SPIRE Baia Mare

SUSTAINABLE USE OF LAND AND NATURE BASED SOLUTIONS

State of the Art

Innovation Landscape Report

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Executive Summary

SPIRE - Smart Post-Industrial Regenerative Ecosystem, proposes an innovative approach to the reuse of heavy metal-contaminated land in the city of Baia Mare (Romania), through adaptive phytoremediation and the creation of new urban ecosystems, as a long-term strategy for sustainable local economic development.

In doing so, SPIRE brings about substantial innovation to the European body of knowledge and practice on the field of brownfields regeneration, ecosystem services, circular value streams, and digital technologies.

Baia Mare's ground-breaking experimentations build on the most advanced research and forefront approaches currently being developed and tested worldwide. This report provides an overview on the state of the art of SPIRE's intervention fields.

Land-use management has a cross-sectoral character and includes fiscal, economic, regulatory and planning tools. It entails focusing on social and environmental concerns insomuch as on profits, paying particular attention to trade-offs as well as to the correct balance between different interests. Moreover, it focuses on the circular potential of land, encompassing interim uses prior to a long-term usage in the land cycle.

Ecosystem services go beyond the simple elimination of environmental loads and apply synergic, circular approaches to sustainable brownfields regeneration, including: 1) the socio-economic integration of lands in the urban system; 2) technological innovation and behavioural change towards land's bioremediation; and 3) participatory and co-creation arrangement with citizens and stakeholders.

Bio-remediation and decontamination use specific plants to limit the mobility, bioavailability and toxicity of pollutants, as well as to remove organic and inorganic substances from soils. For soils with low concentrations of metals phyto-extraction techniques are recommended, while for waste dumps or highly contaminated mines, phytostabilization is preferred.

Biomass-based value streams are defined as a set of interrelated activities which lead to new products and services by adding value to a raw material. In bio-economy a value chain includes the biomass resulting either from primary production activities such as agriculture, forestry or livestock, or from secondary sources, such as sludge, wastewater or household organic waste). Through value streams, biomass can then be upcycled into bioenergy, biofuel, as well as biomaterials usable for a multiplicity of purposes.

New digital technologies such as virtual currencies, GIS and Earth Observation applications are not only innovative urban planning tools, but also constitute innovative immaterial public utilities and open up new alleys to citizens' participation in sustainable local development

Introduction

Baia Mare is currently transitioning from its past as Romania’s mining capital towards a new sustainable social, economic and environmental development model. After the closure of the last metallurgical factories in 2012, the city has been coping with a multi-dimensional set of challenges, which chiefly include economic decline, depopulation, and environmental pollution.

On top of the socio-economic consequences of the closure of the local core productive system, the city’s mining and metallurgic industries left a legacy of circa 627 hectares of land polluted by heavy metals (up to 5 times the acceptable value) within the metropolitan area. Such land is now disconnected from the urban framework and a danger to the inhabitants and the environment, nonetheless it is also a key resource for the regeneration and sustainable economic development of Baia Mare’s urban system.

In this context, SPIRE – Smart Post-Industrial Regenerative Ecosystem – has the ambition of starting a long-term environmental, social and economic redevelopment in Baia Mare through the co-development of new adaptive and productive landscapes, integrated into a circular ecosystem of cascading material and energy value chains.

In doing so, SPIRE will attempt at developing, deploying and testing innovative and ground-breaking solutions across a number of key strategic intervention fields.

SPIRE approaches adaptive phytoremediation and ecosystem creation on urban heavy-metal-polluted land as a strategy for long-term land use management and economic re-profiling. It leverages on the potential for cascading value chains presented by the bio-based material flows and supports its translation into new economies and social entrepreneurship through a system of incentivization via a local token value system creating a circular environmental bonification system. The approach brings radical and innovative improvements to the intricate way in which cities are currently forced to deal with the complex negative externalities of brownfields.

There is now an increasing need for innovative, sustainable, affordable and integrated solutions to pollution of soil, water and air in European cities and urban areas. While phytoremediation as a technology is becoming an increasingly wider-used remediation option, research is still very widely dispersed and varied. Urban applications have been rare, and previous research pilots are typically of one plant species (monocultures) installed in a field application (Kennen & Kirkwood, 2015).

Latest projects bring novel approaches to optimising services for soft-reuse of brownfields (see CABERNET Project, 2012; HOMBRE “Brownfield Opportunity Matrix”, 2014), yet there is still a need for delivering more concrete instruments to cities, as well as for contextualisation in real-life of circular land management situations (Grimski et al, 2018).

SPIRE's gentle in-situ adaptive phytoremediation options will use an experimental mix of hyperaccumulators / extraction plots, short rotation energy coppice and planted stabilisation mats, in a "living lab" urban setting, co-designed with the community, in which citizen interaction will be possible via secured footpaths and walkways. This is a novel way of working with the community in reclaiming brownfields as public good and productive green infrastructure, able to provide ecosystem services at local level.

SPIRE will leverage on the biomass flows of the new productive landscape to collaboratively develop value chains in reproduction and conservation (via experimental bio-based retrofitting materials), supporting and mentoring start-ups to devise circular innovations interlinking inputs, processes and outputs in a high-value cascading land-material-fuel system. This is a very ambitious approach which has not yet been put into practice in Europe.

Lastly, SPIRE innovates local services, through the iLEU: a local immaterial utility (replicable in a network of local, decentralized token systems) creating a digital environmental value chain which engages all key stakeholders at local level (i.e. the administration, citizens, NGOs, and businesses and service providers) and brings them together redefining the relationships between them in a new bio-based circular production chain.

SPIRE builds on forefront studies and cutting-edge experiences and aims at further contributing to the advancement of the international wealth of knowledge and empirical evidence on its intervention fields. Based on a thorough review of academic and policy literature as well as of best practices and model examples, this Report provides a multidisciplinary overview of the state of the art and of the landscape of innovations in the realms of ecosystem services; biomass-based value streams; land-use management; remediation and decontamination; circular nature-based energy systems; and digital technologies and instruments.

Specifically, the Report is organised as follows:

Chapter 1 investigates the role and potential of land-use management as a crucial component of sustainable urban development, and specifically addresses its challenges and applications with respect to brownfields' regeneration.

Chapter 2 introduces the concept of Ecosystem Services and explores their implications in the reclaiming and bioremediation of urban brownfields;

Chapter 3 further develops the concept of bioremediation and specifically analyses the different types of phytoremediation techniques and their remediation potential;

Chapter 4 and 5 deal with the notion of biomass-based value streams (Ch. 4) and provide insights on their implementation in the production of energy and materials (Ch.5);

Chapter 6 investigates emerging trends and innovative digital technologies applied to sustainable development and urban planning;

Chapter 7 provides a multi-disciplinary collection of best practices and model examples of the application of the tools, technologies, approaches and policies presented within the report.

Lastly, the **Conclusions** briefly summarise the main points of the Report and draw the final remarks.

1. Land use management

Land management is the process of managing the use and development of land resources in both urban and rural settings. Land management is a complex process of decision-making, influenced by the wide range of functions needed and demanded by a given urban system (e.g. food production, housing, recreation and leisure, mining, reforestation, water management, etc.), as well as by the nature and the properties of the land itself (Foley et al., 2005; Verheye, 2009).

