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Implementing the Urban Nexus approach for improved resource-efficiency of developing cities in Southeast-Asia

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ABSTRACT

Resource challenges are particularly dominant in fast-expanding cities in the Southeast-Asian region and include inefficient infrastructure systems leading to energy black-outs, urban flooding, lack of waste recycling and increasing emissions and air pollution.

This article addresses the development of integrated infrastructure planning approaches as a tool for increased resource efficiency. It aims to link the circular economy discourse with the Urban Nexus. Three specific case studies called 'living labs' implemented the Urban Nexus approach relating to energy, water, food and waste/material (EWFW) flows.

The article speculates about anticipated systemic changes that will be required to transform urban life, describing a cross-sectorial urban ecosystem approach. The nexus project is introduced along with some challenges that are likely to be encountered.

The Resource Nexus is the interrelated complex system where energy, water, food and material flows/waste treatment systems intersect. The *Southeast-Asian Urban Nexus* project, initiated by significant organisations, commenced in 2013 and is currently in its second phase, aiming to integrate resource management processes that increase the efficiency of natural resource use, transforming infrastructural systems and planning practice to reduce CO_2 emissions and waste generation. The approach is based on the untapped inter-dependencies between the sectors (rather than understanding these in an isolated single-purpose, single-sector linear way).

The article provides a brief overview of the different nexus approaches and presents findings from the three case studies; it provides a literature review and relevant policy and planning recommendations.

The author expects that the Urban Nexus approach will enable a closer link between the principles of a Circular Economy and urban planning. The objective of the EWFW Nexus project is therefore to provide an informed framework for determining trade-offs and synergies to meet future demand, while increasing urban resilience and resource efficiency, without compromising safeguards for the environmental protection.

The article ends by asking for more research into the impact of urban development decisions on the consumption of our planet's natural resources. One conclusion is that the Resource Nexus is a time issue and there are clear overlaps with the concept of the Circular Economy.

1. Introduction

Continuous urbanisation, raising consumption, system inefficiencies due to inadequate and underdeveloped infrastructure, severe shortages of affordable housing, dysfunctional land and housing markets leading to informal settlements, transportation and mobility challenges, socio-economic issues and environmental degradation present some of the greatest challenges to resource efficiency and the sustainable management of natural resources that must be addressed. This places increased pressure on water supply and sanitation, energy supply and efficiency, waste recycling and resource recovery, land use and food security in particular. The interdependence of the four sectors points towards the urgency of better integrated systems thinking and the advantages of a circular economy approach to better acknowledge their interconnectedness (this challenge was specifically highlighted at the Rio +20 outcomes as well as in the 2030 Agenda for Sustainable Development; UN, 2016).

The challenges of urbanisation in the Southeast-Asian region are driven by climate change, shifts in demography and wasteful consumption behaviour. By 2050 the urban population in the Southeast-Asian cities is expected to grow by 44 million people every year (GIZ, 2015). However, the environment's capacity to support human needs (eg. the ever rising need for water, food and energy) is decreasing as a result of human actions, such as excessive urbanisation, alteration to

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land cover and population growth – leading to escalating energy and food prices. As a consequence, the environment's ability to deliver the essential ecosystem services necessary to support the survival of future generations is being undermined (Folke, 2006; IPCC, 2015; Potschin, Kretsch, & Haines-Young, 2016).

Urbanisation is the catalyst for many of the mentioned challenges. The sprawling growth of urban areas to accommodate the increasing number of people continues to convert (often informally and in an uncoordinated manner) productive natural and agricultural land into urbanised areas (Arezki, Deininger, & Selod, 2015). The rising demand for more urban space and the desire for higher quality of life coincides with growing consumption levels, increasing vulnerability to climate change impacts and declining investment in urban development and public space, all contributing to lower urban resilience. In addition, urban design, planning and management still happen along sectoral lines (in 'silos'), rather than as an integrated process, meaning municipalities in the Southeast-Asian region in particular have been unable to utilise the potential synergies across the Energy-Food-Water-Waste (EWFW) sectors or exploit the benefits of better integrated resource management.

Emphasising the practical potential of the EWFW Nexus project, this article reports on the Southeast-Asian Nexus project, introduces three case studies with lessons learnt, and looks ahead to the future.

1.1. Why is an Urban Nexus necessary, and what is it aiming for?

When land is converted through the process of urban development, the landscape is intensely transformed and precipitation systems, hydrological cycles, productivity of the ecosystem, energy balance and local climates are all disrupted and modified (Alberti, 2005; Foley et al., 2011). While cities currently use merely 2% of worldwide land cover (Scheider, Friedl, & Potere, 2009: 182), resource availability constraints and climate change create challenges for the provision of healthy food, essential energy and clean water supply for a growing population.

The term *Urban Nexus* refers to linkages, interconnectivity and interdependencies in urban systems (energy, water and food and material provisioning systems) and to the need for integrated holistic approaches across these sectors (Bazilian et al., 2011). It describes the key interactions between parts of a system or systems. The Nexus is aiming to integrate resource management processes that increase the efficiency of natural resource use and infrastructural systems, transform planning practice and reduce CO_2 emissions and waste generation. The approach is based on the untapped inter-dependencies between the sectors; for instance, looking holistically at the energy and water system as part of a multi-dimensional network of urban systems.

More and more urban experts agree that the currently used systems of food, water and energy provision and waste treatment for material recovery are on an unsustainable course (Bringezu and Bleischwitz, 2009). Policy and decision makers are concerned that climate change impacts, an overuse of land, increasing inequality and other urban challenges threaten our food, water and energy security and place pressure on future cities globally, particularly in the Southeast-Asian region (even the P.R. of China has recently changed its GDP-driven approach to growth towards a more sustainable model). Moreover, with targets to cut greenhouse gas emissions, stakeholders from civil society, industry and government are looking for support and guidance for 'good' decision-making in urban design and development.

The *Circular Economy* is "an economy which balances economic development with environmental and resources protection. It puts emphasis on the most efficient use and recycling of resources, and environmental protection. A Circular Economy features low consumption of energy, low emission of pollutants and high efficiency; it involves applying cleaner production processes in companies, eco-industrial park development and integrated resource-based planning for development in industry, agriculture and urban areas" (UN EP, 2013, pp. 16–18).

In contrast to an unsustainable linear economy, a Circular Economy is restorative and regenerative by design and can be seen as a practical solution to the emerging resource crunch which has resulted in growing tensions around geopolitics and supply risks, contributing to volatile and insecure conditions. The circular economy can help to stabilise these issues by decoupling economic and urban growth from resource consumption. Key principles of the Circular Economy include: to preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows, to optimise resource yields by designing for remanufacturing, refurbishing and recycling to keep materials and components circulating and contributing to the economy, and to foster system effectiveness by revealing and designing out negative externalities (Ellen MacArthur Foundation, 2014).

