Chapter 5
Circular Approach in Green Planning Towards Sustainable Cities

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Abstract Cities are like organisms, drawing in resources and emitting wastes. In nature, organisms are related to ecosystems characterized by a circular metabolism, so a green planning to move towards sustainable cities needs to adopt a circular approach to the way in which are managed the resources consumed (materials, food, energy, water and land) and the emissions produced (solid waste, airborne and waterborne) in cities and their related territories. Initially, the origins of the theme of circularity are illustrated, in particular, in relation to urban applications (urban metabolism) and territorial (industrial ecology) and current developments, with the analysis of a virtuous example. Thereafter, some possible strategic approaches to favour urban circularity (urban mining, building regeneration) are analysed, highlighting the importance of flow mapping and the creation of exchange platforms. Finally, some methods of assessing environmental impacts are shown to verify the effectiveness of circularity with respect to the objective of sustainability, and examples of benchmarks/targets adopted in some concrete cases experienced are presented.

5.1 Well-Being and Resource Reduction: A Challenge

The ultimate goal of green planning is to guarantee the well-being of the people who live in a city or territory. In Western societies, despite the high levels of access to consumer goods and services, a perception of a reduction in well-being is becoming more widespread. This is due to the deterioration of the quality of the environment in which people live (pollution, stress, social insecurity, etc.). Therefore, people's well-being is not based solely on economic stability, but also on the quality of social relations and on the healthiness and beauty of the environment that surrounds them. In particular, natural capital is a direct source of well-being for people (Bonaiuti 2011): drinking at a high mountain source, being able to swim in a clean sea, contemplating an alpine landscape are already free and available elements of well-being, which

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must not be “produced”, but must, however, be preserved (and not destroyed by the expansion of human activities).

“The environment was considered a sort of inert stage in which the actors, that is the organisms, played the game of natural selection. Now we recognize that the “stage” and the “actors” interact with each other constantly so that not only do organisms relate to the physical environment, but they also change the environment” (Odum 2003).

The pollution we create (heavy metals, chemicals, micro-plastics) enters the water cycle, contaminates the soils and the air and becomes elements that we breathe and eat, also thereby contaminating our organism.

Nature is therefore not simply a place to contemplate, but it is the source of the resources that sustain our life, so the changes that people make to the natural environment also affect their well-being in terms of health (toxicity) and survival (availability of resources, e.g., food due to infertility of contaminated soils).

It must, therefore, be considered that the natural capital is also the necessary basis for all human activities, even urban ones.

5.2 Urban Input and Output Flows

Cities are the expression of mankind’s construction of an “artificial” environment, separate from nature: man is, in fact, a “deficient being” (Gehlen 1988), unfit to survive in the natural environment, so he must construct his conditions of survival through technical acts (building artefacts, building a refuge, building the city, etc.), which become elements of protection and mediation between mankind and nature.

At the same time, man (and his environment, like the city) continues to depend on nature: he needs natural resources to produce artefacts, to produce energy and to feed himself and he needs to be able to remove scrap, solid waste and polluting emissions, which nature is able to re-absorb. Cities are thus totally dependent upon natural ecosystems.

Cities are sustained by input flows of resources from nature (food, water, materials, energy) and output flows of emissions into nature (waste, air and water pollution). These flows lead to a close relationship between the city and its surrounding territory. Urban areas and cities occupy only a small part of the total land area (only 2%). However, although the surface area occupied by the city is relatively small, it is the part which represents the greatest threat to the rest of the land area (Fig. 5.1).

It is possible to identify a relationship between the city and the surrounding area, in terms of flows of resources and waste, in all periods of urban development; where the resource management has not been prudent and the territory has been degraded, civilisations have fallen (Agudelo-Vera et al. 2011). Today the problem is more pronounced: the more cities grow, the greater their dependence upon the surrounding areas. Attacks of robbery against the occupied territory, then lead to the infertility of the soils, to floods due to excessive waterproofing of the land, to water pollution, etc. Thus, it is necessary to establish a balance between the city and its territory.

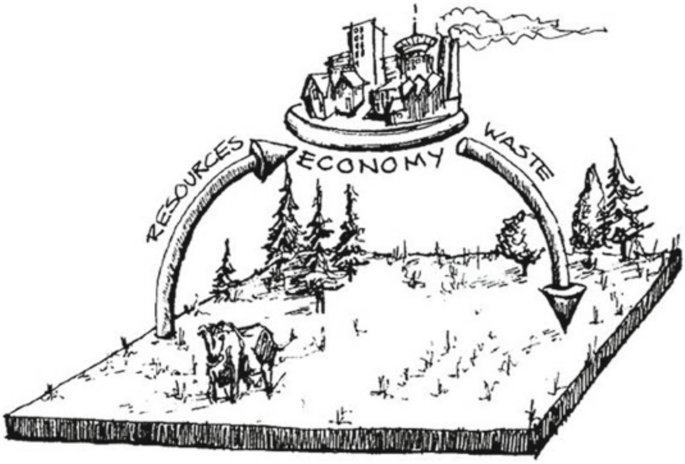

Fig. 5.1 Relationship between man's artificial sphere and the ecosphere: nature "feed" the city with flows of resources in input and assimilate the waste in output, to support the human activities and life. *Source* Rees and Wackernagel (1996)

In addition, cities have direct and indirect impacts on a global scale (e.g., greenhouse effect due to emissions into the air released by cities and their own territories). So it is also necessary to find a balance between the city and the planet globally.

As long as the flows were small, nature was able to regenerate resources and dispose of waste and pollution. But in the last century, the exponential growth of the world's population, per capita consumption, urbanisation processes, industrial production have led to an unsustainable pressure on a planet limited in its resources. "Large-scale urbanization is a profoundly resource-demanding process, to build as well as to run cities (…). We can argue that we no longer live in a *civilization*. We live in a *mobilization*—of people, resources and products" (Girardet 2003). Today the cities, the territory and the entire planet suffer from environmental degradation, land use, scarcity of resources (raw materials, food, water, fuels), air pollution, water pollution, waste disposal (landfill, transboundary shipment of hazardous wastes, groundwater contamination), climate change, biodiversity loss, etc.