In a context of fast urbanization and population growth, the pressure on land and its resources is constantly rising: the degradation, fragmentation and unsustainable use of land in the Union is jeopardising the provision of several key ecosystem services, threatening biodiversity and increasing Europe's vulnerability to climate change and natural disasters. It is also exacerbating soil degradation and desertification (European Commission, 2014). Additionally, the LUMASEC URBACT Network (of which the city of Baia Mare was a partner) provided the following, more broad definition:

As management is the human activity meaning the action of people working together in the aim to accomplish desired goals, land use management is a process of managing use and development of land, in which spatial, sector-oriented and temporary aspects of urban policy are coordinated. Resources of land are used for different purposes, which may produce conflicts and competitions, and land use management has to see those purposes in an integrated way. Therefore, land management covers the debate about norms and visions driving the policymaking, sector-based planning both in the strategic and more operative time spans, spatial integration of sectoral issues, decision-making, budgeting, implementation of plans and decisions and the monitoring of results and evaluation of impacts.[5]

Thereby, cities are challenged to adopt a sustainable development paradigm, and foster a growth model capable of meeting contemporary needs without compromising the ability of future generations to meet their own needs (Bruntland, 1987). To do so it is crucial to focus on the integration of urban planning with objectives related to resource-efficiency, an innovative safe and sustainable low- carbon economy, sustainable urban land-use, sustainable urban mobility, urban biodiversity management and conservation, ecosystem resilience, water management, human health, public participation in decision-making and environmental education and awareness (European Commission, 2014).

Accordingly, land use management polices increasingly constitute a crucial challenge for urban authorities, and especially land recycling became a pressing need and a major concern for European cities, in their quest towards a zero net land take by 2050.

[5] https://en.wikipedia.org/wiki/Sustainable_land_management, https://urbact.eu/lumasec

Shrinking and/or post-industrial cities like Baia Mare are particularly concerned with the management challenges for brownfield land in a context of stagnant land markets. Underused land and brownfields can have a negative impact on the surrounding area and community and hinder effective regeneration. Regenerating brownfield and 'greyfield' land, on the other hand, can stimulate opportunities at different levels to improve urban quality of life, enhancing urban competitiveness and reducing urban sprawl (Schlappa and Faber, 2016).

This Chapter will explore the current state-of-the-art in the research and practice on sustainable land-use management and brownfields' regeneration, and it will provide an overview of the most relevant concepts, challenges, and approaches at European level.

1.1 Brownfields Regeneration

Following the definition elaborated by the experts of CABERNET Network (Concerted Action on Brownfield and Economic Regeneration Network), brownfields are derelict and underused sites, often polluted and contaminated as a result of their former industrial use. Underused and blighted brownfields are therefore widely diffused across Europe. As of 2016, "for example, the Netherlands has recorded 11,000 hectares of brownfield land, Germany 128,000 hectares while Poland and Romania have identified 800,000 and 900,000 hectares respectively" (Schlappa and Ferber, 2016, p.2)

The number of brownfields in a city is "a barometer of urban wellbeing and sustainable land policies" (Neil and Schlappa, 2016). Hence, nowadays many European urban authorities are called to deploy sustainable land-use management strategies for the vast amount of brownfield areas left as a legacy by years and years of poorly integrated and unsystematic land use policies doubled by unsustainable development plans (ibid).

The following paragraphs explore in depth the most relevant concepts, challenges, approaches and tools for land-use management and brownfields' regeneration currently being developed across Europe.

1.1.1 Concepts for Brownfields' Regeneration and Land-Use Management

In an urban context the management of developed land is part of a continuous land use cycle aimed at facilitating a smooth transition between different types of uses, thereby preventing the emergence of the brownfield problem (HOMBRE, 2014) or promoting interventions to bring them back to beneficial use (Schlappa and Faber, 2016).

Sustainable brownfield regeneration can be defined as "the management, the rehabilitation and return to beneficial use of the brownfield land resource base in such a manner as to ensure the attainment and continue satisfaction of human needs for present and future generations in environmentally non-degrading, economically viable, institutionally robust and social acceptable ways" (RESCUE, 2002; HOMBRE, 2014; TIMBRE, 2014; Rizzo et al., 2016).

Literature reveals several approaches to brownfields regeneration, that go beyond the traditional approach of investing in eliminating the environmental loads (Hou, 2016). In order to achieve the sustainability of the regeneration process, authorities and planners need to focus on the socio-economic integration of the lands in the urban system (Jamecny, 2016) as well as on sustainable remediation practices. Synergic approaches simultaneously acting on the social, environmental and economic dimensions, and collaboratively designed with all interested parties are key to reduce the negative impacts and maximize the long-term benefits of the regeneration projects.

Recent studies pinpointed a range of different approaches to brownfield regeneration, which include risk assessment (such as remediation costs assessment, social acceptance assessment, etc), policy analysis, optimization of remediation, general success factors for brownfields regeneration, infrastructure redevelopment, etc. (Abdullahi, 2015).

Furthermore, experts are stressing on the need for building evidence-based strategies for brownfields redevelopment, and thus are highlighting the need for data collection. Information management is one of the main challenges that urban planning processes in general, and brownfield lands planning in particular, are facing nowadays, as a good management of data represents one of the key success factors in achieving a coordinated approach to land use management. Information is also necessary for raising the awareness regarding the socio-economic and environmental impact of brownfields development. (Neill and Schlappa, 2016).

Additionally, communication and storytelling are also crucial in determining how brownfield sites are perceived by the population and potential investors. Quality information and territorial marketing are in fact key factors in influencing decision-making processes over the transformation of abandoned lands. And if these information are further supported by (ideally data-based) development scenarios, stakeholders' motivation tends to grow and with it the chances to stimulate development initiatives (Krieger et al., 2003).

The cross-sectoral character of land management requires a wide array of fiscal, economic, regulatory and planning tools and instruments (Bartke, 2016). Sustainable remediation processes not only need to consider social, economic and biophysical factors, but they also need to embrace the Triple Bottom Line (TBL) approach, thereby committing to focus on social and environmental concerns just as they do on profits. The TBL posits that instead of one bottom line, there should be three: profit, people, and the planet (Elkington, 1999).

Moreover, it is also crucial to carefully deal with the trade-offs of a development process, in order to assure a proper balance between different interests, the money spent and the outcomes, and ultimately to reduce the risks of conflicts. Under this perspective it is essential not to leave anyone behind, thereby assuring both intra and inter-generational equity, and encouraging participatory planning arrangements (Ridsdale, 2016).

In line with the idea of sustainable development, Ferber (2011) and Van Arkel (2012) introduced the concept of “Circular land management”. Circularity applied to land use means avoiding new brownfields and getting rid of the existing ones, therefore reducing greenfield consumption and brownfield production through remediating existing brownfields.

The concept has been further developed by the HOMBRE project (2014) with the introduction of the Brownfield Navigator: a tool that guides stakeholders by showing synergies between services and the opportunities they create at different stages of the land use cycle, thus highlighting the circular potential of land.

The concept also proposes interim uses of land, prior to a long-term usage in the land cycle (Bardos, 2015). The interim use of land further leads to the concept of “soft reuse” of land, whereby land remains unsealed and soil maintains its productivity for another type of – mostly green – services such as agriculture, landscaping, forestry, etc. Soft reuses vitally rely on soil functionality, which, especially in the case of brownfields, often needs to be restored with (bio- or phyto-) remediation procedures. When soil is recovered, its potential to host productive activities is enhanced and its overall value increases.

Most often the soft reuse of brownfields is considered unprofitable by local authorities as the immediate benefits of this approach are not obvious. Soft reuses nonetheless allow to generate added value on other dimensions, not only by improving the public perception of a place and enhancing citizens’ quality of life, but also – in a longer timeframe – by setting favourable conditions to pursue other development goals in the future.

Figure 1 illustrates the circular flow of land use management.