There are clear overlaps in the Resource Nexus and in the concept of Circular Economy. The *decoupling* concept is key to the circular economy and urban metabolism concepts (as outlined in the *Hannover Principles* by McDonough & Braungart, 1992, which led to the *Cradle-to-Cradle* concept). An attempt to decouple growth from the use of resources was successfully initiated in Curitiba (Brazil) in the 1990–2000s: Community-level decoupling is achieved through the exchange of recyclable waste for bus vouchers and fresh local produce, such as locally grown vegetables. Curitiba's Bus Rapid Transit (BRT) is a lower cost alternative to rail transit. 90% of Curitiba's residents are involved in daily recycling activities of their waste and achieve around a 70% recycling rate. This highly successful initiative creates a strong link between integrated public transport, waste recycling and job creation (empowerment of unemployed people).

The 3 key concepts (resource nexus, circular economy and decoupling) are not exactly the same – each has another focus – however, they have all resource efficiency of urban systems at their core. The multi-scale EWFW Nexus approach aims to introduce integrated urban planning and management processes that will increase the efficiency of natural resource use, reduce emissions and waste and as a result contribute substantially to the resilience of cities and their regions. The importance of such an integrated approach has frequently been acknowledged and there is now increasing recognition of the dynamic interplay of resources and their supply systems in the urban context, such as the close interconnection that energy, water, food and material flows could provide as an opportunity for a 'policy nexus' to better integrate planning and resource management within and across urban boundaries, sectors and jurisdictions that can be translated into tangible, handbook-like insights for cities and regions elsewhere. (Daher & Mohtar, 2015).

The author suggests to add the 'Waste/Material Flow' component to the common water-food-energy nexus domains, as the embodied energy and water contained in non-recovered materials pose a significant factor. For instance, biomass generation provides renewable energy, while nutrient cycling and urban farming in cities improves food security, rainfall catchment allows for aquifers recharge, and the remanufacturing of waste material recovers the embodied energy and helps to avoid the further depletion of scarce or virgin materials. The addition of material flows in the Nexus assessment has also been supported by the pivotal UN EP report (2013), Chapter 4: "Urban material flows in cities in the developed and developing world". Therefore, the question is: how can the Nexus concept be actively combined to close the loop and enable a resource-efficient city?

1.2. The need for integration: the resource challenge of our urban systems

The effectiveness of the use of water and energy resources and the successful recovery of materials/waste is still limited and widely determined by the fragmentation of systems, availability of technology and by the type of resource management.

The *Urban Nexus* is frequently described as the interrelated complex system where food, water, energy and waste treatment systems intersect (Gold & Bass, 2010). The EWFW Nexus outlines an approach to the

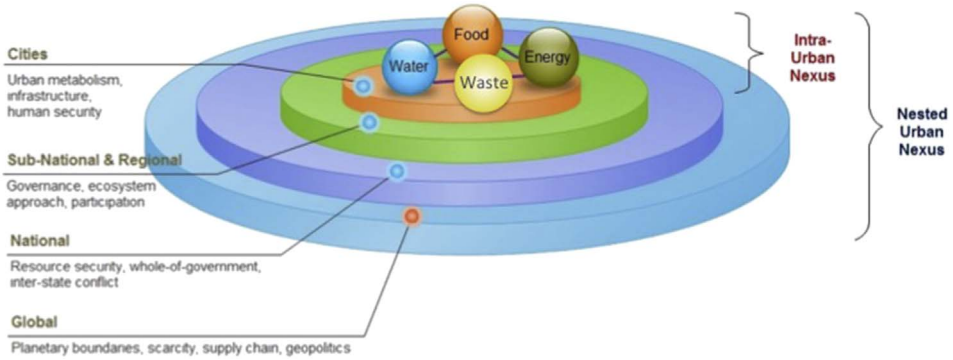

Fig. 1. Intra and nested perspectives of the Urban EWFW Nexus (2015, p. 70).

design of sustainable urban development solutions where the systems are integrated, providing benefits to each other. However, the urban planning and transformation has so far not paid adequate attention to the resilience of city systems and appears poorly prepared to face adaptation and mitigation challenges (Davoudi & Porter, 2012; Davoudi, 2014).

Typically, options for solving problems facing the food, water, energy or waste sectors are approached in isolation and in piece-meal planning, eg. exploring how to meet water needs, whilst overlooking the implications for energy consumption, or setting targets to change land-use and ignoring knock-on impacts for agriculture. This 'silo' mind-set does not allow important interconnections between these systems and explore the potential benefits or trade-offs.

The proposed EWFW Nexus recognises the linkages and aims to better respond to the need for integrated policies and implementation mechanisms with systems optimisation through an approach to counter silo-thinking between the urban sectors, transforming the inefficient system and moving away from out-dated single-purpose solutions. The following Fig. 1 illustrates the intra and nested relationships of the urban EWFW Nexus.

1.3. A brief literature review of the Energy-Water-Food-Waste Nexus thinking

Over the last decade, the Water-Energy-Food (WEF) nexus concept has emerged as an increasingly prominent global policy, governance and research field, with numerous articles published to shed some light on the interdependencies of the domains.

It is frequently argued that out-dated urban governance and management practices, in which resources are managed in isolation by their respective sectoral departments, have resulted in wasteful fragmentation and disconnect of infrastructure and governance mechanisms at the city and metropolitan level. In this context, the Nexus concept suggests to move from mono-sectoral planning and a fragmented infrastructure system towards more integrated resource cycles (Brandi, Richerzhagen, & Stepping, 2014, pp. 297–310; Granit et al., 2012; Gu, Teng, & Wang, 2014; Howells et al., 2013; Hussey & Pittock, 2012; Mohtar, 2016; Siddiqi & Anadon, 2011).

To sustainably govern the rural-urban linkages and resource interdependencies, it is increasingly recognized that an integrated approach to urban development and resource management is essential, both across sectors and across scales (Bennett, Cassin, & Carroll, 2016; Lehmann, 2010). Strategies such as optimising supply chains and establishing cascades and cycles of resources between systems have been successfully tested by some few 'front-runner cities' and are now ready for implementation (see the discussed cases) (European Commission, 2014; 2015, p. 70).

Over the last ten years, the importance of the energy–water nexus has been recognized by a number of international institutions—such as the United Nations, the World Business Council for Sustainable Development, the World Economic Forum (to name a few), and individual national governments and multinational corporations—and has been featured prominently in discussions about the concept of a green, circular economy and a resource-efficient city (Decker, Elliott, & Smith, 2010; Hoff, 2011).

Bizikova, Roy, Swanson, Venema, and McCandless (2013) have developed a practical planning and decision-support framework for landscape investment and risk management. The work confirmed that water, energy and food securities are interdependent and not easily disentangled. The researchers also found that any strategy that 'focuses on one part of the nexus without considering its interconnections risks serious unintended consequences' (2013: 1). They found that recent reviews (such as Allan, Keulertz, & Woertz, 2012; Keulertz, Sowers, Woertz, & Mohtar, 2016) have emphasized that the critical asset sought in the land acquisition process is usually water because it is instrumental to higher land productivity and a prerequisite for urbanisation and agriculture.