So we build cities to survive (as deficient beings), but the cities we build are the major cause of the destruction of natural ecosystems, which support our survival; consequently, we are putting our survival at risk.

In the face of climate change and the damage of anthropization, one talks of implementing strategies of resilience. However, it would be more appropriate to act to prevent changes rather than to act to adapt to devastating changes (living with a polluted sea, between destructive weather events, etc.). Hence, the need to rethink mankind's consumption and emissions on all scales, including the urban one. Currently, consumption and emission rates have become unsustainable, and to conserve the remaining natural capital (now irremediably eroded and deeply polluted), necessary for mankind to survive, it is essential to reverse the trend.

To trigger a reduction in mankind's consumption and emissions, a possible strategy is to extend the life of resources in two ways: extending the life of artefacts and reusing/recycling resources at the end of their useful life (closing the cycle). It is no coincidence that current policies are aimed at promoting the circular economy, which focuses precisely on these two objectives.

When referring to the circular economy, the aspect on which the most attention appears to be focused is end-of-life recycling (waste management), to reduce the transfer to landfills and reduce the withdrawal of new resources from nature (thanks to the availability of recycling resources).

However, the broader objective of the circular economy should in fact be that of the efficient use of resources, thereby reducing the resources necessary to guarantee the essential services for the functioning of mankind's activities and the extension of the useful life of the products in which resources are stored: all this is in order to avoid new waste streams and new withdrawals of resources (which occur also in the recycling activity).

Furthermore, the circular economy is a segment of the broader objective of environmental sustainability, so it is not only a question of using resources efficiently but also of guaranteeing a reduction in overall impacts and a better environment for human well-being (Fig. 5.2).

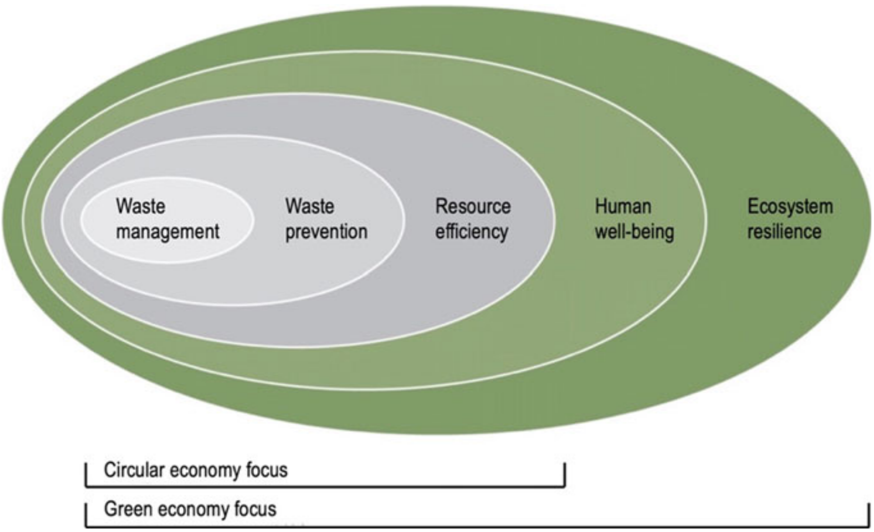

Fig. 5.2 Strategies of circular economy and green economy. *Source* EEA (2015)

5.3 Origins and Developments of Circularity Approach

The circular economy is currently focusing attention on issues that seem new since only now they find expression in political documents and roadmaps and therefore are expressed in concrete actions and virtuous applications. Actually, the themes are not new at all and originate from theories and principles developed as early as the 1960s, in parallel with, and within the reflections on sustainable development, developed in that period.

The first time the Earth was viewed by satellite in 1957, humanity became aware of the limited and fragile nature of the planet and the importance of the presence of man in the modification of the planet. It is precisely from that image that Kenneth Boulding, in his "The Economics of the Coming Spaceship Earth" (1966), recommends a change in the approach of the economy: from an attitude of conquest (cowboy economy), linked to the presumption of an infinite availability of territory and resources, to an attitude of prudent management (spaceman economy), linked to the effective limitation of territory and resources (the Earth as a spaceship). Then, in this context, he proposes the idea of a circular circuit of materials, water and energy (as happens in spaceships), taking into account that on Earth nothing enters except energy from the sun.

In their 1976 research report to the European Commission in Brussels, "The Potential for Substituting Manpower for Energy" (published as a book in 1982 with the title "Jobs of Tomorrow"), Walter R. Stahel and Genevieve Reday-Mulvey introduced the argument of extending the service life of buildings and such goods as cars and highlighted the waste inherent in disposing of old products instead of repairing them. In 1981, Stahel summarized these ideas in his article "The Product-Life Factor" and identified the sale of the use of goods (service) in place of the sale of goods as the sustainable economic model of a closed-loop economy: in this way, the industry adopts the reuse and service-life extension of goods as a business strategy (Fig. 5.3).

Extending product-life reduces the depletion of natural resources and consequently waste and decouples wealth from resource consumption.

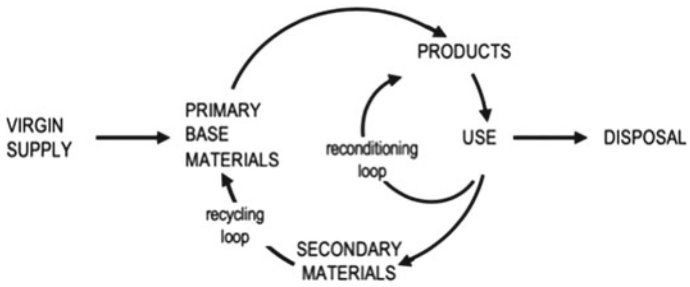

Fig. 5.3 Alternative life cycles of an industrial product (Stahel 1981)

Parallel to these theoretical developments, one can identify declinations of the circularity on the urban and territorial scale already in the 1960s, with urban metabolism and industrial ecology.