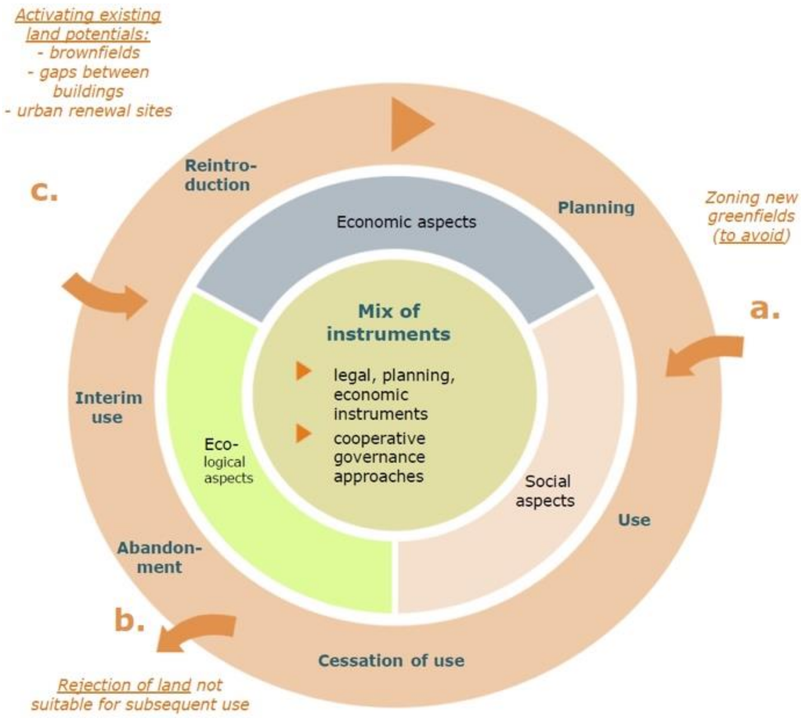

Figure 1 - Circular Flow Land Use Management[6]

Furthermore, literature states that an ecologically informed approach leads to significant financial benefits after investing in ecological restoration on contaminated sites (Handley, 1996). Soft reuses such as open spaces, urban gardening, renewable energy production (biofuel), leisure, culture and ecosystem services can in fact generate gains and benefits on different levels. The immediate effects are the mitigation of heat island, which is one of the main climate goals of European Union, but also improvements in quality of life in urban areas (citizens' health and comfort, air quality, urban image, creation of habitats, etc) (Bardos, 2015). Furthermore, the presence of green infrastructure in former derelict areas can have positive effects on surrounding property values.

1.1.2 Challenges to Brownfields' Regeneration

According to Decalck (2019), the main challenge when redeveloping a brownfield site is to solve the issues that kept it vacant, such as contamination, stigmatization or socio-economic stagnation in the community. Thus, their socio-economic and ecological functions need to be recovered. Furthermore, the strategies for land use management of brownfields should aim at reconciling human use with the provision of ecosystem services. In order to effectively reach the ecological potential of brownfields in urban areas, qualitative and quantitative assessments need to be undertaken. Parameters such as degree of soil sealing, species inventory or vegetation structures are relevant for evaluating brownfields potential in providing microclimatic regulation services, habitat services or recreational ones (Mathey, 2015).

[6] Source: Armijos Moya, 2014

Despite its crucial role in the achievement of sustainable development goals, brownfields regeneration is still a very difficult process that relies on complex negotiations among different stakeholders and requires huge financial resources (Abdullahi, 2015). Furthermore, it is very often hard to identify the priority areas for intervention, as these decisions depend on the land value, which is estimated by the type of land use and the demand for that land use (Syms and Weber, 2003), but also according to the costs needed for decontamination. The potential of brownfield sites is hard to estimate also because of their higher liability burden, which relates to potential risks of monetary or reputational losses (Bartke, 2016).

Other obstacles and potential blockages to brownfield regeneration initiatives lay in planning and permission procedures. These can be highly time-consuming and add further complexity to the process, especially when a large number of stakeholders are involved and need to cooperate and coordinate their activities. Such a slow process often hinders the interest of potential investors, which often tend to prefer the faster but less sustainable development of greenfield areas over the regeneration of brownfields and dismissed industrial sites. According to Zanon and Marcinczak (2011), it is thus essential for decision-makers to make brownfield regeneration more competitive in comparison to greenfield development. The approaches presented in the next paragraphs provide relevant examples in this direction.

1.1.3 Current Approaches to Brownfields' Revitalisation

Analysing the most recent experiences that brought brownfield sites back into productive use, Schlappa and Faber (2016) developed the following categorisation:

- ***Industrial reuse of abandoned sites**: This type of project includes relatively simple interventions at site level, such as demolition or adapting service infrastructure. However, given the urban location of many brownfield sites this option encounters limitations on development options arising from emission or noise pollution standards, transport and road infrastructure. The projects developed by the Etablissement Public Foncier in Lorrain/France (http://www.epfl.fr) illustrate how these challenges play out in practice and what can be done to address them.*
- ***Development of commercial centres**: There are many examples where private investors are driving forward brownfield redevelopment for retail use. This can be done in a sensitive way, preserving and integrating historical buildings – for example the Silesia Centre in Poland (http://silesiacitycenter.com.pl/en/). Also, service and office buildings, as illustrated by many successful office developments in industrial buildings, are mainly privately driven brownfield redevelopments and are examples of economically successful transition management from industrial to service sectors. The Custard Factory in Birmingham is an interesting case because this redevelopment of a derelict factory was led by a consortium of third sector organisations and aimed to provide affordable space for social enterprise close to the city centre.*
- ***Housing redevelopment**: Popular options include the refurbishment of industrial buildings into apartments, such as the fashionable lofts in former industrial districts of cities. Alternatively, we also find examples where old structures are demolished and measures are taken to address the real, or at times perceived, contamination problems of former industrial land. Innovative*

examples are the ecological Quarters, e.g. Quartier VAUBAN in Freiburg in which residential quarters were built upon a former military site to a high ecological and social standard. Due to its previous use as a military base, decontamination activities had to be undertaken to ensure safe living standards in the district (www.vauban.de).

- ***Cultural after-uses**: There are many examples where former mills were converted into museums which capture local historical development. Industrial buildings are also used for the purpose of arts projects, for example the 'Spinnerei' in Leipzig (http://www.spinnerei.de/).*
- ***Green after-uses**: These are dominant in former mining regions but also in metropolitan areas where brownfield sites offer an important opportunity for the creation of urban green corridors and networks. Demographic change and ageing populations in shrinking cities put a high importance on the recultivation of brownfields sites in ways which support the reorganisation of settlements and infrastructure. The Land Restoration Trust in England shows a wide range of successful projects where recultivation has been used strategically to reshape settlements (http://www.landrestorationtrust.org.uk/ community/).*
- ***Energy production**: The generation of energy from wind or solar, as well as gas from biomass technologies, is a further option for long term or interim use of brownfield sites (http://www.wald-und-holz.nrw.de/wald-und-holz-nrw/forschung/ forschungsprojekte/biomassepark-zeche-hugo.html).*

(Schlappa and Faber, 2016, pp. 3-4).

Since the costs of reclaiming brownfield land are high while its economic value is low, governments in most European countries established specific governance arrangements to allow the success of regeneration initiatives. These take very different forms and reflect the particular institutional, policy and economic contexts of the countries concerned. Schlappa and Faber (2016) identified four approaches towards recycling and managing brownfield land which are different in regard to lead agency and also scale of intervention: 1) entirely public sector led initiatives; 2) projects led by a publicly controlled not-for-profit agency; 3) land trusts managed by independent charitable organisations; and 4) public–private partnership.

1.1.4 Prioritising Interventions

In order to support decision makers in strategically allocating resources for brownfields management and development, several specific tools were developed at European level. The ABC model has been developed as an output of the European project CABERNET building on the experience of 15 countries from all over Europe and has also proven its effectiveness outside the network's experience (Cotič, 2019).