Several authors argue that the nexus approach should not be limited to the three-way water-food-energy security concept but could also include other concerns such as land, material flows, minerals and climate change (UN ESCAP, 2013).

Berkes, Colding, and et al (2003) have extensively researched urban resilience and its complex relationship to social-ecological systems by drawing on expertise in ecology, ecological economics and political and social science to understand how human communities respond and adapt to change in their natural resources and systems. They found that such research requires bridging disciplines, political boundaries, and temporal and spatial scales. Karnib (2017) developed a quantitative assessment framework of the water-energy-food nexus that allows integrated assessment by considering all the WEF inter-sectoral linkages and competing demand for resources to evaluate future development scenarios.

The Nexus has had many different names, more recently with *Food Security* being mentioned first. In 2008, the World Economic Forum (WEF) commenced to explore nexus concepts and published a series of relevant papers on the topic (Allan, 2003; Waughray, 2011). The WEF considered the water-food-trade sub-nexus and the energy-climate change sub-nexus as essential to be integrated into a grand nexus scheme; however, at this time the work failed to provide an accessible framework that identified the key issues and stakeholders in the important private-sector supply chains and waste management practice (Allan & Matthews, 2016; Andrade et al., 2011).

Bulkeley and Betsill found that the implementation of sustainable and resource-efficient cities is mainly shaped by forms of policy and governance which stretch across geographical scales and beyond the boundary of the urban (2005). In consequence, Allouche, Middleton, and Gyawal (2014) asked if the nexus debate masks a bigger debate on resource inequality and access. They promote a mix of large-scale and small-scale systems and note: "Responding to the emerging WEF nexus discourse, we seek to introduce a more dynamic perspective to water, energy and food security, and argue that a shift in governance is required towards also incorporating solutions where the limits to control

are acknowledged" (2015; 1). They also argue that while it is difficult to disagree with a vision of integration between the systems there was some consensus about what exactly it might mean in reality. While some consider the nexus approach and framing to be too restrictive (eg. excluding climate change), other actors see it as linked to green economy or emphasise the value chain management. Albrechts (2010) pointed out the changing role of planners and that it is only by working backwards (reverse thinking, also called 'backcasting') is urban planning able to open up new perspectives and take other directions.

Hernandez (2017) points out that a new web-based Nexus platform or tool 'will be useful to understand how the water-energy-food systems benefit from and impact on ecosystem services over their entire life cycles at multiple spatial scales. Such a tool does not yet currently exist.

A number of published nexus frameworks, including those by Hoff (2011), Rasul (2014), the World Economic Forum (2011) and the Stockholm Environment Institute (2012), demonstrates varying definitions of the relationships between the energy-water-food-material flow elements and the range of potential responses within the nexus. (Bizikova et al. (2013): 7) noted that the future challenges in water, energy and food security indicate that any WEF nexus needs to be integrated and addressed in tandem to fully understand the nature of the relationships among the elements (the four domains or sectors) and the consequences of their changes and resulting impacts in other sectors.

Daher and Mohtar (2015) described in 'The Ultimate Nexus' how water, energy and food perform together as a main system that forms a nexus, and how the system transformation from silos to Nexus is best approached to achieve better resource management; they launched an online web tool at www.wefnexustolol.org that allows the user to create and test different scenarios with varying self-sufficiencies. The tool's output includes a summary of effecting parameters, including:

- Water requirements (in m3)
- Local energy requirements (in kJ)
- Local carbon emissions (in tons of CO_2)
- Land requirements (in ha)
- Financial requirements (in QAR)
- Energy consumption through import/transport (in kJ)
- Carbon emissions through import (in tons of CO_2)

Stringer et al. (2014) combined the nexus approach with resilience thinking and launched a novel multi-scale framework with the aim to enable a more equitable and just access to resources and resilience outcomes. They hope that applying the framework across different social-ecological systems will enhance the understanding of factors that shape equitable and just outcomes.

Biggs and colleagues (Biggs et al., 2015) have found that the water-energy-food nexus is being promoted as a conceptual tool for achieving sustainable development; however, they criticise that so far, these frameworks for implementing nexus thinking have failed to explicitly or adequately incorporate sustainable livelihoods perspectives.

More recently, Wharton Business School noted that the growing scarcity of resources across the globe already is forcing innovation at forward-looking corporations, "which are increasingly realizing that the inter-related problems of food, energy and water threaten their own sustainability. At the same time, many organizations see a business opportunity in increasing efficiency and reducing waste that could offer a reasonable payoff period" (Wharton and IGEL, 2013). They have already discovered the Nexus as a great future business opportunity.

Based on the brief literature review, the identified research gap leads to the following research questions for this article:

- Should the Urban Nexus approach relate to energy, water, food and waste/material (EWFW) flows, including 'waste/material flows' in what has usually been limited to the energy, water and food sectors?
- Urban life in Southeast-Asian developing cities is changing rapidly. How can the concepts and ideas of the Urban Nexus best be taken up in these cities?

1.4. Considering urban governance and community: the Nexus approach to energy planning

The aim of the Nexus project is to look holistically at activating the sectoral inter-linkages and principles of a resource-efficient city (using the approach of the Circular Economy), by establishing a closer dialogue between national and local governments to identify and remove policy barriers and create new strong partnerships at the local level. It aims to enhance co-operation between different levels of government, municipal administrations (departments) and planning offices, city administrations and across city jurisdictions. In terms of energy planning, the inter-linkages must be better researched. We need to ask: what are the implications of biomass harvesting to generate energy for other essential ecosystem services and how will its impact affect food production and water availability?

With the recent literature in mind, the author expects that the nexus approach will form the groundwork for new future policies and directions, to enhance the synergies across sectors that will extend and impact the future. The unique approach of the Energy-Water-Food-Waste Nexus will guide stakeholders to identify and pursue synergies between sectors, jurisdictions and technical domains to increase system's performance, optimise resource management and services quality at the local level.

The Nexus project is likely to redefine the future tools of urban development. 'Nexus thinking' wants to introduce an approach that addresses the inter-connections and interdependencies of the urban sectors and redefines relevant policy areas, in order to achieve a more efficient and effective use of resource cycles in urban areas. It is essential to the Urban Nexus project to identify the policy barriers that are currently holding back the promotion of integrated resource management in cities and work towards the enabling factors and solutions to removing these barriers. The enabling factors for the Urban Nexus are illustrated in the following Fig. 2. Urban governance and community engagement play an important role in delivering EWFW security. The solution based approach aims to understand the risks, to better engage decision-makers and empower citizen participation, project partners and local leaders.