5.3.1 Urban Metabolism and Material Flow Analysis

Cities can be assimilated to living organisms. Cities absorb, transform and release various forms of energy and materials, such as food, water, heat and waste. In this, they recall the functioning of biological organisms and natural ecosystems. The set of "internal" chemical–physical energy transformations to these systems necessary for their support is called metabolism.

To manage urban ecosystems, it is necessary to study their metabolism.

In 1885 to create awareness of the massive flows of resources in cities, Geddes used the concept of urban metabolism and established an urban energy and material budget in physical input–output terms (Geddes 1885), but without any immediate follow-up and application.

In 1965, the health engineer, Abel Wolman, revised the concept of urban metabolism proposed by Geddes and developed the first wide-area environmental budgets, estimating the material flows that cross *cities* (Wolman 1965).

Starting from his studies of 1963 on energy flow and nature's metabolism, in 1975, Eugene Pleasants Odum highlighted the importance of urban metabolism and provided some data on the urban material balance (Odum 1975).

Howard Thomas Odum, the younger brother of Eugene, provided fundamental methodological bases for the analysis of energy flows in urban metabolism. In particular, he has developed the analysis of the energy necessary to produce the goods and services of anthropic systems (Emergia; Odum 1983). The energy balances are performed in units of energy on a temporal basis (powers) regulated by the equation: incoming flow rate = outgoing flow rate—consumption flow + stored flow rate. The same type of budget/balance can also be applied to materials.

In the early 1970s, the analysis of material flows through urban ecosystems was also promoted by UNESCO with a programme (Man and Biosphere, MAB) aimed at promoting studies on ecological approaches to urban systems and other human settlements [Unesco 2010].

Since the 1990s, the Material Flow Analysis (MFA) and the Input-Output Analysis (IOA) of anthropic systems have developed above all on a national scale in the USA and Europe (Wernick and Ausubel 1995; Matthews et al. 2000; European Communities and Eurostat 2001), but also on regional and urban scale, as in the case of Vienna (Daxbeck et al. 1997), Stockholm (Burström et al. 1998), Geneva (Faist Emmenegger and Frischknecht 2003), Hamburg, Vienna and Liepzig (Hammer et al. 2003), Paris (Barles 2009). These studies, carried out to understand urban metabolism, have become very important in supporting public sector policies and actions.

The urban ecologist, Herbert Girardet, (1992) has argued that the key lies in cities aiming at a circular "metabolism", where consumption is reduced by implementing efficiencies and where re-use of resources is maximized. Girardet significantly coined the concept and defined the difference between a "circular" and "linear" metabolism.

These scientific reflections and practical applications do not only affect the decisions of government and of the local authorities, but also the activity of designers and urban planners.

Richard Rogers, in his "Cities for a small planet" (1997), emphasizes that cities must be viewed as ecological systems and this assumption must provide information to our approach to designing cities and managing their use of resources. Rogers promotes the transition from a linear metabolism to a circular metabolism, considering it necessary to obtain sustainable cities, and considers it essential to introduce experts in urban ecology into city planning (Fig. 5.4). Rogers points out that the circular attitude must also concern land and buildings. "In cities, we cast off buildings, used land, industrial waste and millions of other damaged, used products directly into the urban environment and its wide hinterland.

Most of this is unnecessary. Careful recycling of land, buildings and waste could make a difference not just to the landscape and viability of both town and country,

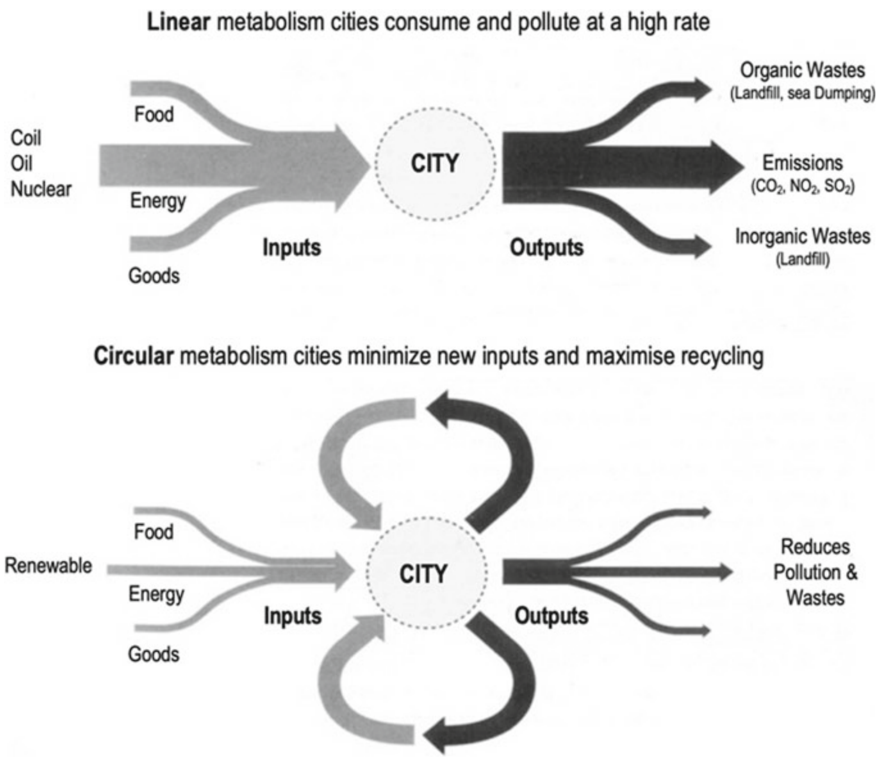

Fig. 5.4 From linear to circular metabolism of cities (Rogers 1997)

but also to our approach to cities in general. With care, buildings can last twice or three times their predicted life" (Rogers and Power 2000).

Tackling the analysis of urban flows in terms of metabolism allows one to move from the end-of-pipe approach, which has characterized the first attention paid to the environment, that is to say mainly controlling the environmental deterioration caused by emissions to water, soil and air, to an approach of prevention. It became understood that it is important to manage not only the outgoing polluting flows but also the incoming flows (consumptions) because decreasing consumption also reduces emissions. Hence, great importance is given to the closure of the cycles.

