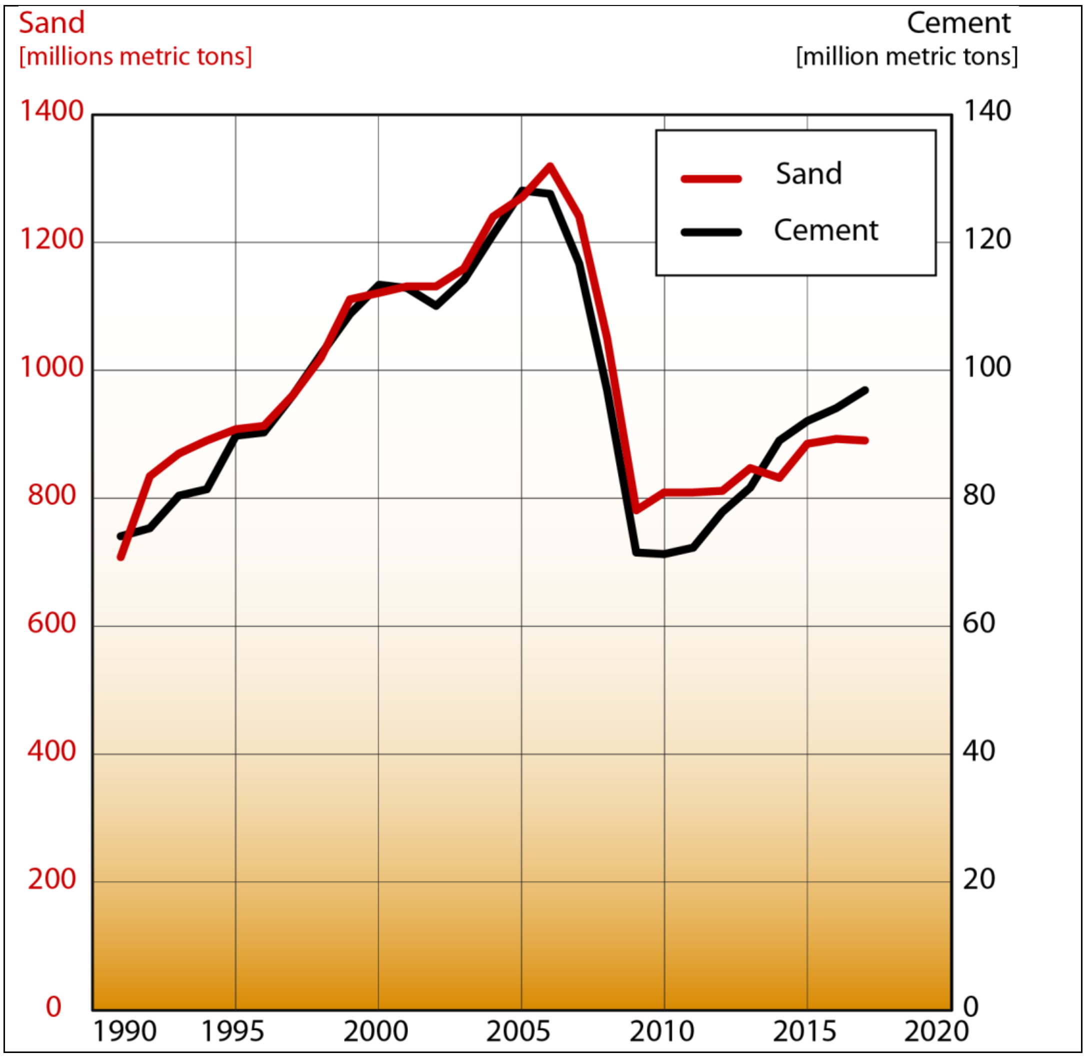

Figure 2 The consumption of sand and gravels for construction versus cement as reported between 1991 and 2017 in USA. The correlation between the two commodities reaches 96%. For each metric ton of cement, there is a use of about 10 tons of sand and gravels.

It means that being conservative, we can estimate that the total consumption of sand must be around 50 billion tons per year. This is 2.5 the yearly amount of sediment carried by all of the rivers of the world (Milliman and Syvitski, 1992), making humankind the largest of the planet's transforming agent with respect to aggregates (Radford, 2005).