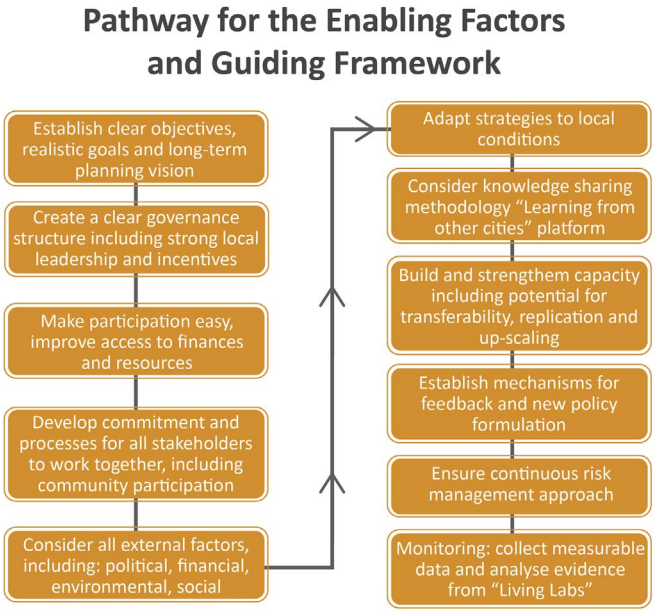

Fig. 2. Flow chart of the enabling factors for activating the EWFW Nexus, as identified by the author (2016).

2. Project context, partners and the target audience

The Urban Nexus project commenced in 2013 and is currently in its second phase (2016–18). It was initiated, and is supported by UN ESCAP, GIZ and ICLEI.

UN-ESCAP is the United Nation's Economic and Social Commission for the Asia-Pacific; it is the regional development arm of the UN for the Asia-Pacific region that promotes regional co-operation and assists countries in building and sustaining shared economic growth by providing assistance to member states in the form of rigorous analysis and peer learning, as well as good development practices.

The GIZ, Deutsche Gesellschaft für Internationale Zusammenarbeit, is the German Government's provider of international cooperation services. As a federal enterprise, the GIZ supports the German Government in achieving its objectives in the field of international cooperation offering services for sustainable urban development, specializing in international development.

ICLEI, the International Council for Local Environmental Initiatives, is an international association of more than 1600 cities, towns and regions, including local governments and national and regional local government organizations that have made a commitment to sustainable development.

Twelve cities in seven Asia-Pacific countries participated in Phase I (which ran from 2013 to 2015). The participating countries include China, India, Indonesia, Mongolia, the Philippines, Thailand and Vietnam. During this phase, the project assisted selected front-runner cities in identifying opportunities for initiating the Nexus approach, to develop and implement concrete project ideas and establish a close dialogue between national and local governments.

The main focus of Phase II (from 2016 to 2018) is in developing a guiding conceptual framework to facilitate more cities to participate and to link the Urban Nexus to the United Nation's global agenda: 'The New Urban Agenda' (UN, 2016). It has been recognised as essential to the future growth of the Urban Nexus to overcome policy barriers that exist in some countries. Therefore, Phase II mainly aims to assist cities and relevant stakeholders in mainstreaming and replicating the Nexus approach as a national initiative, implementing the principles of the circular economy (See: Fig. 4).

2.1. From silos to Nexus: three selected cases, pilot projects that have put the Nexus approach in practice

Some of the results from researching the Nexus can already be seen, for example, in new technologies that are dramatically reducing the amount of energy needed to create fresh water from salt water, helping to make better use of both of those resources. Practically-oriented Nexus pilot projects include the following three cases ('Living Labs') that are presented here, to demonstrate how the Nexus approach has positively impacted in Southeast-Asian cities:

Case 1. Nashik, India – Energy, land and water resources: designing an integrated local production system.

Nashik is the fourth largest city in Maharashtra with a total population of over 1,5 million people (2013). Nashik is an important agricultural hub in the state, supplying vegetables and fruits to Mumbai and the rest of the world. The Urban Nexus pilot project in Nashik focused on the efficient management and optimized utilisation of energy and groundwater to limit the impacts of constrained resources on farmers. As an agro-intensive hub, Nashik consumes large amounts of pumped water for agriculture and irrigation, and the intensive groundwater pumping has led to a dramatically decreased water table and increased energy consumption.

Traditionally, the three sectors of the Nashik Urban Nexus – water, energy and agriculture (food) have worked in isolation. This fragmented approach has led to major inefficiencies (Vogt, Schlenk, Horne, & Gügel, 2014). The Nashik Municipal Corporation adopted the Urban Nexus approach to improve resource productivity at the local and regional level and to enhance the city's resource management. Co-creation with local citizens and engagement with community stakeholders was part of the process from the very beginning. Regular workshops in Nashik allowed for participatory planning which was not used previously.

Fig. 3. Demonstration of high-efficiency pumps to local farmers, Nashik (India) (GIZ, 2014).

Finally, four interlinked pilot projects were implemented in the Nashik Makhmalabad area, consisting of an evaluation of water pumps in the area followed by training and awareness-raising among farmers on the most appropriate selection of pumps, their operation and maintenance; and the economic gains from energy efficiency resulting in lower utility bills. The importance of groundwater recharge and rainwater harvesting was brought to the attention of the local farmers; previously, they depended on groundwater due to a lack incentives of alternatives, highly subsidised electricity and use of inefficient pumps. Nashik Municipal Corporation (NMC), along with the Groundwater Survey and Development Agency, suggested to create potential groundwater recharging structures in the city. Subsequently, NMC undertook a study for the entire city and identified four potential sites (See Fig. 3).

The implementation of the Urban Nexus approach resulted in an interlinked systemic approach including the installation of energy-efficient pumps to reduce electricity consumption, regular groundwater recharging to maintain the water table, and the development of biogas to reduce the dependence on fossil fuels and inefficient energy inputs. The project implementation fed into the larger goal of promoting urban and peri-urban agriculture in Nashik to meet food security issues along with the minimization of required resource inputs such as energy, water and fertilizer.

The Urban Nexus approach led to increased positive interaction between all concerned stakeholders and a transparent and well-informed decision making process, with participation from all relevant city departments in regard to future activities. Energy efficiency was improved by replacing the inefficient pumps with more efficient right-sized pumps and the installation of low-friction valves and piping. Resource efficiency was met through promoting the revival of non-functional biogas plants. Awareness was raised among students and within the community about practical applications of resource efficiency and organic farming, and community ownership became an important aspect of the project. Significant energy savings (around 20 per cent) and reduction in water usage are reported.

Case 2. Naga, The Philippines - Land use management, housing, waste water and energy: a systems' approach.