5.3.2 Industrial Ecology

The city should not be seen as an isolated system, but conceived in its relations with the surrounding land. Therefore, besides studying the flows that cross, enter and leave a city, it is also necessary to extend the analysis to the related territory.

In 1969, McHarg published the book "Design with Nature", in which he argued that cities should be planned as an integral part of natural systems. He proposed to use ecology to understand interactions between people and their environment and to use these as guiding principles for urban planning (McHarg 1969).

At the end of the 1980s, a scientific discipline was born, industrial ecology, which uses the methods of ecology to study material and energy flows in industrial systems. What for one industry is a waste for another can become a resource. The principle is based on the idea of closing the cycles of productive activities, connecting them in a network. This means not only analysing the individual activities but assuring a relationship between them thanks to their territorial proximity.

One of the first examples of industrial ecology is that of Kalundborg, in Denmark, where the waste heat of the thermoelectric plant is recovered and used to supply district heating to the city, the fly ash deriving from the combustion processes of the thermoelectric plant is reused in a cement works, and the washing sludge is reused in a plasterboard plant, etc. (Fig. 5.5).

There are many other examples. City rubbish, which is usually either dumped as landfill or incinerated, both with polluting effects, can be burned by local combined heat and power plants (CHPs) and supply a community's energy needs. Organic waste, which is currently discharged in such high concentrations that it poisons the environment (eutrophication), can instead be recycled to produce biofuel and fertilizers. Grey water can be filtered through natural systems on site and be reused for irrigation of the urban landscape or to restock local aquifers. Other possibilities along similar lines will be apparent to the reader.

This approach can solve not only the resource management but also the disruption of natural cycles, for instance the phosphorus and carbon-cycle, with benefit for the environment. It is not necessarily related only to industries, but can involve urban activities, creating a network with the urban metabolism.

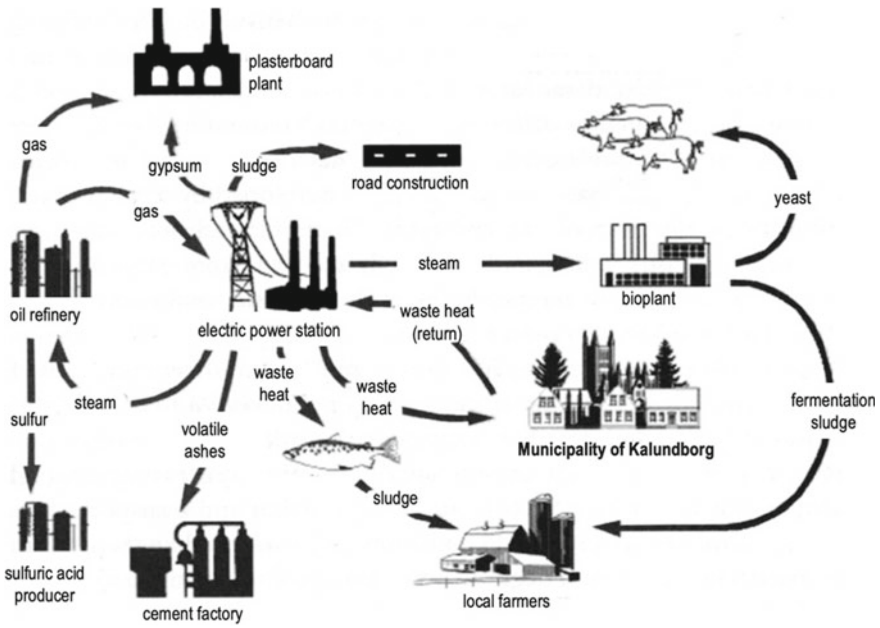

Fig. 5.5 Example of industrial ecology: relationship of waste as food for other industrial processes in Kalundborg (DK), 1989 (Kibert 2005)

5.3.3 The Eco-Towns and the Hammarby Model

Started in the 1980s, the eco-cities or eco-towns movement focuses on redeveloping the industrial centres of large towns and cities through industrial metabolism projects (Prendeville et al. 2018).

There are many new eco-towns which have been built in northern Europe (e.g. Vauban, Amersfoort, Malmö) based on the principles of sustainability. Particularly interesting is the case of Hammarby Sjöstad ("Hammarby Lake City"), in which the principles of industrial ecology were applied during the design of the city, connecting the city to its surrounding territory through a series of entering and exiting flows of resources (thus also taking into account waste and wastewater) (Fig. 5.6).

A first interesting aspect is the application of the circular approach already in the identification of the settlement, as a recovery of an abandoned industrial area. In the early 1990s, Stockholm's City Planning Administration acknowledged that the city's population was growing and would continue to grow into the next century. The 1999 city plan identified several areas across the city for development, most of which had once been industrial sites. Hammarby was developed on an old brownfield site. All contaminated soil was sanitized prior to development.

The most interesting aspects concern the strategies of optimisation of resources and circularities applied to energy, water, waste, in the so-called Hammarby model.

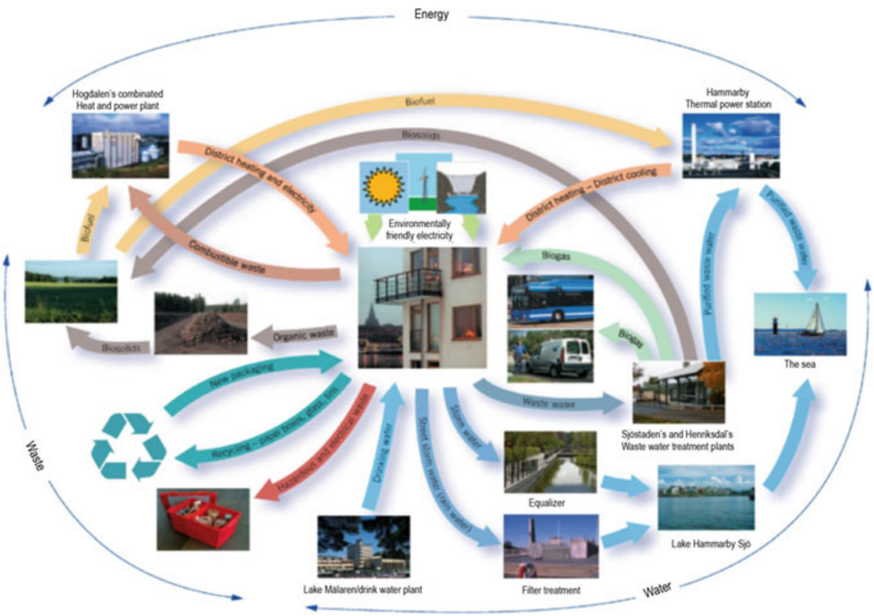

Fig. 5.6 Hammarby model. *Source* Lena Wettrén, Bumling AB, Hammarby Sjöstad Project