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[10] USGS: Https://minerals.usgs.gov/minerals/pubs/commodity/silica/mcs-2018-sandi.pdf

This large quantity of material cannot be extracted (Figure 1) and used without leading to significant impacts on the environment (Sonak et al., 2006, Kondolf, 1994). Extraction has an impact on biodiversity, water turbidity, water table levels and landscape (Table 1) and on climate through carbon dioxide emissions from transportation. There are also socio-economic, cultural and even political consequences. In some extreme cases, the mining of marine aggregates has changed international boundaries, such as through the disappearance of sand islands in Indonesia (New York Times, 2010; Guerin, 2003).

Most of this new demand comes from the rapid economic growth in Asia (UNEP and CSIRO, 2011), and spurred by China's development, which in 2017 absorbed 59% of the world cement production, or 2.4 billion tonnes. Two thirds of the cement is being used by China (58.5%) and India (6.6%) (USGS, 2017).

5.3 Source of sand and environmental impacts

Sand was until recently extracted in land quarries and riverbeds; however, a shift to marine and coastal aggregates mining has occurred due to the decline of inland resources. River and marine aggregates remain the main sources for building and land reclamation. For concrete, in-stream gravel requires less processing and produces high-quality material (Kondolf, 1997), while marine aggregate needs to be thoroughly washed to remove salt. If the sodium is not removed from marine aggregate, a structure built with it might collapse after few decades due to corrosion of its metal structures. Most sand from deserts cannot be used for concrete and land reclaiming, as the wind erosion process forms round grains that do not bind well (Zhang et al., 2006).

5.3.1 Impacts on the environment

In developing countries, mining and dredging regulations are often established without scientific understanding of the consequences, and projects are carried out without environmental impact assessments (Maya et al., 2012; Saviour, 2012). As a result, aggregate mining has affected the provision, protection and regulation of ecosystem services.

5.3.2 Impacts on biodiversity

The mining of marine aggregates is increasing significantly. Although the consequences of substrate mining are hidden, they are tremendous (Figure 3). Marine sand mining has had an impact on seabed flora and fauna (Krause et al., 2010). Dredging and extraction of aggregates from the benthic (sea bottom) zone destroys organisms, habitats and ecosystems and deeply affects the composition of biodiversity, usually leading to a net decline in faunal biomass and abundance (Desprez et al., 2010) or a shift in species composition. Long-term recovery can occur only where original sediment composition is being restored (Boyd et al., 2005).

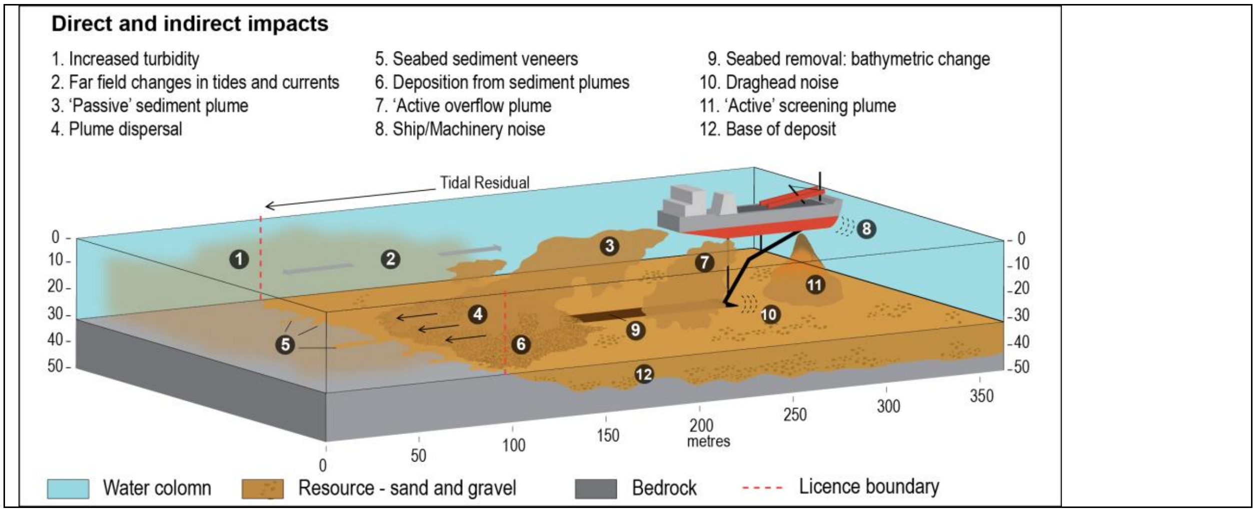


Figure 3 Direct and indirect consequences of aggregates dredging on the marine environment. Graph adapted from Tillin et al., 2011

Aggregate particles that are too fine to be used are rejected by dredging boats, releasing vast dust plumes and changing water turbidity, resulting in major changes to aquatic and riparian (i.e. river banks) habitats over large areas (Ashraf et al., 2011).