Naga City in the Philippines has an estimated population of around

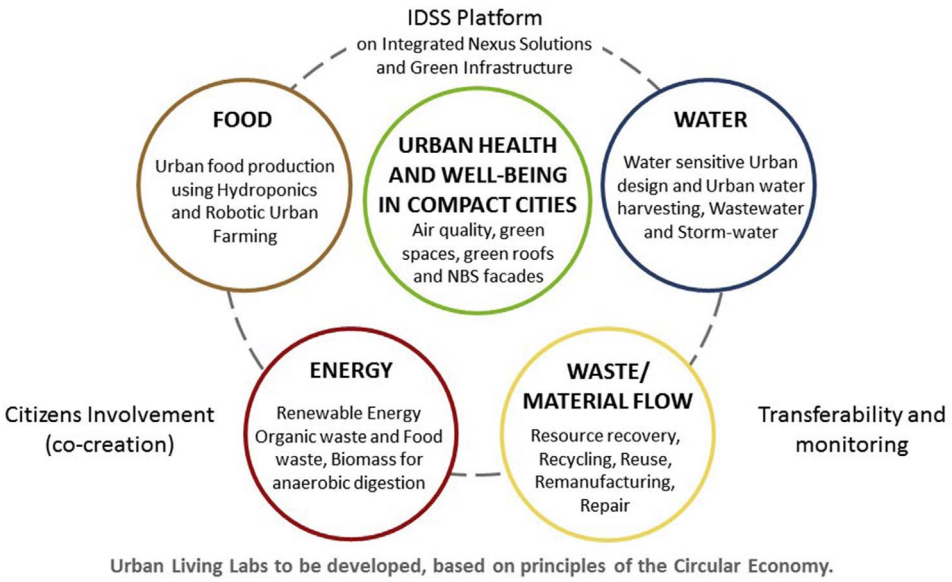

Fig. 4. The Urban Nexus thinking is central to health and well-being in cities. To holistically transform the urban systems, waste/material flows must be part of the approach (by the author, 2017).

200,000 people (2015) Naga City's rapid development as a bustling hub of economic activities threatens its environment and protection of natural resources. The changing climate also adds challenges through extreme weather conditions, urban flooding, and shrinking agricultural yield and energy shortages.

The city government has been met with the task of meeting rising demand for new residential areas as the population continues to increase. The planning and implementation of cost-efficient housing schemes encompasses roads, energy systems, water, wastewater treatment, storm water drainage and solid waste management, giving ample opportunity to apply the Urban Nexus approach within the project. As a first step, a close partnership was formed between different sectors and levels of local government. At the moment, septic tanks and a constructed wetland are used to treat the slaughterhouse's effluent. However, this causes a strong smell in the neighbourhood, affecting people's health. On the other hand, the penitentiary's effluent runs off directly into a nearby creek, thereby polluting the environment and groundwater. No sewer facility network currently exists in the city (GIZ Case study report 2015, p. 70).

A new public housing project in Barangay Del Rosario, commissioned by the city government, includes an innovative wastewater treatment plant, which allows the conversion of wastewater (black water) into renewable energy in the form of biogas and organic fertilizer production. The new plant will treat wastewater sourced from the nearby slaughterhouse, district jail, housing estate and a planned high school. This form of integrated resource management is a closed-loop system that is not only environmentally friendly, but is practical, efficient and can even become economical when applied at a larger scale. One central septic tank was installed, resulting in economic savings, and some changes were introduced such as making the foundations more earthquake resistant, reducing unnecessary structural elements and adding reinforcements to protect the roof for the typhoon season. Using the Urban Nexus approach, the new wastewater treatment system demonstrates the technical feasibility and cost-benefits arising from the production of energy from wastewater in the form of biogas and the reuse of treated wastewater for irrigation in agriculture; again, significant energy savings (reduction of fossil fuel for energy generation by over 20 per cent) and reduction in water-based diseases are reported. It has the potential to become an exemplary implementation of the Nexus approach (Mohr & Renz, 2014).

Case 3. Pekanbaru, Indonesia - Solid waste and energy: thinking about the waste resource differently.

Pekanbaru is the capital of Riau Province on the island of Sumatra; with a population of over a million people (2016) it is Sumatra's fifth largest municipality. The City of Pekanbaru generates around 700 tonnes of solid waste each day, which is disposed of at a local landfill in the Rumbai District. This landfill has been operating for over twenty years and is expected to run out of available space in less than five years. The landfill has pipes installed to release methane gas to prevent explosions, but no methane gas is collected. There is also a simple leachate treatment system conveying the leachate by gravity through the drainage system into the leachate treatment ponds.

The municipality is in the process of purchasing land for a new landfill close-by, but also looking to learn from the experiences of a privately run waste-to-energy plant in the Bantan Sanitary Landfill in Chiangmai (Thailand), which generates profit from feeding electricity into the grid of the provincial electricity authority. Pekanbaru urgently needs to find solutions for better landfill management and how to make use of the landfill methane gas and biogas from leachate treatment; the project entails the improved management of the existing and future sanitary landfill, as well as installation of an efficient methane-gas collection and energy production system.

A major component of the project was awareness rising and the engagement of local residents in the co-development of the project. Participatory planning led to a strong identification of the local community with the project's aims and outcomes.

In Indonesia, waste-to-energy plants have become a favoured way to reduce the burden of the growing waste generation, while meeting the needs for reliable energy supply. A series of decentralised waste recycling centres have been founded that manage a large proportion of the municipal waste and created new jobs for locals. The resource recovery rate and diversion from landfill rate has been increased to over 65 per cent. In addition, the collection of methane gas provides an opportunity to generate income through selling electricity as well as reducing the gasoline expenditure by fuelling trucks with compressed biogas. The municipality has now the choice of either producing biogas or electricity. Applying the ‘Sustainable Sanitary Landfill to Energy System’ model to the new landfill will enable the city to protect the environment, produce energy and other valuable products from waste, as well as achieving a sustainable sanitary landfill solution.

2.2. The key lessons learnt from the three cases

The main points learnt from the three cases are:

Table 1
The elements of the EWFW Nexus (by the author, 2017; after: Bizikova et al., IISD 2013).

Energy security	- Stable and reliable energy supply relative to demand - Availability of energy supply from renewables - Supply sufficient to satisfy demand at given price
Water security	- Access to clean water - Water safety - Water affordability
Food security	- Production, distribution and availability of food - Affordable access to healthy food - Utilisation of food: nutritional value, social value and food safety - Food stability over time
Material flows and waste recovery	- Resource recovery of waste materials - Affordable recycling, reuse, repair and recovery - Avoidance of material waste and the minimisation of waste - Doing more with less materials, because materials are finite

- Beyond helping to improve resource-efficiency, it is essential to put a clear and reliable governance structure in place that ensures the longevity of the initiatives. This is supported by co-development with local stakeholders and the engagement of community groups to allow for participation and empowerment with agreed feedback mechanisms.
- The specific actions optimised different technological solutions that were integrated in the planning procedures using the Nexus approach.
- To be successful and ensure impact, all three cases used a local and decentralised systems approach, including the relevant waste/material flow sector as part of the approach (see Table 1).