Specifically, "the ABC model provides a quick assessment tool to identify different types of sites in terms of their economic viability. It also highlights how the character or status of a site can change in relation to changes in the location, site treatment costs and economic conditions, which can support policymakers identifying priorities for the reuse of individual brownfield sites. The ABC model uses three categories to indicate the economic viability of the site. While the definitions used here describe ideal types, whereas the reality of assessing brownfield sites is likely to raise debate about which category is most closely related to which site, attempting to classify sites according to these three criteria has been found to be an effective way of supporting the strategic allocation of scarce resources for the management and redevelopment of brownfield land" (Schlappa and Faber, 2016, pp.5-6)

The model has been developed

As shown in Figure 2[7], the ABC Model proposes the following approach to brownfield sites categorization in terms of economic viability:

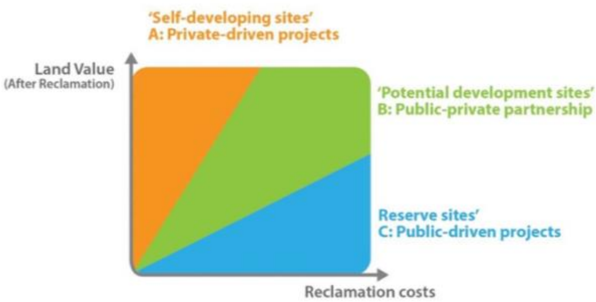

Figure 2 - A-B-C Model

- **A Sites** → economically viable, with development projects driven by private investors
- **B Sites** → on the borderline of profitability, can be funded through public-private partnerships
- **C Sites** → their condition makes restoration unprofitable, and interventions rely mainly on the public sector; in order to stimulate interventions on these sites, public funding or specific legislative instruments are required.

In Baia Mare the vast majority of brownfields are currently unprofitable with high reclamation costs and low land value (C-sites). In this context, thanks to the ERDF co-financing, the Urban Innovative Actions' project SPIRE will allow the opportunity to start a bioremediation process on five pilot sites, ultimately aiming at creating the condition for their upscaling to *potential*

[7] Source: CABERNET project

development sites (B-sites) and *self-developing sites (A-sites)* in the mid- and long-run, respectively.

Additionally, the European project TIMBRE (Tailored Improvement of Brownfield Regeneration in Europe) launched the Timbre Brownfield Prioritization Tool (TBPT/TBP-Tool): "a web-based solution to assist stakeholders responsible for wider territories or clusters of brownfield sites (portfolios) to identify which brownfield sites should be preferably considered for redevelopment or further investigation. The prioritization approach is based on a set of success factors properly identified through a systematic stakeholder engagement procedure. Within the TBPT these success factors are integrated by means of a Multi Criteria Decision Analysis (MCDA) methodology, which includes stakeholders' requalification objectives and perspectives related to the brownfield regeneration process and takes into account the three pillars of sustainability (economic, social and environmental dimensions)" (Pizzol et al., 2016). Furthermore, three integration levels were established (Bartke, 2016):

- Dimensions (regeneration potential of each specific site): local development potential, site attractiveness and marketability, environmental risks, etc;
- Success factors: conditions, circumstances, actors which can enable the regeneration process;
- Indicators.

SPIRE has been inspired by the TIMBRE approach already in the selection of the five pilot sites and will further draw upon- and build on this approach in the preparation of the Masterplan 2050.

The next Chapters will explore in detail innovative concepts, tools and strategies that can be implemented for the successful regeneration of highly contaminated brownfields in post-industrial cities like Baia Mare.

2. Ecosystem Services

One of the key challenges that cities are facing nowadays lies in finding a balance between the demand for land and the integration of natural ecosystems. There is general acceptance of the fact that urbanization has a major influence on ecosystem dynamics, affecting both positively and negatively the ecosystem services (Devalk, 2019). According to literature, ecosystem services represent that type of services provided by nature and exploited by mankind (Mathey, 2015), which are materialized in direct and indirect benefits people acquire from the presence of ecosystems within the urban environment (Devalck, 2019). Furthermore, ecosystems are considered to be one of the main elements contributing to the human well-being and to sustainable urban transformations (Koch, 2018).

From an objectivist point of view ecosystem services are the benefits that people derive from biophysical processes. Yet, if we adopt follow a hybrid definition amalgaming social and ecological processes, "ecosystem services should not be understood as purely biophysical; rather each ecosystem service, in order to come into view and be accounted as a 'service' in concrete political processes, are in need of that certain actors mobilize or build networks of humans and non- humans that can translate what is of value (using technology (e.g. maps, GIS), social arenas, science etc.). This means that certain biophysical processes receive their status as ecosystem services through *hybrid actor-networks of translation*" (Ernstson, 2010).

2.1 Ecosystem Services in Urban Areas

According to the Millennium Ecosystem Assessment (MEA) 2003, there are four types of ecosystem services: supporting services, provisioning services, regulating services and cultural services, which materialize in multiple benefits for humans and the environment such as local climate change regulation, recreational activities, better conditions for biodiversity, food supply, above-ground carbon storage, air pollution reduction, and health benefits (Koch, 2018).

Ecosystem services can be provided by numerous types of urban areas, such as natural green and blue areas (e.g. parks, gardens, lakes, rivers, etc.), green roofs as well as brownfields (Kock, 2018). After remediation, in fact, the latter can be converted into green areas or transformed into different types of Ecosystem Services' providers. In many cases they can contribute to regulating the local climate and storing CO2 when kept green and occupied with the right plant species (Mathey, 2015).

Building on the MEA (2003) framework, Mathey (2015) elaborated a classification of potential ecosystem services provided by brownfields:

- Habitat Services, develop naturally through a process of ecological succession which results in particular green areas accompanied by particular species of insects, birds, etc. Green urban brownfields usually host various habitats, depending on local climatic conditions, soil types, or the pace of ecological change;

- Recreational Services, as cultural services which can be developed on urban brownfields once their reputation is changed and residents' perception becomes positive. The author states that there is a positive change in people level of acceptance regarding brownfields, and that it depends on site's characteristics in comparison to other green areas, such as aesthetic qualities resulted from a big diversity of shapes and colours (due to ecological succession), which tend to attract children in particular;
- Microclimate Regulation Services, as regulating services provided by the presence of vegetation, which has cooling and CO2 storing effects.
- Provisioning service refers to edible and non-edible products (such as construction or energy related materials), the former depending on soil quality - if it is or not contaminated - while the latter can be undertaken during the process of decontamination[8].

Decontamination is the essential first step in order for brownfields to enable Ecosystem Services. The next Paragraphs will thus explore the state of the art and emerging technologies for the bioremediation or urban brownfields.

2.2 Bioremediation of Brownfields

Without appropriate legislation and measures, brownfield sites may be left abandoned for very long periods, even for decades. What results in many cases is the spontaneous development of a wild and diverse vegetation, even providing some kinds of ecosystem services (Mathey, 2015). Yet, brownfields are very often contaminated, and their pollution poses high risks to human health, thereby hindering the sites' development potential. In recent years, however, the need to reclaim such areas induced urban authorities to undertake remediation or decontamination initiatives in an increasingly growing number of countries.

Decontamination can be made in two ways: the traditional one, which is more complicated and more expensive requires digging and dumping, excavations, transport, landfilling, soil washing, treatment with oxidants such as hydrogen peroxide or potassium permanganate and incineration (Megharaj, 2017). This process is usually abandoned by the initiators as is requires a lot of time, money and human resources in order to be accomplished.

The second option is bioremediation: a process mediated by biological agents such as microorganisms or plants, which is considered more efficient in terms of costs, time and other material resources (ibid.) and consequently, overall, a more sustainable technology. Figure 3 graphically illustrates such process.

[8] Provisioning Services, however, have not yet gained a general acceptance in the specialty literature.

According to literature (see Azubuike et al., 2016; Megharaj, 2017), bioremediation can be done in situ and ex-situ, depending on what type of contaminants are present on site. Usually, in situ treatment is more popular as it is cheaper, and it doesn't involve excavations and transport of contaminated soil. In situ treatment can be further divided into natural attenuation and enhanced, the latter consisting in bio-stimulation, bioventing, bioaugmentation and phytoremediation.