5.3.3 Impact on inland biodiversity and rivers

The mining of aggregates in rivers (Figure 4) has led to severe damage to river basins (Sreebha and Padmalal, 2011), including pollution and changes in levels of pH (Saviour, 2012). Removing sediment from rivers causes the river to cut its channel through the bed of the valley floor (or channel incision) both upstream and downstream of the extraction site. This leads to coarsening of bed material and lateral channel instability. It can change the riverbed itself (Kondolf, 1997). The removal of more than 12 million tonnes of sand a year from the Vembanad Lake catchment in India has led to the lowering of the riverbed by 7 to 15 centimetres a year (Padmalal et al., 2008). Incision can also cause the alluvial aquifer to drain to a lower level, resulting in a loss of aquifer storage (Kondolf, 1997). It can also increase flood frequency and intensity by reducing flood regulation capacity. However, lowering the water table is most threatening to water supply (Myers et al., 2000) exacerbating drought occurrence and severity as tributaries of major rivers dry up when sand mining reaches certain thresholds (John, 2009).

5.3.4 Coastal and inland erosion

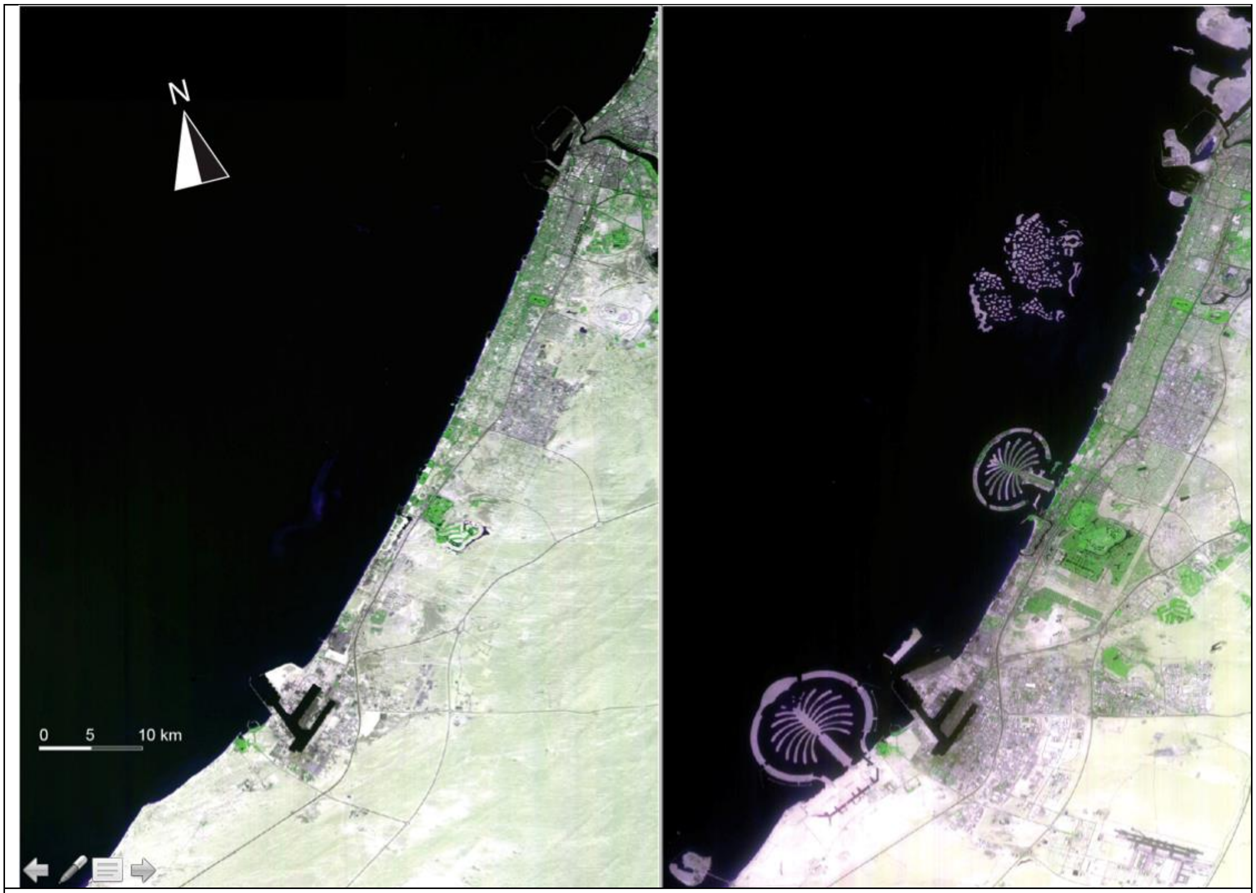
Erosion occurs largely from direct sand removal from beaches, mostly through illegal sand mining. It can also occur indirectly, as a result of near-shore marine dredging of aggregates, or as a result of sand mining in rivers (Kondolf, 1997). Damming and mining have reduced sediment delivery from rivers to many coastal areas, leading to accelerated beach erosion (Kondolf, 1997). Onshore sand mining in coastal dune systems such as those in Monterey Bay, California, in the United States, can also lead to long-term erosion, in this instance, 0.5 to 1.5 metres a year (Thornton et al., 2006).