3. Relevance of the EWFW Nexus to the transition of urban systems

The three presented cases in Southeast-Asia illustrate how the Urban Nexus supports the integration of resource management processes that both increase the efficiency of natural resource use and reduce the generation of waste by looking at energy in an integrated (not isolated) way. In future, it is envisaged that new infrastructure for larger urban populations will allow for more decentralised systems that further improve the resource-efficiency of cities while dramatically reducing their resource consumption. Moving away from conventional centralised systems to a decentralised scale of operation, the Nexus will serve as a viable guideline for the better integration of decentralised energy infrastructure into urban form (Table 2 gives an overview of the expected results from Nexus integration).

The urban energy system is understood as part of a network of urban systems that require transformation. Decentralised energy and water systems have increasingly been integrated into buildings and districts, and solar PV modules (in combination with battery storage systems) have been enabling renewable energy to be used locally, contributing to the decarbonisation of cities and turning clusters of buildings into 'powerstations' that generate at least half of their own energy demand at the point of consumption (Lehmann, 2015). The combination of building-integrated photovoltaic (PV) panels with battery storage systems allows buildings to produce and store their own energy or export their surplus energy, so that the buildings become independent from the energy grid (which is particularly helpful during peak energy demand periods).

Centralised water treatment facilities, power-stations and waste landfills are still reminiscent of the systems introduced during the industrial era, but are now being replaced by new infrastructure for district-scale technologies with decentralised energy, water and waste management solutions. These new district scale technologies are often owned and operated by the utility companies, community cooperatives, housing associations or local government. It allows districts to reduce their carbon emissions, their energy load (demand) on the electricity grid, and even become 'surplus districts' that can generate more energy than needed and feed energy back into the grid. Decentralised systems facilitate the integration of district-wide technologies including micro wind turbines, biomass and geothermal power (Droege, 2008).

Importantly, the Urban Nexus approach facilitates the energy transition away from the fossil and nuclear paradigm to renewables and decentralised systems – as well as the minimisation of resource use. However, in developing countries, development promoting the prospect of reducing energy use in an already energy-impoverished context would be highly unattractive. Instead, the deployment of renewable energy technologies must be accelerated and subsidised, to ensure more people can benefit from the life-changing impact of reliable energy supply, clean water, healthy food and recycling of waste. The motto frequently heard is: 'From no-energy to renewable-energy!', meaning that there is a particular opportunity in developing countries to short-cut the technology deployment straight into low-to-no carbon technologies instead of repeating the roll-out of outdated fossil-fuel technologies (eg. the uptake of the mobile phone in Africa and Asia is a good example for this and has been impressive; mobile phones enable new jobs and are playing a key role, giving small farmers instant access to information on better farming methods and markets). Here, the Nexus could become a powerful vision of restricting fossil energy use in favour of an abundance in renewable energy supplies, helping to envisage a future powered by 100% renewable energy (Droege, 2008; Scheer, 2006).

It is likely that conventional electricity markets for the fossil-fuel age and traditional fossil-fuel based utility models are coming to an end. Renewable energy generated from wind, solar, biomass and hydro are disrupting the century-old model of providing electricity from centralised coal-burning powerstations, introducing decentralised systems – suggesting that the age of centrally generated electricity from fossil fuels is coming to an end. Over the last decade, the cost of generating renewable energy have significantly come down, particularly for wind energy, which is now very competitive to burning coal. Innovations in smart electricity grid optimisation, new storage technology and smart-home management systems is further accelerating the take-up of decentralised systems using renewables. With redesigned electricity grids (supported by big data), smart enough to allow for renewable energy to feed-in and with increased storage capacity built in, the necessary infrastructure to decarbonise the energy supply has become affordable and is now introduced in more and more cities (especially if one calculates the costs for building and operating a plant over its lifetime). However, there is still a long way to go: in 2015, renewable energy sources accounted for only 7% of electricity generated worldwide. Over 80% of the world's energy is still generated by old-style CO_2-emitting fossil fuels (IEA, 2017).

The good news is that capacity in solar power is likely to continue to increase despite a drop in investment and subsidies in solar power (eg. a reduced feed-in tariff). This is mainly due to improved PV-cell efficiency; efficiency further brings down the cost of solar-generated electricity. In solar-rich Abu Dhabi in 2016, for instance, the cost of solar generated electricity has been as low as Euro 0,03 per kW/h - much less than electricity from any coal and gas-powered generators (Diermann, 2017).

3.1. Introducing Nexus thinking in developing cities: some of the dilemmas that emerged in the cases and how these were resolved

Integrating renewable energy sources and introducing the Nexus thinking in developing countries was not always as straight forward as it might appear. At the outset, the process of engaging the Urban Nexus partners in the participating cities posed some significant challenges.

Table 2
The results from the implementation of the EWFW Nexus research project, indicating the trade-offs between improved health and environmental benefits (by the author, 2017).

Impacts	Expected results from EWFW Nexus integration
Regenerated neighbourhoods and derelict areas	Deprived and derelict neighbourhoods receive a boost from implementation of the Nexus and are regenerated socially and environmentally; active citizenship is empowered and strengthened, the social fabric is enhanced. Empowerment of residents; reduced crime and vandalism due to improved attractiveness of the area.
Improved health and well-being	Health risks, especially to the elderly and children due to urban heat, are reduced, and a comfortable ambient temperature is reinstated. Energy-efficient cooling through plants.
Enhanced inclusiveness of public space, reducing social conflict	Improved access to high-quality green spaces (ranging from parks to small pocket or community gardens to green roofs) leads to more integrated planning processes for an ageing population and happier urban residents. Uneven access to public green spaces is avoided. Cultural benefits, including the city's attractiveness and overall satisfaction; as a result, the percentage of citizens involved in greening projects and park maintenance has increased.
Ecological benefits, including reduced risk of urban heat and flooding	Improved climate adaptation (temperature decrease in summer) of urban areas to climate-risks such as urban heat islands or urban flooding is mitigated; the delivery of eco-system services is enhanced and restored. Increased energy demand for cooling is avoided. Flood retention measures include ponds, constructed wetlands and green roofs for an increase in local water retention.
Strengthened urban resilience	Increased resource efficiency: the principles of a circular economy can be adopted towards a more resource-efficient city. Even increase in property values is possible.
Guidance from high-quality research outputs	Scientific peer-reviewed papers, publications and presentations. Open-access databases containing analytics of empirical data.
Policy development impact for governmental officials and practitioners	Capacity building. Policy briefs for participating cities and various digital tailored outcomes available online. Validation of the novel assessment framework of inclusive neighbourhood regeneration and identification of the challenges of the Nexus integration and operation. For the end-user target groups in the Front-Runner Cities who are engaged in the pilot neighbourhoods, they will also be a part of co-creating strategies for inclusive neighbourhood regeneration.

One of the main lessons learnt is: Solutions must be local. Simply trying to transfer techniques that have worked in developed countries has proven problematic. Education and ongoing training and capacity building for local teams is also an essential factor to overcome likely obstacles and facilitate participation by locals. In fact, getting buy-in from locals and advocating for gradual steps are probably essential recommendations for any technology project in developing countries. At first, partners were first sceptical about the innovative technology and this was only overcome by organising site visits and capacity training workshops. Today, each city has a cross-sectoral Nexus Task Force to ensure its success is sustainable.