Energy self-sufficiency is achieved through energy-saving measures, the use of renewable energy sources (solar collectors, photovoltaic, hydroelectric and wind power plants), the use of bioenergy and incineration of local waste producing both locally generated heat and co-generated electricity (80% of the energy extracted from waste and wastewater). All apartments are connected to the district heating system, and the household waste supplies fuel for the district heating plant.

Separate waste collection takes place via underground channels with a vacuum system and is recycled. That waste which is not recyclable is taken to the waste-to-energy plant. 100% of waste is sorted and only 0.7% of waste goes to landfill, 50% of waste is recovered as energy, 16% of waste is turned into biogas, 33% goes into recycling of materials, and 1% is hazardous waste (Jernberg et al. 2019).

Wastewater is treated locally. The sludge produced by the treatment process is recycled and used for fertilizing farmland and forestry land. The waste releases biogas during processing that is used as fuel for vehicles such as buses, taxis and waste collection trucks, and to heat 1000 homes in the area. Heat is extracted from the treated water in the treatment plant, which is then used for district heating.

The Hammarby model was designed as a project that might be replicated in other cities. Hammarby Sjöstad has become an international example of sustainable urban planning. For example, it has inspired the design of Toronto's Waterfront, London's New Wembley and many cities in China and Thailand.

"Hammarby Sjöstad is a good example not only of focusing on the short-term aspects and obtaining short-term profits but also of investing for the future and increasing revenue. The cost for Hammarby was roughly 5% higher from a purely construction cost perspective, but in the end you get back roughly 25% more property value out on the site over time which shows how real value is created over time". (Henrik Svanqvist, Director of Communities, Skanska).

These experiences, however interesting, are linked to very particular situations, of small-scale intervention, with the ex-novo design of an urban reality (as generally associated with the regeneration of abandoned industrial areas), where it is easy to build relationships and virtuous activities. The intervention on existing cities is much more complex and with consolidated realities that are difficult to modify, where these models struggle to find an application. However, having such a model which demonstrates the advantages of its operation and functionality is a precious stimulus to try to apply it in a widespread manner.

5.3.4 Circular Economy

In the contemporary world, attention to the circular approach has been renewed as a result of the growing need for raw materials (increase in consumption) and to the growth in the costs of supply of raw materials. Finding alternative solutions, therefore, becomes essential to continue supporting the economy. This is why the circular approach is associated with the economy: it is necessary to change the approach of the economy (from linear to circular) to permit further economic development.

It is no coincidence that the productive and economic world then moved before the political world did so. Since 2009, the Ellen Mc Arthur Foundation (a US private foundation) has promoted the circular economy (in all sectors), so as to bring the themes back to the centre of the current debate and above all to favour their adoption at the political level. "A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the "end-of-life" concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models" (Ellen Mc Arthur Foundation 2013).

The circular economy was introduced into European policies as of 2014, with the European Commission Communication "Towards a circular economy: A zero waste programme for Europe" (COM 398), that aims to be an incentive for investment in efficiency improvements or innovative business models, using the European Resource Efficiency Platform in order to identify opportunities for recycling business and exchange of by-products. In 2015, the European Commission Communication "Closing the loop—An EU action plan for the Circular Economy" (COM 614) highlights industrial symbiosis opportunities in production and consumption stages and supports innovative business models (sharing economy, supplying of services rather than the sale of goods) and information technology for efficiency platform, with the aim of maintaining the value of products, materials and resources for as long as possible.

According to Pomponi and Moncaster (2017), the circular economy in the built environment can be treated on three levels: at macro-level, which concerns the system of cities or urban agglomerations (such as eco-cities), at meso-level, that is at the scale of the buildings and at micro-level, focused on the materials.

Studies of the circular economy in the built environment have also been performed by the Ellen MacArthur Foundation and CE100 network (CE100 2016). They suggest the six actions called the "ReSOLVE framework" (Regenerate, Share, Optimise, Loop, Virtualise, Exchange). It is possible to apply the "ReSOLVE framework" at urban level: there "Regenerate" can be the regeneration of the building stock; "Share" can be car sharing but also building sharing (residential and office) and the infrastructure sharing (parking sharing, shared infrastructure areas, shared green areas) and shared water consumption (water treatment facilities); "Optimise" can be the promotion of industrial process (industrial ecology) and smart urban design (use inner-city vacant land, promoting compact urban growth, high-quality urban environments, integrated, sustainable and participative urban development); "Loop" can be the activity to close the cycle of urban flows (urban metabolism, urban mining); "Virtualise" can be a virtualisation of products (service than physical products) and tele-working; "Exchange" can be the development of platform for create networks of stakeholder and scrap trading.

In 2019, the Foundation, in collaboration with Arup, launched Circular Economy in Cities, a suite of easily accessible resources which provide a global reference on the topic. Its modules have been developed to respond to the growing interest in circular economy from city governments and mayors, and will offer insights to many other urban stakeholders. Circular Economy in Cities focuses on opportunities in three key urban systems (buildings, mobility and products) and looks at how city governments/councils can work to enable a transition to a circular economy.

5.4 Urban Resources Management Strategies

The scarcity and costliness of raw materials has led to the shifting of the focus from "fixed stocks", still, immobile materials in the natural matrix, to "anthropogenic stocks", real anthropogenic stocks of resources, imagined over the years in the cities (and neighbouring territories).