By 2100, global average sea level rise is expected to reach 0.26 to 0.55 metres under the best-case scenario (of 70% reduction of greenhouse gas emissions), and nearly one metre under unabated increase in greenhouse gas emissions (IPCC, 2013a). This problem is particularly acute for small islands states, where retreat options are limited. In the Maldives, a few of the largest and highest islands, such as the capital city, Male, are being consolidated to ensure they can host the population displaced from low-lying islands (Figure 5). To strengthen the city, a large amount of sand is being imported to Male, to be used in building higher towers and coastal protection. The sand is taken from offshore sand islands. Paradoxically, the sands extracted for the protection measures in Male are leading to the lowering of some islands, increasing the need to relocate their populations (Delestrac, 2013).

Lake Poyang, the largest freshwater lake in China, is a distinctive site for biodiversity of international importance, including a Ramsar Wetland. It is also the largest source of sand in China (De Leeuw et al., 2010) and, with a conservative estimate of 236 million cubic metres a year of sand extraction, may be the largest sand extraction site in the world. By comparison, the three largest sand extraction sites in the United States combined represent 16 million cubic metres a year (De Leeuw et al., 2010). Sand mining has led to deepening and widening of the Lake Poyang channel and an increase in water discharge into the Yangtze River. This may have influenced the lowering of the lake's water levels, which reached a historically low level in 2008 (De Leeuw et al., 2010).

Box 1: Dubai

The city of Dubai in the United Arab Emirates is among the world's most spectacular architectural developments, albeit one that has put significant pressure on marine aggregates. The Palm Jumeirah, an artificial set of sand islands (see below), required 186.5 million cubic metres (385 million tonnes) of sand and 10 million cubic metres of rock, and cost US$12 billion (Jan De Nul group, 2013). Dubai is also home of the Burj Khalifa tower, the highest building in the world at 828 metres. While such development is impressive, in 2013, 31% of office space was vacant in the centre of Dubai (Jones Lang LaSalle, 2013). The Palm Jumeirah was quickly followed by a second Palm project, The Palm Jebel Ali, and then by The World islands project, a set of 300 artificial islands representing a map of the world. The World project cost US$14 billion to construct and required 450 million tonnes of sand.



Left: Dubai February 2002 ASTER image. **Right:** July 2012 ASTER image. The two Palm islands and The World artificial islands required more than 750 million tonnes of sand. Images processed and analysed by UNEP/GRID-Geneva.

5.3.5 Impact on climate

The transport of large quantity of aggregates, sometimes over long distances, has a direct impact on greenhouse gas emissions. The indirect impacts of aggregate mining come from the production of cement. For each tonne of cement, an average of 0.9 tonnes of carbon dioxide are produced (Mahasenan et al., 2003; USGS, 2012)[11] . The Carbon Dioxide Information Analysis Center (CDIAC) estimates that 1.65 billion tonnes of carbon dioxide emissions were from cement production in 2010 alone, or nearly 5% of total greenhouse gas emissions (EDE, 2014). Total carbon emissions from cement amount to eight billion tonnes of carbon (equivalent of 29.3 billion tonnes of carbon dioxide) (IPCC, 2013b, p. 474) and has increased from 3% in the 1990s to 4% of greenhouse gas emissions from 2000 to 2009 (IPCC, 2013b, p.489).

5.3.6 Economic impact

Aggregates are, in most cases, a free resource, but their extraction comes at the expenses of other

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[11] In CDIAC computation the ratio used is 0.49. However, most scientific publications are using a ratio between 0.73 and 0.99 (Mahasenan et al., 2003), or 0.87 to 0.92 t of carbon dioxide (USGS, 2012).