The integrated approach was repeatedly introduced in a variety of ways such as in Nexus Force Task meetings (a method to bring all stakeholders together to give a taste of 'breaking silos'), official letters to city leaders and reports. Interaction and building trust with the community is of critical importance in order to generate a sense of ownership among the community towards the project, and an understanding of the benefits of the project. Utilizing public procurement and tendering processes boosts innovation and has facilitated the uptake of Urban Nexus solutions.

Training and capacity building is required at all levels to be successful on a larger scale, and can help to guarantee the long-term institutionalisation of such reforms. Raising awareness and incentives for the efficient usage of resources, such as the discussed water pumps in Nashik, can make communities more responsive to challenges. Efficient resource usage depends on the cooperation of all departments that use the given resource or are related to its management. As the Urban Nexus is a new concept to the region, most institutions will have traditionally worked in isolation, without considering repercussions or collaborations with other departments, meaning efforts are needed to change the conventional silo thinking (sectorial management). There is a need to engage all stakeholders in meaningful discussions to assist in making more informed and integrated decisions and management procedures.

Other obstacles included the need for simpler and more robust technology, to withstand the higher user demand and extreme weather conditions. Traditional attitudes towards food, water, energy and waste can also pose implementation obstacles. For instance, changes to food storage methods to reduce post-harvest losses of food can pose a real barrier to increasing efficiency. It's important that sustainable agriculture also increases the incomes of small farmers. In developing countries, food is often not only inadequately distributed but also frequently wasted because of vulnerable storage methods, and inadequate food supply and distribution system from the farm to the city.

With a predicted global population in 2030 reaching 8.5 billion people, there will be a need for 60% more food, 45% more energy and 30% more drinking water supply (IRENA, 2015; IEA, 2012). The United Nations reports by 2025, 1.8 billion people are likely to be living in regions with absolute water scarcity. Food insecurity can be both a cause of civil conflict, and a result of it; food scarcity can easily lead to social unrest. Overall, the impact of climate change will make it more difficult in the developing world to grow crops, raise animals and catch fish (due to droughts and floods, lack of appropriate irrigation and soil moisture, leading to loss of crop yields). This includes the installation of robust irrigation systems that do not drain the drinking water, but replace the amount of used water through rainfall (eg. do not deplete by over-pumping aquifers, which can lead to falling water tables and groundwater depletion).

Increasing the number of new cities participating will ensure the transferability of concepts and be crucial in bringing in new industry partners, which has so far been a weak part of the implementation phase. According to GIZ, the steps for Phase II include:

- Collecting evidence base from case studies,
- Further enhancing the Nexus methodology and inter-linkages,
- Improving capabilities for integrated urban resource management by implementing the principles of the Circular Economy, and
- Identifying a better way to measure growth that is not based on the economic GDP.

4. The conceptual problem with 'decoupling growth' and the Nexus key messages so far

The urban Nexus approach has now been widely accepted as one of the future methods for implementation of the UN's 'New Urban Agenda 2030' (2016), which was developed with an emphasis on such synergies and innovative approaches. It is expected that the conceptual framework of the Urban Nexus will deliver a number of expected benefits (listed in Table 2).

It is widely acknowledged that health and well-being are directly connected with a well-planned and healthy built environment. But much of the economically-driven decision making has not supported the built environment to promote this (eg. think of overdeveloped neighbourhoods such as in Hong Kong or Mumbai). Knowing that the

commonly used GDP-driven (gross domestic product-driven) approach has frequently been at the expense of the ecosystem, better metrics are needed to account for the environmental impact of business decisions. If GDP growth is not a suitable indicator and an outdated measure of 'well-being', would it instead be more appropriate to ‘re-couple’ the goals of human progress with the creation of a healthy environment and urban well-being – ie. measuring human progress by indicators other than just GDP growth? Today, it is recognised as an impediment to sustainable development that most economic policies around the world are still driven by the goal of maximising economic growth through a singular, simplistic increase of the GDP. The increase in economic growth will always mean an increase in the use of resources, which is not infinitely possible (Meadows, Meadows, Randers, & Behrens, 1972).

Combating climate change and adapting the Nexus thinking is linked to the new approach described as ‘green growth’: accepting lower growth rates and in some cases maybe even a lower standard of living. The concept of 'green growth' describes growth where carbon emissions have been decoupled from economic growth. However, there is no real ‘alternative way’ where the economy can continue to grow indefinitely without increasing carbon emissions. While most conventional economists endorse the idea that economic growth can be 'decoupled' from environmental impacts, and that the economy can keep growing without using more resources and exacerbating environmental problems (Meadows et al., 1972; UN EP, 2013) − decoupling may just be a delusion and not a viable solution (Ward, Chiveralls, Fioramonti, Sutton, & Costanza, 2017).

While there is a slow global shift away from coal to generate power (towards natural gas and renewables) and technical improvements in energy efficiency are showing an impact, the recent announcement by the International Energy Agency (IEA, 2017) that ‘CO_2 emissions stay the same for third year despite global economy growing’ doesn't give the full picture and is probably too optimistic. The IEA reports that global emissions from the energy sector were 32.1bn tonnes in 2016, the same as the previous two years, while the economy grew by 3.1%. The IEA put the halt in growth down to growing renewable power generation, switches from coal to natural gas and improvements in energy efficiency but said it is too soon to say whether global emissions have peaked.

An increasing number of researchers argue that ‘decoupling’ means substituting the real problem, eg. where the 'rebound-effect' is eliminating all gains, while any efficiency gains may just prolong economic growth and only look like decoupling for a while. Indeed, there is the danger that we only substitute carbon-intensive energy use with cleaner or carbon-neutral energy solutions, but not really freeing up the economy of its dependence on finite resources. The other danger of delusion stems from the assumption that we frequently shift the carbon emissions to poorer nations, such as moving resource-intensive modes of production overseas and away from the point of consumption. Many goods consumed in Western nations are now manufactured in developing nations, where the environmental impact from manufacturing takes place out of sight and out of mind (and usually unmeasured in its environmental impact). ‘Substitution’ and ‘shifting’ has created an inaccurate picture of carbon emissions where wealthy developed nations have appeared to decouple their GDP from domestic raw material consumption; but as soon as imported materials are included into the calculation, these high-consuming countries observe no real improvements in their resource productivity at all (Ward et al., 2017).

5. Looking ahead: the Urban Nexus and the circular economy – how do we get there?

Overall, the Urban Nexus is still an immature, emerging concept that requires more clarification and testing, even for the developed European cities (Allouche et al., 2014). Future studies of the Nexus will need to include a focus on inequality in resource access, questions of ethical supply chain management and a more practical framing of Nexus thinking: how does water, energy, food and waste generation form an interconnected system of resource flows that directly and indirectly affect one another? Given the array of interests at stake, addressing problems associated with the Nexus will require a multi-dimensional approach. Towards this aim, political, technological and legal innovations must be implemented.