Hence, the birth of the concept of urban mining, which means to think of the city as a mine of materials, and the actions aimed at the regeneration and monitoring of the building stock, as a place of conservation and storage of the materials to be regenerated through maintenance or reuse/recycling. The mapping of materials within the cities, on the one hand, and the creation of platforms for the interchange of resources, to favour the creation of networks to keep resources alive (also keeping their economic value), on the other, become indispensable tools to promote these processes.

5.4.1 Urban Mining

The city is seen as a mine of materials that can be reused and hence the concept of Urban Mining (Brunner 2011), which is understood as the management of stocks of anthropogenic resources (as products, buildings, spaces) and waste, from urban catabolism (Baccini and Brunner 2012). It proposes long-term environmental conservation, conservation of resources and economic benefits (Cossu and Williams 2015).

For example, WEEE, waste electrical and electronic equipment, represent today real urban mines: it suffices to realize that from a ton of electronic circuit boards, one can obtain more than 2 t of copper, over 46 kg of iron, almost 28 kg of tin and aluminium and about 18 kg of lead, in addition to smaller quantities of silver, platinum and palladium. Indeed, it becomes less expensive to obtain them from waste management rather than from actual physical mining (Fig. 5.7).

This can be extended to the chain of construction and demolition waste, plastics, paper, metals and organic wastes. This opportunity to prolong the life of resources is important, but is orientated to waste management, with an end-of-pipe approach. Circular economy strategies should be orientated towards extending the useful life of products, and this aspect is particularly important for durable goods, such as buildings.

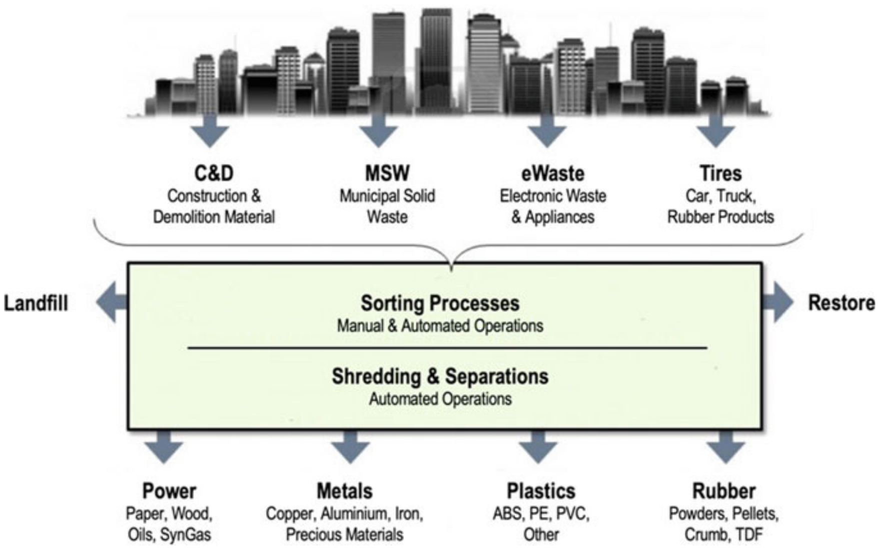

Fig. 5.7 Urban mining, recycle of urban waste streams and new value for resources (Vollmer and Soriano 2014)

5.4.2 Building Stock Regeneration and Building as Material Bank

Existing buildings constitute a precious asset of stored resources. These resources can be reused and recycled if the building is demolished, or they can be maintained, extending their useful life.

Urban regeneration is important first and foremost to avoid consuming new soil (using brownfield instead of greenfield sites) but also to avoid the presence of degraded and unsafe areas within the city. Furthermore, intervening on the existing stock means being able to manage the resources stored up in the building itself, reducing the extraction of new raw materials.

Urban regeneration works often aim at demolition and reconstruction, in order to construct a building with the performances required by contemporary standards and user expectations: in this case, it is important to try to intervene through selective demolition, recovery and reuse of materials (avoiding disposal in landfill) and construction of new flexible buildings (able to adapt to changes over time) and reversible buildings (with removable materials and components, so as to favour the reuse and recycling of the components).

Clearly when compared to demolishing and reconstructing, the possibility of extending the useful life of buildings and the materials stored therein is a more advantageous scenario since it is not necessary to reprocess the materials. So surely, the regeneration of the existing building stock must be encouraged and promoted (Giorgi et al. 2019).

The theme of the building as a place for storing materials and maintaining the value over time of the materials it contains has been the subject of European research BAMB (Building As Material Bank). Within this research, the role of selective deconstruction practices (to be applied in the case of demolition of existing buildings), with a view to reducing the use of natural resources (virgin quarry materials) through the recovery of construction and demolition waste has been emphasized. In addition, it has highlighted the role of design practices for new buildings (or renovation of the existing), attentive to the adaptability of the building over time (to prolong its useful life) and to the use of solutions of reversible construction (to facilitate the reuse of materials and components at the end of the building's life).

5.4.3 Madaster: The Cadastre of Urban Materials

"Waste is a material without an identity" (Rau and Oberhuber 2016). Starting from this assumption, the idea was to define a "cadastre" for materials stocked in the built environment, a real estate materials register, called Madaster.

Thomas Rau and Sabine Oberhuber, in the book "Material Matters" (2016), describe the transition to a new economic system where consumers are no longer owners, but temporary users of products and materials: "First, we must realize that with ownership comes responsibility. Nowadays, by necessity, all kinds of items end up in our possession for which, in the long term, we cannot bear responsibility. If the building we work in no longer meets our requirements, we are completely out of our depth when we are asked to consider its responsible use. We are not able to take care of all (raw) materials that were used to create the building—let alone reuse them".

The Madaster promotes the Material Passport: the passport ensures "identity" of the materials (as a guarantee), displaying also the value of materials and products during the life time of the building. Madaster also gives, for each building upload to the platform, a "circularity indicator" (CI). A building that was built with virgin materials and ends up as waste after a shorter average life is a completely "linear" building with a Madaster CI of 0%. On the other end, a building constructed from reused and/or rapidly renewable materials, that can be disassembled and easily reused at the end of the lifetime is a "fully circular" building with a score of 100%.