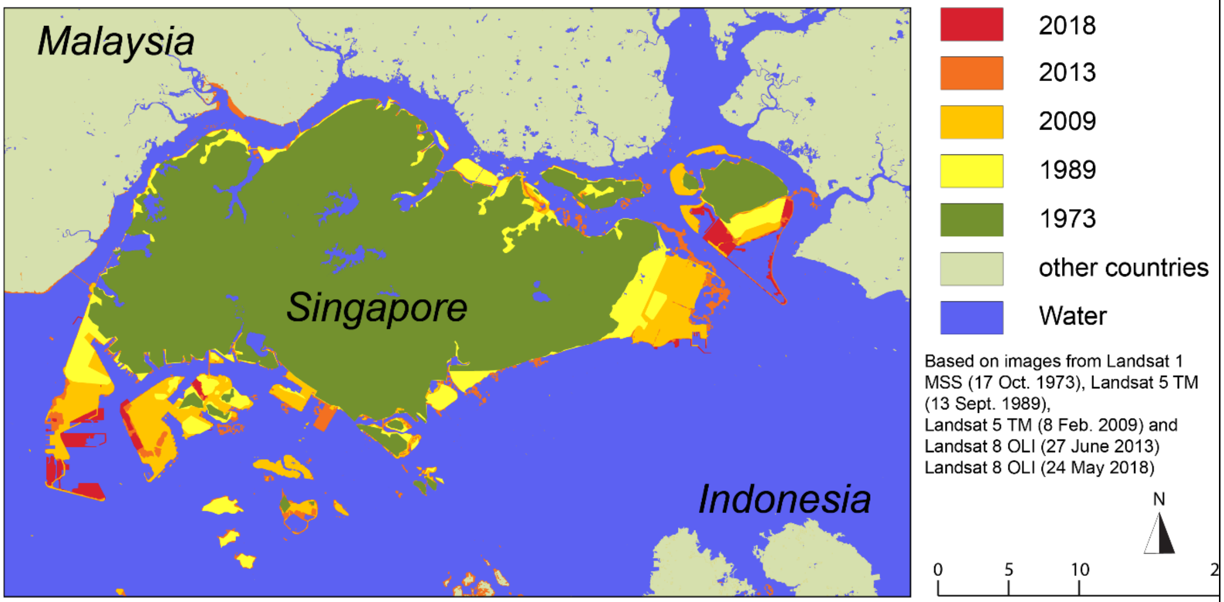
economic sectors and local livelihoods. Tourism may be affected through beach erosion (Kondolf, 1997), while fishing — both traditional and commercial — can be affected through destruction of benthic fauna (Cooper, 2013; Desprez et al., 2010). Agriculture could be affected through loss of agricultural land from river erosion (John, 2009) and the lowering of the water table (Kondolf, 1997). The insurance sector is affected through exacerbation of the impact of extreme events such as floods (Kondolf, 1997), droughts (John, 2009) and storm surges through decreased protection of beach fronts (Thornton et al., 2006). The erosion of coastal areas and beaches affects houses and infrastructure (Thornton et al., 2006; John, 2009). A decrease in bed load or channel shortening can cause downstream erosion including bank erosion and the undercutting or undermining of engineering structures such as bridges, side protection walls and structures for water supply (John, 2009; Padmalal et al., 2008).

A lack of proper scientific methodology for river sand mining has led to indiscriminate sand mining (John, 2009), while weak governance and corruption have led to widespread illegal mining (Saviour, 2012; Ashraf et al., 2011). Sand trading is a lucrative business, and there is evidence of illegal trading such as the case of the influential mafias in India (Ghosh, 2012).

In Morocco, half of the sand – 10 million cubic metres a year – comes from illegal coastal sand mining (Au fait, 2011). Sand smugglers have transformed a large beach into a rocky landscape between Safi and Essouira (l'Economiste, 2005; Khardijamal, 2011). Sand is often removed from beaches to build hotels, roads and other tourism-related infrastructure. In some locations, continued construction is likely to lead to an unsustainable situation and destruction of the main natural attraction for visitors — beaches themselves.

Box 2: Singapore

Singapore is developing rapidly and its population has increased by a factor of three since 1960, from 1.63 million to 4.84 million inhabitants in 2010. Given its small area, Singapore needed more space for its infrastructure development. To respond to this demand, the city has increased its land area by more than 20% in the last 40 years (an addition of 130 square kilometres), mostly by using aggregates to reclaim land from the sea (see map).