More research is required into the circular economy principles and how to reduce the impact of urban design decisions on the consumption of our planet's natural resources, to identify alternative ways to the current linear “take, make and throw-away” system. The provisioning of food, water and energy services and the management of material flows in urban areas involves infrastructures and resource flows which are heavily dependent on each other and on the natural environment. It is essential to conceptualise these interdependencies through the urban Nexus approach in order to meet overall resilience objectives, whilst addressing the vulnerabilities experienced by urban communities and individuals.

Potential solutions include holding, cleaning and draining water naturally through an integrative and systemic ecological approach combined with sustainable storage solutions and urban drainage (reducing flood risk and providing water supply); urban food production with mixed renewable energy systems through biomass (anaerobic digestion, using food waste and garden clippings; combined with robotic hydroponics for urban farming). EWFW systems are complex and dynamic by their nature. In future, cities will have to better integrate their infrastructure systems through data harvesting and real-time information from the target domains. For cities to get smarter and increase their resource efficiency, their systems must become truly integrated.

It's critical to manage the complex interactions and trade-offs between EWFW systems and the basic ecosystem services that support them. Besides the creation of new businesses (and skilled jobs), the Urban Nexus is likely to strengthen public participation and enhance awareness of citizens in infrastructure planning, and sharing of data and knowledge (city-to-city learning). Increasingly, municipalities will establish city-wide platforms to stimulate innovation and long-term planning goals within the coherent Nexus framework and collaborative governance structures. To introduce the Nexus approach to other cities, it will be essential to allow for:

- Institutional enabling factors: creating a critical mass of organisations seen to be working together,
- Clarifying indicators (local vs global),
- Establishing measurable objectives, criteria and targets to assess inter-relationships and case studies,
- Capacity building: provide access to technical expertise in areas such as policy development and proven practical tools,
- Establishing agreed feedback mechanisms,
- For cities to increase their resource efficiency, their governance systems must become truly integrated.

The results from the presented cases show that Nexus thinking is working. Innovative waste water management concepts have been applied that are directly linked to renewable energy generation, the use of treated waste water for irrigation and treated sludge for organic fertiliser and compost in agriculture. This form of integrated closed-loop resource management allows for synergies between water, energy, food and organic waste (biomass) (Lehmann, 2014a,b).

Further outcomes include: peer-to peer learning that has strengthened the South-South dialogue, resulting in innovative, environmentally friendly and financially feasible solid waste management concepts. A regional Nexus learning platform that has been established, holding regional Nexus workshops twice a year; the platform includes the corresponding national, regional and intermediate level organisations, as well as civil society/community leaders and private-sector participants, international donors and other city networks (GIZ, 2015). As a consequence, decision makers at various levels are now aware of

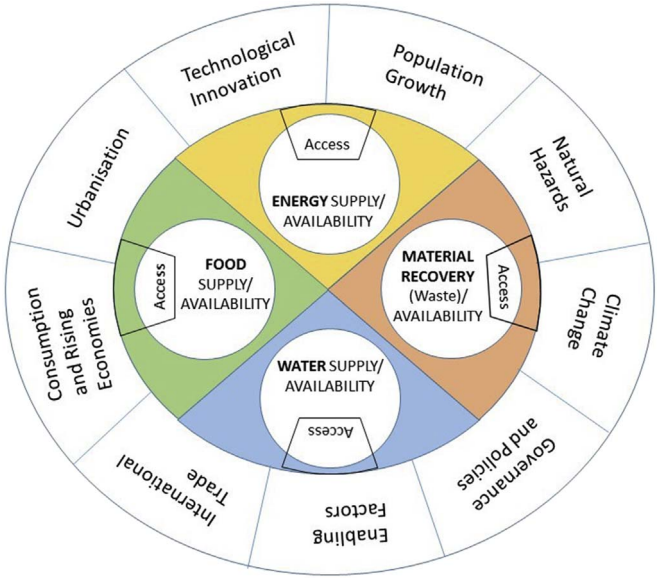

Fig. 5. Developing a conceptual framework for the Energy-Water-Food-Waste Nexus with the effecting parameters, defining the major flows within and between natural and built systems, in regard to the natural supply and human demand (by the author, 2017).

how significant integrated, cross-sectoral resource management, public consultation and private sector involvement are for the creation of resilient cities.

A key factor for the success of the Urban Nexus approach is the proposed methodology for both vertically and horizontally integrated urban governance, building upon existing development strategies and evidence-based, informed decision making, management of trade-offs through integrated urban planning, behavioural change and collaborative decision-making (See Fig. 5). Sustainably managing the resource interdependences will be one of the 21st-century's main challenges and will affect how cities develop over the next decade. There is a critical need to equip decision makers with evidence from research, new tools and increased capacity to address the Nexus challenges, in order to plan ahead for the required transition of our ecological, social and economic systems.

5.1. Conclusion: the expected results from implementing the Urban Nexus

The aim of this article was to firstly report on the literature review and, secondly, to present 3 empirical cases in Southeast-Asian developing cities; and finally, to inform about the future work that should be done in the field.

The quantitative effects and impacts that resulted from these cases will require further study and monitoring over time to better validate the Urban Nexus approach.

One conclusion is that further development of a sustainable, resource efficient and competitive economy will require an accelerated transition to a more circular economic model, with products, processes and business models that are designed to maximise the value and utility of resources while at the same time reducing adverse health and environmental impacts. However, cities are likely to continue to struggle in their transition to implement a full circular economy model, properly stimulate regenerative practices and alter established urban consumption patterns.

Future cities need innovative solutions for closing the loop across the nexus, while reducing material and resource flows across urban processes and stimulating sound management of trade-offs and synergies among sectors. All initiatives for regenerative urban planning should therefore be geographically located close to residual resource streams to stimulate their uptake and integrated in mixed urban neighbourhoods. To address the full range of product lifecycle stages, from production (including design) to consumption, waste management and using secondary raw materials to complement primary raw materials, the focus would need to become more 'circular' by:

- An increased recycling rate for end-of-life materials, to reduce landfill and incineration;
- development of products designed for durability, repair and reuse, with markets based on durability;
- Improved environmental performance of the operations and a better recovery of resources from waste;
- Significantly reduced use of water from freshwater sources, and improved recovery of resources;
- Reduced natural resource consumption in urban and peri-urban areas and environmental footprint of cities as well as enhanced regenerative and productive capacity;
- Increased repair maintenance, reuse (including sharing), remanufacturing and recycling of products and materials, which enhances the urban resilience;
- Exploitation of complex and heterogeneous secondary raw materials deposits ('urban mines').

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ccs.2017.10.003.

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Related web resources

The Nexus Network, ESRC-supported web site (2015), UK: www.thenexusnetwork.org
World Economic Forum: www.wefnexustool.org.