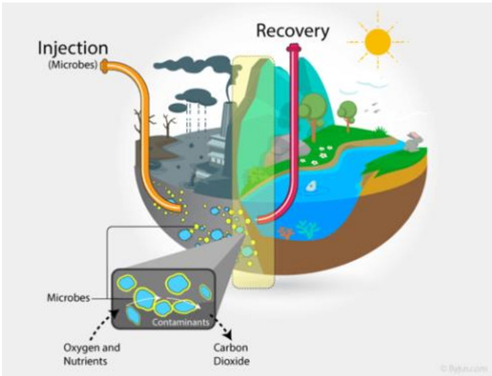

Figure 3 - Process of Bioremediation[9]

Phytoremediation, the chief bioremediation technology adopted in SPIRE, relies on the physical, biochemical, biological, chemical and microbiological properties of specific plants to remove pollutant agents from soils (Azubuike et al., 2016; Megharaj, 2017). In particular, Megharaj (2017) identifies two types of phytoremediation suitable for sites contaminated with heavy metals: phytoextraction and phytostabilization: the former extracts the contaminants from soil, while the latter reduces heavy metals mobility in soil. There is no general consensus regarding which method is more effective, still phytostabilization seems to be preferred as it allows to reduce the bioavailability of contaminants in brownfields (Sarkar, 2005; Azubuike et al, 2016). In what concerns the plant species for phytoremediation, several aspects must be taken into consideration when choosing them, such as root system (fibrous or tap depending on pollutant's depth), the biomass existing underground, toxicity of pollutant to plant, plant's capacity to adapt to prevailing environmental conditions, plant growth rate, plant's resistance to diseases and pests, site monitoring and time required to achieve the envisioned level of decontamination (Azubuike et al, 2016).

Beyond allowing the sustainable decontamination of land, phytoremediation has additional potential in the development of ecosystem services for brownfields' regeneration. Figure 4 illustrates how SPIRE aims at tapping on such potential.

[9] Source: www.byus.com

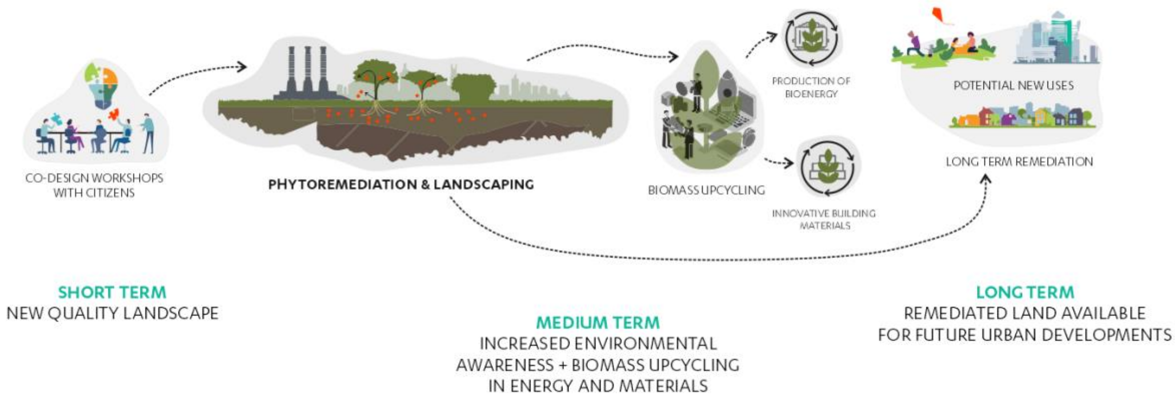

Figure 4 – SPIRE's Ecosystem Services for Brownfields Regeneration[10]

In practical terms, in fact, implementing a long-term bioremediation strategy means to convert abandoned land into cultivated fields or even woods, thereby providing an underused part of the city with a renatured, quality landscape.

Additionally, this also means to establish seasonal cycles of planting and harvesting for different kinds of vegetation, with the consequent regular production of a stock of biomass to be potentially upcycled within a circular/cascading value stream.

The following Chapters will thoroughly explore such potential, in terms of both bioremediation and biomass -based value streams.

[10] Source: Authors' elaboration

3. innovation in Remediation and decontamination

Pollution caused by heavy metals (HM) represents a serious threat for both the environment and human health. Due to their elemental character, HM cannot be chemically degraded, and their detoxification in the environment mostly resides either in stabilization in situ or in their removal from the matrix, e.g., soil (Suman et al., 2018).

For this purpose, phytoremediation, a passive technology for soil recovery, has been proposed as a promising green alternative to the traditional physical and chemical methods. Conventional physical and chemical methods of HM removal from polluted environment are usually not usable at large scales and are often costly and not well accepted by the public (Khalid et. Al, 2017). Instead, phytoremediation – from the words "phyto" (plant) and "remediation" (recovery) – is an ecological remediation technology that uses specific plants to remove organic and inorganic substances from the contaminated soils.

3.1 Phytoremediation Techniques

Phytoremediation is the use of green plants in the removal of the contaminants from the area or in their recovery (Raskin *et al*, 1997). Phytoremediation is ecological, does not need any special equipment during application and at the end of the process it delivers plots of land fully re-usable. The root depths and climatic conditions play an important role in the efficiency of the system. First of all, the soil must be appropriate to the needs of the plant for the removal of the contaminants from the soil by the plant. The pH of the soil is one of the most important parameters. The pH levels of the area must be between 5.8 and 6.5 for the nutrient elements to be taken (Vanli et al., 2007). The absorption of the contaminants and their accumulation by the plants is illustrated in Figure 5.

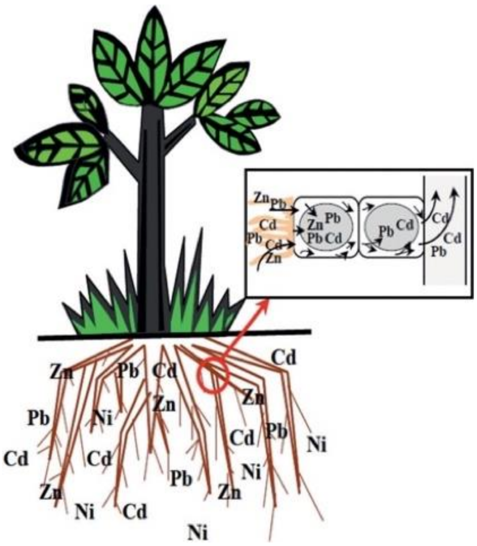

Figure 5. Heavy Metal Absorption and Accumulation in Root and Shoot of the Plant[11]

The nutrient element absorption is completed in three stages: (1) the transportation of the nutrients to the root circle and root surface; (2) the absorption of the nutrient ions into the roots; and (3) the transportation of the nutrient ions which entered into the root to the necessary parts by the transmission branches. There are two basic theories in the transportation of the nutrients to the root surface: “Intersection and Contact Change” and “Carbonic Acid Theory” (Karaman et al., 2012).

This method is highly effective in a relatively short time span in low-polluted areas, whereas in the case of heavy contaminated soils it can have significant effects only in the long run (EPA, 2000; Yildiz, 2008).

According to Salt *et al*. (1998) phytoremediation techniques can be subcategorized as:

- Phytoextraction
- Phytodegradation
- Rhizofiltration
- Phytostabilization
- Phytovolatilization
- Rhizodegradation

Phytoremediation techniques are very effective in the sterilization of the areas which are medium-contaminated and have a slight risk (Sevinç Adiloğlu, 2017).

Figure 6 illustrates the main steps of phytoremediation in HM-polluted soils: (a) metal (yellow dots) adsorption on soil particles or cell walls (induced by rhizosphere metabolism) and compartmentalization of metals into root cell vacuoles (blue circles inside cells), preventing

[11] Source: Eke et al., 2010

transport to the shoot; (b) metal accumulation in aerial organs (e.g., in vacuoles or trichomes) upon root-to-shoot xylem transport; (c) for particular metalloids (e.g., Se and As), leaf metabolism allows volatilization of the toxic compound.