Remote sensing, GIS analysis and cartography, Pascal Peduzzi, UNEP/GRID-Geneva 2018

A map of Singapore shows its area increasing from 1973 to 2018. Remote sensing analysis: UNEP/GRID-Geneva.

Having imported a reported 517 million tonnes of sand in the last 20 years, Singapore is by far the largest importer of sand world-wide (UN Comtrade, 2014; Aquaknow, 2014) and the world's highest per capita consumer of sand at 5.4 tonnes per inhabitant.

Sand is typically imported mostly from Indonesia, but also from the other neighbouring countries of Malaysia, Thailand and Cambodia. Export of sand to Singapore was reported to be responsible for the disappearance of some 24 Indonesian sand islands. It is reported that this triggered political tensions regarding maritime borders between the two countries (New York Times, 2010; Guerin, 2003).

The reported sand exported from Indonesia to Singapore declined sharply since a temporary ban declared in February 2002 (Guerin, 2003). Other neighbouring countries are now reporting few exports to Singapore. Overall, the reported total amount of sand imported by Singapore (517 million tonnes) and the sum of sand exports to Singapore from its four neighbouring countries (637 million tonnes) does not match (see graph left), showing an underestimation of 120 million tonnes of sand imports. Obviously, these statistics do not include illegal imports and highlight the need for better monitoring. There is also an alleged illegal sand trade (Global Witness, 2010). As the price of sand increases, so does the traffic of sand by local mafias (Global Witness, 2010; Milton 2010; Handron, 2010). The average price of sand imported by Singapore was US $3 per tonne from 1995 to 2001, but the price increased to US $190 per tonne from 2003 to 2005 (UN Comtrade, 2014).

5.4 Policy Response and Solutions

The mining of aggregates, such as sand, has not been high on the political agenda, primarily, because sand has not yet reached a level of scarcity that would threaten the economy. Increasing sand mining, trade and consumption and their socio-environmental impact urge for a global sand governance (Torres et al., 2018). As of today, insignificant measures are taken to monitor and regulate sand mining, except within the European Union (see Box A) (Velegrakis et al., 2010; Tillin et al., 2011). Lack of monitoring systems and regulatory policies have led to indiscriminate mining, triggering severe damage to the environment and related ecosystem services. This highlights the importance of understanding the implications of (il)legal sand mining through socio-scientific research, increasing wider public awareness, and working with actors involved in sand mining to mitigate associated risks. It would be essential to collect comprehensive and reliable data, develop and enforce solid legal frameworks on national and international levels, and reduce sand consumption in order to address alarming environmental and social impacts of sand mining. Building on these suggestions, the report will present policy options and solutions in the current section.

Box A. Relevant existing policies

Activity-based regulations and land and marine protection are the two policy frameworks that govern extraction of aggregates. Land and marine protected areas restrict extraction of aggregates within their limits.

International Conventions. The United Nation Convention on the Law of the Sea (UNCLOS), 1982, regulates rights and obligations related to usage, development and preservation of maritime zones, including resource mining (Radzeviius et al., 2010). Several regional conventions have been ratified to minimize the impact of human activities with some references to aggregate exploitation. These include:

- Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR Convention), 1992
- Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention, 1992
- Convention for the Protection of the Mediterranean Sea against Pollution, 1976,
- Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention), 1995
- Convention for the International Council for the Exploration of the Sea (ICES), 1964
- Convention on Environmental Impact Assessment in a transboundary context (ESPOO), 1991
- Protocol on Strategic Environmental Assessment (SEA Protocol), 2003
- Protocol on land-based sources of pollution from the Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region (Cartagena Convention)

However, there are no specific guidelines on extraction of marine aggregates under the Barcelona Convention. No international conventions regulate the extraction, use and trade of land-based sand (sand quarry, riverine and lake aggregate). There are no global standards (Velegrakis et al., 2010; Radzeviius et al, 2010) and coherent governance system that harmonizes regulations between national and international conventions.

5.5 Mapping Sand Mining

The first step is to collect data on sand consumption on local and global levels with consideration of how much of it is replenished through natural processes. There is a lack of adequate information on sand extraction, which has led to limited (if any) regulation of the sector, especially in developing countries (Sreebha and Padmalal, 2011). Access to data is difficult, and data are not standardized. Collaboration and coordination is needed between the marine scientific research establishments and the marine aggregates industry to better map out sand mining (see Velegrakis et al., 2010).