Madaster is the first developed example of a platform available to provide information about a building as material banks.

5.4.4 Mapping of Flows and Exchange Platforms

In addition to mapping the materials stored in buildings, the next step would be the ability to monitor the flows of materials and resources at the urban level. Through surveys and statistical analysis, it is necessary to analyse the (quantitative economic) flows of resources/waste in an urban area (district) in order to have a general mapping of the flows and be able to trigger controlled re-use strategies. The new digital technologies, ICT, can help the management of natural resources: through the use of "big data" and GIS, it is possible to manage and track waste, water, energy and the exchange of information on consumption between suppliers and users (Neirotti er al. 2014).

In addition to these tools, which should be in the hands of public administrations/local authorities, operators express the need to set up exchange platforms both for stakeholders to exchange information and good practices, and for producers/demolition companies/waste operators for the exchange of secondary raw materials.

The latter is particularly interesting, since they could help to build networks between processes, in a logic of industrial ecology.

Unfortunately, the waste involved is often fragmentary and impromptu (event), and this generates the problem of the location and the quantity of waste (the meaningfulness of the collected flows) to be reintroduced into a new production cycle. For the preliminary feasibility of creating new value chains, it is essential to be able to characterize the waste and verify the possibility of diffused collection in the territory, creating economies of scale. It is also necessary to identify significant and stable quantities: if the scrap is limited and occasional, it becomes difficult to activate recycling chains. If instead the waste being examined is significant and constant, stable relationships can be created between operators. For example, pre-consumer recycling is generally more easily characterized, because the origin tends to be stable and constant (Migliore et al. 2016). A good example is quarry waste which can become inert material for concrete.

In any case, mapping activities and interchange platforms can constitute an important scenario to facilitate the identification of forms of circularity.

5.5 Environmental Impacts at Urban Scale

The control of environmental pressures (consumptions and emissions) implies the need to effect environmental balances with a large area. It is not enough to quantify the flows of material in input and output (Material Flow Analysis), but it is also necessary to evaluate the environmental repercussions on, and consequently the implications for the natural environment.

Different approaches have been developed to study urban complexity and its impacts. Some examples of those approaches are to be found in Ecological Footprint and Life Cycle Assessment.

5.5.1 Ecological Footprint

The ecological footprint measures the environmental pressures determined by anthropic systems, expressing the "quantity of surface" necessary to support the metabolism of people, cities, regions, nations or anthropic systems in general. The methodology is based on the fact that many material and energy flows can be converted into land-area equivalents. Thus, the ecological footprint of a specified population is the area of land required to produce the resources consumed and to assimilate the wastes generated (Wackernagel and Rees 1995).

The "quantity of surface" measured with the ecological footprint includes both the natural resources necessary to support the communities (for example, the surface of the fields to produce wheat, the trees planted for paper, the space occupied by the buildings) and the territory needed to absorb the emissions and the waste generated (for example, the forest surface needed to absorb carbon emissions). It is expressed in "global hectares", being the extension of biologically productive territory, calculated with respect to the average of world productivity.

Some analysts have used the ecological footprint to quantify the metabolic nature of cities, thus clearly demonstrating that the territories necessary to support urban consumption have an amplitude hundreds of times greater than the directly constructed areas (Girardet 2004), and the dependence of cities not only on their surrounding territory and region, but also their dependence upon other nations if not indeed upon other continents.

This "visualisation" of the impacts makes it possible to become aware of one's dependence on foreign supplies of resources (raw materials) and the need to contain one's impacts within the limits of the bio-productive capacities of one's territory. Extending the reasoning globally, it possible to become aware of the need to contain the impacts of human beings within the limits of the bio-productive capacities of world's territory.

5.5.2 Life Cycle Assessment of Cities

Life Cycle Assessment (LCA) is a methodology typically used for the environmental evaluation of buildings, but can also be used in the assessment of a city or an urban region, even if there is no standardization for this level of application (Albertí et al. 2017).

LCA is a technique to assess environmental impacts of a system (a building or a city), compiling an inventory of relevant energy and material inputs and environmental releases and evaluating the potential impacts associated with identified inputs and outputs. In order to compile this inventory, it is necessary to define the spatial and temporal boundaries of the system.

LCA can support a policy and decision-making process, identifying the most effective environmental strategy among the various possible alternatives. The peculiar aspect of this evaluation is that it permits the verification of the effects with respect to all the phases of the life cycle (from the extraction of the raw materials to the disposal in landfills or the conferment to the recycling of all the resources necessary for the operation of the system). It also allows a broad picture of impacts to be considered, thus avoiding the possibility of burden-shifting and trade-off, actions which shift environmental problems from one phase of the life cycle to another or from one environmental impact to another. For example, moving towards the choice of nuclear energy can be viewed positively if one looks only at the reductions in CO_2 emissions during the usage phase due to the non-combustion of fossil fuels, but significant problems are created for waste disposal, thus with significant environmental impacts on other environmental indicators and in other phases of the life cycle. Strategic choices made without considering the complete set of environmental effects generated can cause significant consequences.

5.5.3 Sustainability Benchmarks at Urban Scale and Planetary Boundaries

Environmental assessments can allow one to know the environmental impact of a system (e.g. a city) and to make comparisons between alternative strategic actions, but they also provide information to make comparisons between alternative cities, to understand which is the most virtuous.

Being able to make comparisons between systems becomes very useful in establishing which are the best practices, trying to extend them to other situations. Through the comparison between systems, it is possible to define what is the "typical" impact of a city and therefore to establish environmental impact benchmarks (Lavagna et al. 2018; Frischknecht et al. 2019), and consequently also the targets, to be introduced in the policies.

Examples can already be found in which public administrations/local authorities act through the definition of targets, which in some cases are quite radical.

For example, the C40 Climate Leadership Group (more than 75 of the world's largest cities connected with the aim of developing and implementing policies and programmes which generate measurable reductions in both greenhouse gas emissions and climate risks) launched the call for "Reinventing Cities", with the aim of promoting the regeneration of disused urban areas through zero-emission redevelopment.