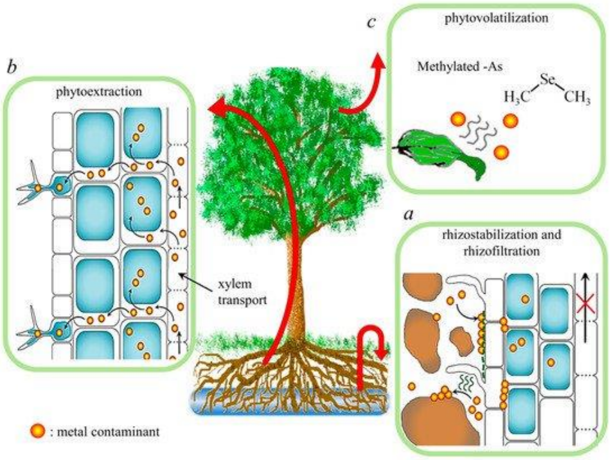

Figure 6 – Phytoremediation Techniques[12]

3.1.1 Phytoextraction

This technique is used in the absorption of the organic and inorganic contaminants from the matrix through their uptake into the harvestable parts of the plant. It is a valid method for the recovery of the contaminated areas, in which the plants that are able to absorb HM are chosen and the contaminants are removed from the soil when harvesting or removing the plant.

Because this technology's application takes more time compared to other techniques, its application on heavy polluted areas is very hard. Also, a plant which grows in that ecosystem should be chosen. It should not be seasonal, because they will be harvested later. After harvest, they are burned in incinerator or exposed to another method with composition. When the plants used in this method are compared to other plants, it can be observed that they can accumulate contaminant elements 100 times more. with this method *Brassicacea, Euphorbiacea, Asteraceae, Lamiaceae* and Scrophulariaceae and 400 other types are identified which can accumulate heavy metals. The residues of the harvested plants can be isolated by drying, burning, composting and recycling to biological metal minerals (Memon *et al,* 2000). Additionally, *Cannabis sativa L*. has the potential to serve as phytoremedial agent to remove toxic metals from contaminated sites as well as yields high biomass which could be used for production of bioenergy (Sanjeev *et al.*2017*). Cannabis sativa L*. demonstrated to possess the ability to transfer Cu from the root to the shoot, one of the criteria that must be met to consider a plant well suited for phytoremediation (Laura Arru *et al*., 2004). There are certain characteristics of hemp, which makes it very suitable for phytoremediation such as high biomass, long roots and a short life cycle of 180 days (Rafiq et. al. 2015). Cost analysis

[12] Source: Dal Corso et al., 2019

indicates that industrial hemp could generate higher gross profit per hectare than other crops like kenaf, switchgrass and sorghum (Lalitendu Das *et al.,* 2017).

Phytoextraction has considerable advantages over traditional techniques, especially because its cost effectiveness, potential treatment of multiple HM simultaneously, no need for the excavation of contaminated soil, good acceptance by the public, the possibility of follow-up processing of the biomass produced etc (Suman *et al.,* 2018).

3.1.2 Phytodegradation

Phytodegradation is a method in which organic contaminants are degraded by the compounds that are produced by plants through metabolic processes. Vegetal degradation can be applied to soil, clay, sediment and underground waters. The most advantageous aspect of the method is that the reduction and degradation occur inside the plant as a physiological process, and do not depend on microorganisms, while the emergence of toxic intermediate and end-use products, and the difficulty of their detection create a disadvantage (Pivetz BE., 2001). The absorption of the organic compounds into the plant depends on the plant type, the residence duration of the contaminant element in the soil, and the soil's physical and chemical form. The easily dissolved compounds are difficult to absorb. Plant enzymes are known to be able to degrade hazardous substances such as herbicides, munitions waste and chlorinated solvents (Memon *et al*, 2000).

3.1.3 Rhizofiltration

In rhizofiltration method, contaminants cling to the roots or are absorbed by the roots in accordance with biotic and abiotic processes. During these processes, contaminants may be taken or trans- ported by the plant. What is important is to maintain the immobilization of the contaminants in or on the plants. Later on, the contaminants can be taken from the plants with different methods. This method is applied to underground waters, surface waters and waste waters (Vanli O. *et al*, 2007; Sogut Z. *et al*, 2002).

Rhizofiltration is used to remove the radioactive substances or metals from the contaminated waters. The plants which are used in this method are directly planted on the contaminated soil and the contaminant's adaptation is ensured. The plants are raised hydroponically in clean water instead of soil, until they have a wide root system. The rooted plants are transported to the contaminated water source in order to make them adapt to their new environment. When the roots become saturated the plants are harvested. This method provides an opportunity for the use of terrestrial and aquatic plants. It is also used in basins, tanks, and ponds besides natural environment (Salt *et al*, 1998; Mirsal IA, 2004).

3.1.4 Phytostabilization

This method is used in the stabilization of soil. Phytostabilization plants are able to tolerate heavy metal levels and immobilize the metals through sorption, sedimentation, complexation or reduction of metal valences. The contamination factors in soil occurs as a result of the immobilization of the contaminants around the plant roots, their accumulation by the roots, cohesion or sedimentation around the roots (Mirsal IA, 2004).

Wang *et al*. (cited by Turkoglu *et al*, 2006) conducted a research on the development and Cu absorption in corn plant (*Zea mays* L.) which is inoculated or non-inoculated by *Acaulospora mellea*, an arbuscular mycorrhizal fungus, by using different doses of Cu-applied pots in laboratory conditions. They concluded that the low absorption of the plants in the high concentrated Cu pots results from the soil's pH value. They observed that the concentration and the structures of the organic acids in the soil such as malic acid, citric acid and oxalate acid were modified by the fungus. The researchers revealed that *Acaulospora mellea* is not suitable for the phytoextraction of copper by the corn plant; however, mycorrhizal plants are more applicable for phytoextraction because of their high capacity of Cu absorption in their roots. On the other hand, contaminants' transportation by wind, water erosion, washing out or soil dissemination can be prevented. In a system which is closely related to the plant's root environment microbiology and chemistry, the plant is able to modify the contaminant factor's form into non-resoluble or non-transported in water (EPA-Environmental Protection Agency, 2000).

3.1.5 Phytovolatilization

The root depth is very crucial in phytovolatilization. If it is about underground waters, the roots should be deep. To sterilize contaminated underground waters, the water can also be pumped to the ground to provide absorption for the surface roots. The most important aspect of this method is the transformation of the excessive toxic compounds (mercury contained compounds) into less toxic forms. However, the potential release of these hazardous and toxic materials into the atmosphere is a disadvantage (EPA, 2000). The contaminants can be removed from the plant by transpiration or evaporation. As a well-known fact, water is carried from the roots to the leaves with the help of vascular system; therefore, the contaminants are released to the air through evaporation or volatilization. Poplar tree can be an example for this mechanism (EPA, 1995).

Ghosh and Singh (cited by Wang FY, 2007) pointed out that some plants such as *Brassica juncea* and *Arabidopsis thaliana* can release heavy metals to the atmosphere with phytovolatilization by absorbing and transforming them into gas form. Some types of trees such as *Populus* and *Sali*x are often used in phytovolatilization because of their capacity to take contaminants with phytoremediation (Ghosh M. and Singh SP., 2005).

3.1.6 Rhizodegradation

Rhizodegradation is the decomposition of the organic contaminants in soil surrounding the roots of the plants as a result of microorganism activities. There are amino acids, sugar, organic acid, sterol, fat acids, growing factors, nucleotide, flavanone and enzymes which are released from the plant's roots and affect the microbial activities in the surrounding area of the roots. The most important benefit of Rhizodegradation method is the dissolution of the contaminants in their natural environment (EPA, 2000; Yildiz N., 2008).

Pesticides (herbicide, insecticide), benzene, toluene, ethylbenzene, xylene (BTEX), total petroleum hydrocarbon (TPH), polycyclic aromatic hydrocarbons (PAH), surface active substances, chlorinated solvents (TCE, TCA), pentachlorophenol (PCP) polychlorinated biphenyls (PCB) can be exemplified as contaminants that can be dissolved with Rhizodegradation. Mint (*Mentha spicata* L.), red berry (*Morus rubra* L.), alfalfa (*Medicago sativa* L.), and reedmace (*Typha latifolia* L.) are used in Rhizodegradation method (EPA, 2000; Sevinç Adiloğlu, 2017).