5.6 Towards Sand Governance

In the context of lack of institutions and political will in public and private sectors, it would be essential to have governance mechanisms in place to enforce sustainable use of sand. A comprehensive mix of policies is needed on (a) reducing sand consumption through optimizing the use of existing buildings and infrastructure, (b) recycling and avoiding waste along the supply chain, (c) obligating environmental scientific assessments, (d) regulating better planning, permission, prospecting, extraction, and monitoring of the industry, (e) introducing payments for environmental and social damage, and (f) building capacity for sustainable use of sand. These policies are complementary and should be integrated into the governance system (Torrest et al., 2018, p. 971; Chauhan, 2010).

Large-scale mining, quarrying and reclamation activities should only be authorized, once sound scientific assessment shows its limited impact on the environment (Maya et al., 2012). Quality-controlled environmental impact assessments should be conducted in an obligatory manner prior to providing licenses for sand extraction. Monitoring sand extraction should go hand in hand with reporting on licenses and conducting independent oversight. If there is a concession, the local authorities and communities should be made aware and have their say on the matter. It is important to work with local communities involved in sand mining to increase their awareness about the impacts and explore sustainable use of sand and alternative sources for maintaining their livelihoods.

Countries should set international guidelines and legislation on marine sand extraction[12] to protect near-shore sources of sand (e.g. within 1 mile from shore), shallow seas (e.g. if less than 20 m depth), and other sensitive habitats (e.g. reducing turbidity of water, preventing the use of sand to re-charge/maintain beaches under certain tidal and current systems). Two-meter sampling from the surface should be considered in order not to destroy unnecessarily the topsoil. Other policy actions include conducting scientific mining operations along with ecological restoration; and creating a consumer awareness label such as a Sand Stewardship Council (SSC) to communicate which sand and associated products are extracted according to sound social and environmental practices.

Introducing a tax or charge on the extraction of sand could reduce demand for this natural resource, encourage more efficient use of sand and incentivise the use of alternatives such as recycled construction and demolition waste and secondary materials. The effectiveness of such a fiscal policy instrument depends on the price elasticity of demand for sand, i.e. how much a given change in price (caused by a tax) will feed through to a change in demand. If elasticity is high, then a given tax should have a big impact. The availability of substitutes is a major factor in the elasticity of demand and thus the effectiveness of a given tax. Furthermore, as some sand mining is illegal and takes place in various geographical locations—some too remote to monitor and regulate - the efficiency of taxing sand extraction should be analyzed on a case-by-case basis (Soderholm, 2011).

Revenues from such a tax or charge on sand extraction could be used to subsidize recycling practices, catalyse innovation and increase prospects for the development of economically viable substitutes. Alternatively, the revenue could be used to reduce taxes elsewhere i.e. on businesses

[12] Due to operational costs, most marine aggregate extractions are carried out at short distances from landing ports and at water depths of less than about 50 metres. As these activities occur close to shore, they generally are under national jurisdictions. The same applies to Exclusive Economic Zones or to the Continental Shelf, where coastal states exercise sovereign rights to explore and exploit natural resources (Radzevičius et al., 2010).

affected by the sand tax, as part of a broader tax reform, helping to increase acceptance of the tax among affected groups and reduce transition costs. The introduction of such a tax can also lead to improvements in the monitoring of aggregates activities, as authorities need to know exactly how much aggregates are extracted each year to calculate the tax. This has, for example, been an indirect effect of aggregate taxes introduced in Italy (in the Lombardy and Emilia-Romagna regions) and Sweden (EEA, 2008). Such taxes on sand mining are an important part of the policy mix needed to shift behaviour and encourage the use of recycled materials. To ensure their full effect they should be complemented by other policies such as regulations, integrated product policies, environmental assessments, waste taxes, and other measures discussed above.

Research indicates that taxes on raw materials production are complemented well by integrated product policies, which introduce environmental management techniques along the entire value chain (Soderholm, 2011). While a tax on virgin materials is a better instrument than a tax on waste (Conrad, 1999), it can only correct for limited external costs related to resource extraction, but not for their use and associated wastes (Dinan, 1993; Fullerton & Wu, 1998; Walls & Palmer, 1997, 2001). In this context, some countries have introduced aggregates taxes alongside other policies to address downstream and upstream environmental externalities (Eichner, 2005). In the UK, a levy of GBP 1.60 per tonne of aggregate (sand, gravel and rock) was introduced in 2002 to compensate for negative environmental impacts of aggregate extraction, reduce demand for aggregates and encourage recycling. The intensity of primary aggregate use in the construction sector in the UK has declined dramatically (falling by around 40% between 2010-2014). However, it is unclear how much of this is attributable to the aggregates levy as a reduction was already underway prior to the introduction of the levy, partly due to the introduction of a landfill tax in 1996, which discouraged landfilling of construction and demolition waste and helped create a market for secondary materials. The combined effect of the landfill tax and the aggregates levy appears to have driven a reduction in primary aggregates consumption in the UK construction sector (Watkins et al., 2017).