Another interesting example is the Swiss target 2000 W Society that the citizens of Zurich voted in 2008 to implement in their constitution. The long-term goal is to achieve a primary energy use of 2000 W per person and an emission of no more than 1 ton of CO_2 equivalent per person and year. The target addresses not only personal or household energy use, but the total for the whole society, including embodied energy, divided by the population. The typical uses considered are: living and office space (this includes heat and hot water), food and consumer discretionary items (including services such as transportation of these to the point of sale), electricity, automobile travel, air travel, public transportation, public infrastructure.

In both cases, however, the critical aspect remains that of taking into consideration only one/two indicators of environmental impact and therefore there is a risk of orientation towards choices that determine burden-shifting on to other types of impact.

Furthermore, defining benchmarks can be important to ensure that from the awareness of how much impact is made, one tries to move towards reducing impacts, but if one wants to find a balance between one's activities and the natural environment, it is necessary to take a step further. It is not enough to try to reduce the current behaviours that are now out of bounds, but it is necessary to respect the limits of the planet (Meadows et al. 1972): being sustainable means considering the carrying capacity of our planet, that is nature's ability to provide us with resources and re-absorb our emissions.

In the case of the Ecological Footprint, it has already been shown that mankind's activities are beyond the limits of the planet and that three planets would be required to support growth at current rates.

In the case of LCA, one would need to know what are the environmental boundaries at a planetary level for each of the different calculated environmental indicators, but it is not an easy task to define them.

In 2009 an attempt was made on some indicators by a group of Earth system and environmental scientists led by Johan Rockström from the Stockholm Resilience Centre and Will Steffen from the Australian National University. The group wanted to define a "safe operating space for humanity" for the international community.

They identified nine "planetary life support systems" essential for human survival, attempting to quantify how far seven of these systems had been pushed already. Estimates indicated that three of these boundaries (climate change, biodiversity loss and the biogeochemical flow boundary) appear to have already been crossed.

This type of study is of paramount importance to be able to understand how far we are from sustainability and to address the issue of sustainability not as a small adjustment of behaviour, but as a radical inversion of our production and consumption models.

5.6 Conclusion and Suggestions

The application of the circular economy at the urban level is still to be clearly defined, overcoming the current limitative approach of waste management, aimed simply at solving the landfill problem and at ensuring a continuous supply of resources (without reducing consumption). "The concept of the Circular Economy in itself is over-hyped, scarcely investigated and therefore as yet ill-defined. It is so far dominated by a business-focused narrative for competitive advantage, raising questions about the placement of the Circular Economy within a broader urban sustainability agenda" (Prendeville et al. 2018).

Circular economy strategies must not be reductively interpreted as closing the outgoing flows (and therefore in a perspective of improving waste management), but as an overall reduction in flows, as it was in the original interpretations of the theme.

It is not enough to close the cycle, and it is also necessary to aim at reducing consumptions. The consumption process involves the entropic degradation of the materials and energy used: a certain amount of energy and matter will no longer be usable at the end of the process.

It is necessary also to avoid the rebound effect, that is the risk that people, trusting in the fact that so much the products are recycled, would increase its consumption.

These could also be the "hidden" objectives of the current interpretation of circular economy by economists, still focused on economic growth and the GDP indicator, elements that conflict with a scenario of stationary consumption of resources.

The most interesting strategies of the circular economy are those aimed at an economic paradigm shift: decoupling economic well-being from the growth of produced goods, aiming at other business models (car sharing), shifting the economy from materials-based manufacturing to knowledge-based industries (Chung and Gillespie 1998).

It should also not be forgotten that circularity must be a sustainability-oriented objective, so verification of the effectiveness of circular strategies is required. We must pay attention to strategies that proceed in parallel on different themes because optimizing single-issue actions can cause displacements of environmental problems: if I maximize energy efficiency, maybe increase the materials used and the waste produced (burden-shifting); if I maximize the recycling, maybe the throw-away increases (rebound effect). For example, the incineration of urban solid waste combined with district heating is an effective circularity process; however, if waste were perfectly differentiated, there would not be much to burn, and in addition the burning of waste still creates harmful substances (PM2.5). For this reason, it is important to act on the reduction and the extension of the useful life of the products (and of the resources stored in them).

It is also important that the theme of reuse and recycling does not become a way to solve the problem of landfills, putting waste in the house, or even on the plate. The issue of people's health must be put in the first place, and the recycling of waste must be strictly controlled.

Finally, it is important that politics, industry and research work together to succeed in achieving the ambitious goal of effective environmental improvement, combined with the development and well-being of society.

The policy can be the mover or the obstacle. It is important to act on regulations, regulatory impositions (limits on the consumption of land, prohibitions on the opening of new quarries, etc.) and economic levers (taxes on landfill costs, etc.), as driving elements for effective modification of the market (Giorgi et al. 2018). An appropriate market's use of natural capital is the most effective actions that a public administrator can do. It is also important to identify and remedy barriers, without obviously compromising health and safety.

The industry can be the proponent of change. Even if it is said that it is consumers who orient the market, in reality, today it is industry and the market that build people's induced needs and orient consumption. If the market went from a disposable logic to a circular logic, from a logic of obsolescence programmed to a prolongation of the life of the resources, from a profit based on the sale of the quantity to a profit based on access to quality services, this would reorient society's behaviour, untying profit from resource consumption.

Research can open scenarios (vision and objectives) and provide solutions. It is no coincidence that all the major issues (environmental sustainability, energy efficiency, circularity) were first addressed by the research world and then applied in the market and in politics after at least twenty years. The world of research has the ability to anticipate future scenarios and to identify the technical solutions to follow them.

Many of the themes dealt with in this text are not new, as has been demonstrated, but they are not even current since they are not yet fully applied: it took decades for the policy to welcome them, and years will be needed for the market and society to receive them. The hope is that the change will be more radical than that seen so far. It is not enough for us to adjust our behaviour, but it is necessary an effective change of mentality and objectives, which puts the environment and our health as focus.

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