3.2 Effectiveness of Phytoremediation

Heavy metal (HM) contamination from mining activities is considered a problem quite severe for many regions around the world (Arroyo and Siebe 2007, Lis and *et al*. 2003, Simon *et al*. 2001, cited by Liu J. *et al.* 2010). The activities they are after large quantities of heavy metals are released are mining and mining, combustion and production fuel, intensive agriculture and mining waste (Sigua 2005, Sigua *et al*. 2005, Sigua *et al.* 2004a, Sigua *et al.* 2004b, Paz-Alberto A.M. *et al.* 2007). Heavy metals accumulated in the soil can affect the flora, fauna, health of people living in the neighbourhood or in the direction of the contaminated site. Around the sources of pollution, the air contains both solid matter (soot, ash, fine coal dust, powders of different pollutants either Cu, Pb, Al, Zn, Hg, Cd, etc.) as well as gaseous materials (oxides of S, N, Pb, C etc.). The released substances are a real thin threat from the moment they reach the environment and subsequently become more dangerous because of its complexes of the chemical modification undergone in the presence of external factors.

The main purpose of using amendments - where phytoremediation experiments can be applied - is to limit the mobility, bioavailability and toxicity of metals. For a successful remediation, many types of amendments can be used, they are selected according to the type of substrate and the purpose of the remediation. For soils with low concentrations of metals recommends the application of phytoextraction techniques in general, while for waste dumps highly contaminated mine, phytostabilization technique is preferred (Vangronsveld 2009).

Following the experiments, information about the effects can be obtained interaction between used amendments and / or microorganisms and plants on mobility existing metals in the investigated welded material. The relatively rapid growth of plants could have positive effects in reducing metal transport due to wind erosion, if the cover with plants (protective vegetal canopy) is sufficiently deep. On the other hand, the welded material needs to be compact enough to prevent water loss necessary for plant development. Table 1 shows the phytoremediation potential of different species of plants. Accordingly, the correct selection of the plant species is crucial for the success of the remediation technology. Therefore, it can be concluded that plants can be effective in phytoremediation of settling ponds under the conditions of covering them with different amendments and/or inoculated with microorganisms.

Plant	Nature of pollutant	Initial concentration	Mechanism of removal	%	Reference
Ludwigia octovalis	Gasoline	2,07,800 mg/kg TPH	Biosurfactant enhanced rhizodegradation	93.5	Almansoory et al. (2015)
Aegiceras corniculatum	Brominated diphenyl ethers (BDE-47)	5 μg/gdw	Biostimulated degradation	58.2	Chen et al. (2015)
Spartina maritima	As, Cu, Pb, Zn	5-2153 mg/kg	Bioaugmented rhizoaccumulation	19-65	Mesa et al. (2015)
Arundo donax	Cd and Zn	78,9 and 66,6 kBq/dm3, respectively 0.02-20 mg/L	Rhizofiltration	100	Duresova et al. (2014)
Eichorina crassipes (water hyacinth)	Heavy metals (Fe, Zn, Cd, Cu, B and Cr)	229.67 +- 15.56 μg/g	Rhizodegradation	58.47	Gregorio et al. (2014)
Phragmites australis	PAHs	5-200 mg/kg	[a]Phytostimulation	85.9-99.5	Somtrakoon et al. (2014)
Plectranthus amboinicus	Pb	50 mg/kg	Rhizodegradation	90-98	Dadrasnia and Agamuthu (2013)
Luffa acutangula	Anthracene and fluoranthene	1-5 wt%	Biostimulated rhizodegradation	91.5	Gregorio et al. (2013)
Dracaena reflexa	Diesel	6,260 +- 9.3 10^{-3} μg/g	Phitoaccumulation	25-60	Iori et al. (2013) Moreira et al. (2013)

Sparganium sp.	Polychlorinated biphenyls	25-150 µM	Phytoaccumulation	87	Wang et al. (2013)
Amaranthus paniculatus Rizophora mangle	Ni TPH	33,215.16 mg/kg	Rhizofiltration	20-70	Elias et al. (2014)
Populusdeltoides x nigra and Arabidopsis thaliana	Silver nanoparticles and Ag	0.01 - 100 mg/L	Rhizofiltration	99.3	Ignatius et al. (2014)
Carex pendula	Pb	1.0-10 mg/L	Rhizofiltration	50-100	Yadav et al. (2011)
Cannabis sativa	Cu Pb Zn Cd	1530 mg kg^{-1} 1053 mg kg^{-1} 211 mg kg^{-1} 151 mg kg^{-1}	Phytoextraction - Rhizodegradation	2-8 105 2.3 31.7	(Rafiq et. al. 2015)

Table 1 - Phytoremediation Potential of Plant Species[13]

4. Biomass-based value streams

Value chains are defined as a set of interrelated activities which lead to new products and services by adding value to a raw material (Marone, 2018). In bio-economy - defined by the EC as the part of economy which utilises bio-based renewable resources from the land and the sea, in order to produce materials and energy - a value chain includes the biomass resulting either from primary production activities such as agriculture, forestry or livestock, or from a novel origin (such as microalgae) or from secondary origins, such as sludge, wastewater or household organic waste). Bio-economy is strongly linked with circular economy, as the latter leverages on the cascading of a material, which can be represented by a raw material, a by-product or waste. Furthermore, bio-based value chains are considered the most promising pathways for achieving resource efficiency in the circular economy (Lokesh, 2018).

As shown in Figure 7, usually a bio-based value chain consists of the following phases: feedstock procurement → transportation to laboratories → pre-treatment of biomass → product processing → product formulation → final product testing → product validation → packaging → transportation to retailers → consumption.

[13] Source: Authors' elaboration based on Azubuike (2016) and Rafiq et al. (2015)

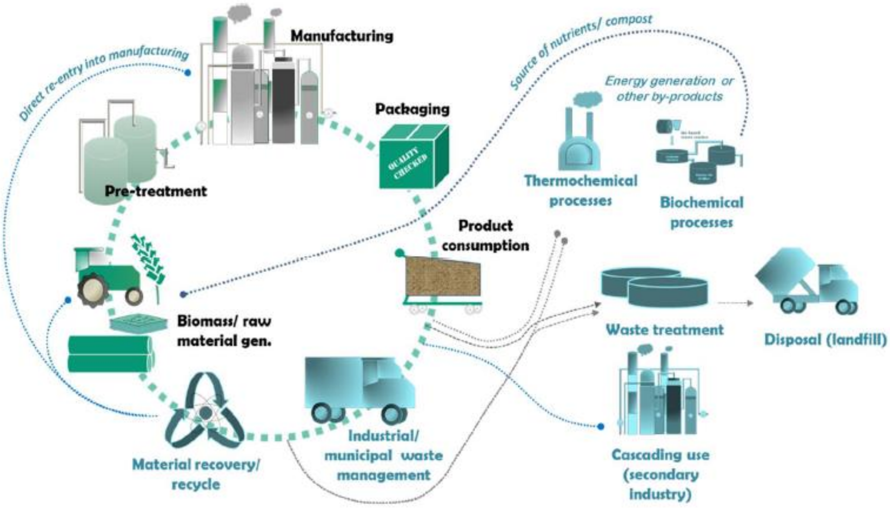

Figure 7 - Bio-based Value Chain Model Example[14]

Each phase has its related actors, which are also the beneficiaries of the value chain process. Thus, feedstock procurement involves farmers and farmers associations which are producing the bio waste, and local waste management companies in charge for waste's stockage and treatment. Both stakeholders benefit from the value chain process as usually the crop waste is burned and the ashes resulting from the process are deposited in landfills and are harmful for the environment. The second phase consists in transporting the waste to laboratories for further treatment, processing, etc, and is accomplished by local or regional transportation companies. Afterwards the pre-treatment phase begins, which is done by specialized chemists in laboratories. For the processing and product formulation research institutes are responsible, while bioengineering companies are constantly informed and consulted in order to reach the expected market results. After this preliminary phase, the final product goes through a testing phase, in which the chemical and physical properties of the construction material are tested by researchers, and if proper results are achieved the product enters the validation phase which is done by national/international standards authorities (ASTIM/ISO). The following steps of the value chain process consist of logistic activities such as packaging (by industries, wholesalers and retailers) and transportation to consumers by local/regional transport companies. In the end it arrives to consumers, and the loop is closed here.