5.7 Reducing Sand Consumption

One of the important solutions is to foster sustainable use of sand and/or its substitutes, which could drastically reduce impact on the environment (Chauhan, 2010). Recycled building and quarry dust material can serve as alternatives to sand. Despite the very high value of minerals found in the sand, it is mostly used for concrete or is buried under highways. Concrete rubble should be recycled to avoid using aggregates, at least for low-quality utilization (Kondolf, 1997). Recycling glass bottles would also reduce sand consumption. Quarry dust could be used to replace sand in general concrete structures (Khamput, 2006). The replacement of sand by up to 40% of incinerator ash exhibits higher compressive strength than regular cement mortars (Al-Rawas et al., 2005). Alternatives such as wood, straw and recycled material should be considered in building houses. Some desert sand could be used if mixed with other materials (Cisse et al., 2012; Zhang et al., 2006).

Although the current construction sector is driven by technical know-hows of concrete use, there is a renewed interest in building with adobe rather than with concrete, for instance, in Morocco. Adobe keeps the interior cool, which is important in the context of climate change. Building techniques which use cross-structures will require far less material for the same degree of resistance. Re-designing sand mining techniques to minimize its socio-environmental impact, training of architects and engineers, and in general, developing positive incentives are needed to initiate a shift for lowering our dependency on sand. The solutions, discussed in this section, are outlined below in Box B.

Box B. Solutions

Map out sand mining

- Collect data on sand consumption on local and global levels
- Increase access to and standardize data through coordination of the marine scientific research establishments and the marine aggregates industry
- Use data to inform decision making

Foster sand governance

- Develop policy regulating sand extraction
- Set international guidelines on marine sand extraction
- Tax sand extraction to shift price signals, using the revenues from such a tax to subsidize recycling practices and foster the use of substitute materials
- Monitor sand extraction
- Support practices of recycling and the use of alternative materials
- Request quality-controlled environmental impact assessment prior to providing licenses
- Work with local communities involved and/or affected by sand extraction
- Create a consumer awareness label such as a Sand Stewardship Council (SSC)
- Re-design sand mining techniques to minimize its socio-environmental impact
- Build system and capacity for sustainable sand governance

Reduce sand consumption

- Build with a longer-term planning horizon. Foster retro-fitting buildings rather than rebuilding. Use cross-structures in buildings to reduce demand for materials.
- Use “bottom ash” from waste burning to replace sand for concrete structures.
- Use sawdust as a substitute for sand when possible.
- Recycle building materials and reuse them in new buildings.
- Diversify the source of sand. Extract sediments (sand and gravels) from dams.
- Collect and redeploy sand in harbours when possible.

5.8 Conclusion

Sand and gravel represent the highest volume of raw material used on earth after water. Their use greatly exceeds natural renewal rates. Moreover, the amount being mined is increasing exponentially, mainly related to rapid economic growth in Asia (UNEP and CSIRO, 2011). Negative effects on the environment are unequivocal. The problem is now so serious that the existence of river ecosystems is threatened in several locations (Kondolf, 1997; Sreebha and Padmalal, 2011). Damage is more severe in small river catchments. The same applies to threats to benthic ecosystems from marine extraction (Krause et al., 2010; Desprez et al., 2010; Boyd et al., 2005).

A large discrepancy exists between the magnitude of the problem and public awareness of it. The absence of global monitoring of aggregates extraction undoubtedly contributes to the gap in knowledge, which translates into a lack of action. Furthermore, there is little incentive to reduce sand consumption as market prices currently do not reflect the environmental, social and economic costs of aggregates extraction. As this issue is truly a major emerging one, there is a need for in-depth research. The implementation of a monitoring mechanism regarding global aggregate extractions and trade would shed light on the magnitude of this issue and bridge the current data and knowledge gap (Velegrakis et al., 2010). This would also raise the issue on the political agenda and perhaps lead to an international framework to improve sand governance, as the current level of political concern clearly does not match the urgency of the situation.

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Case Study 8.5: Impact of sand mining on environment

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