This Chapter firstly provides a general review of the concept of cascading streams, then it narrows the focus on circular nature-based energy systems and concludes discussing the peculiarity of bioenergy at urban level.

4.1 Cascading Streams

[14] Source: Lokesh, 2018

The term "cascading" has in recent years become very commonly used in discussions on policy strategies pertaining to how to allocate biomass resources in order to maximize the local societal, economic and environmental benefits (IEA, 2016).

4.1.1 Cascading in Value

Odegard et al. (2012) describe cascading-in-value as a framework where the resource shall be used with the purpose of maximizing value throughout the cascade chain. The definition of value, however, is not consistent in the available literature (Vis et al. 2014). Some sources refer to added value primarily in the economic sense (IEA, 2016) whereas other discuss both environmental added value and economic added value (Keegan et al. 2013; Vis et al. 2014). The cascading-in-value concept is often illustrated by use of the "bio-based pyramid" (Vis et al. 2014) shown in Figure 8.

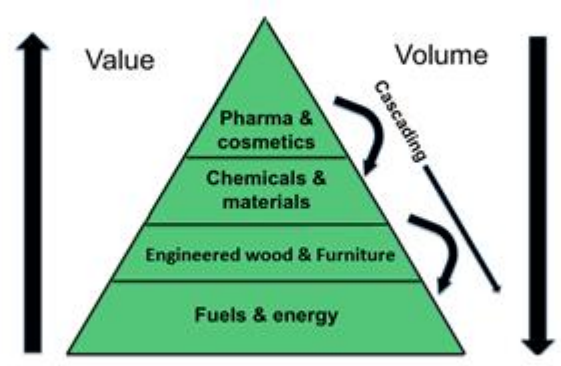

Figure 8: Cascading in value concept in wood industry[15]

In this framework the citizens and the bigger heat consumers like local public institutions in urban and rural areas who used firewood for their heating must rethink the pathway of heating supply. They are pushed to invest and to modernize their heating systems and to switch from firewood or natural gas consumption to lower carbon technologies such as wood residues, wood chips and other woody biomass resource-based bioenergy technologies. Given the low quality of the raw material, the cascade concept suggests to use this significant amount of woody biomass mostly for energy production. Even if wood waste valorisation activities are only at pilot stage in several municipalities in Romania, this approach is developing under many aspects.

4.1.2 Cascading in Time

The main idea of the cascading in time concept is that the wood materials should be re-used sequentially in the order of the specific resource quality and type at each stage (Figure 9). This would enable the wood materials to stay longer in the system and thereby reduce the need for new resource extraction from the forest and reduce strain on natural resources (Fraanje,

[15] Source: Vis et al. 2014

1997). If the concept is applied for the regional wood resources, the potential of long-term carbon storage in wood products has also been highlighted by Sikkema et al. (2013).

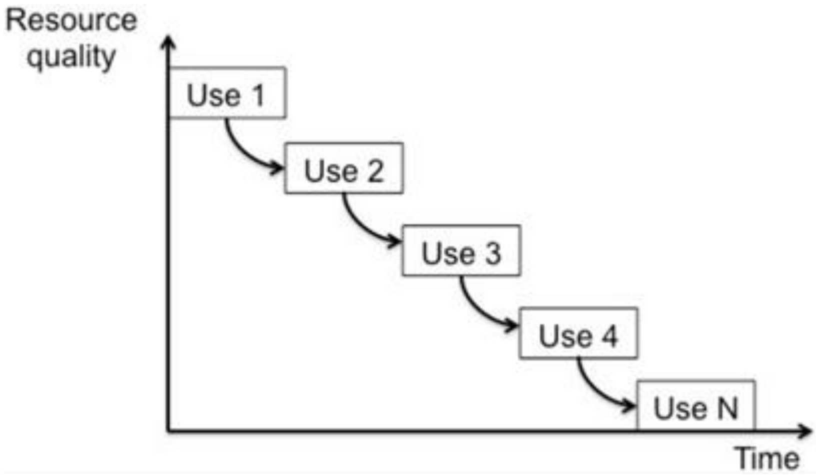

Figure 9: The Cascading-in-Time Concept in the Wood Industry[16]

There are conceptual similarities between cascading-in-time and the waste hierarchy concept. The waste hierarchy approach as specified by the European Commission (2012) mentioned five different waste management steps and the priority in which they should be used:

1. Prevention;
2. Preparation for re-use;
3. Recycling;
4. Other recovery (including energy recovery);
5. Disposal (including landfilling or incineration without energy recovery).

The objective of maximizing the time a resource remains in a certain system is present both in the waste hierarchy and the cascading-in-time framework. These topics also interact in the broader discussions on recycling and circular economy (Ellen MacArthur Foundation, 2012).

The multi-stage cascade approach requires by definition a second material use stage after the first product phase. It has to be used in the subsequent end-of-life treatment step either energetically or processed for further material use. Depending on situations it has to be decided whether the objective should be to maximize the time spent in the system or the number of cascade stages. In the use of wood for construction, the number of cascade phases is less relevant than the actual lifetime of the building (Vis et al. 2014).

4.1.3 Cascading in Function

[16] Source: Sirkin et al. 1994

Cascading-in-time and cascading-in-value are the most common used definitions of cascading concept, however Odegard et al. (2012) also mention “cascading-in-function”. The core idea of this concept is to focus on the importance of optimal use of each subcomponent of log wood, with the aim of guaranteeing that each part of the wood is used for an optimum purpose. This bears close resemblance to the function of a biorefinery, which is “a facility (or network of facilities) that integrates biomass conversion processes and equipment to produce transportation biofuels, power and chemicals from biomass” (Cherubini 2010). Based on the conceptual setup of a chemical refinery, biorefineries process biomass into several different products in a way that maximizes the value on the input unit of wood material. A key difference between cascading-in-time and cascading-in-value on the one hand, and cascading-in-function on the other is that the latter more strongly emphasizes the synchronised production of several different bioproducts with high added value (Keegan et al. 2013; Sokka et al. 2015).

The conversion of wood into bio-fuels and bio-chemicals for a long time is technically feasible. Wood valorisation processes include fractionation, pyrolysis, hydrolysis, fermentation, and gasification. Fast pyrolysis utilizes wood biomass to generate a product that is used both as an energy source and a feedstock for chemical production. The bio-oils from wood pyrolysis are composed of a range of cyclopentanone, methoxyphenol, acetic acid, methanol, acetone, furfural, phenol, formic acid, laevoglucose, guaiacol, and their alkylated phenol derivatives. When wood is rapidly heated in a reduced oxygen environment, the feeding material does not combust but rather becomes a synthetic gas (syngas), a combination of hydrogen (H2) and carbon monoxide (CO). Wood can be converted by hydrolysis into sugars and subsequently fermentation of sugars (Dinesh, 2006).

4.1.4 Cascading in Innovation

There are several European programs that promote an efficient use of bio-based resources especially by providing guidance and dissemination of best practices for cascading use of biomass or supporting innovation in the bio-economy. The EU wood industrial policy and legislation have been framed to support innovative and disruptive technologies in this sector. The national wood industrial policy has to follow the directives, supporting and maintaining the established structures of the wood-based industry. In order to stimulate growth of innovative regional wood manufacturing capacity more research and innovation (R&I) projects are needed, alongside with increased cooperation between the wood companies with the goal of developing of new innovative products is needed. Therefore, the improvement of information flow between research institutions and communities, investors and manufacturers to promote innovation is recommended. It has to be continued to improve hosting economic conditions that attract capital investment and encourage strategic alliances for R&I. According to statistical data the annual average investment in the wood logging sector between 2015-2019 varied between 12 and 26 mio. EUR. Compared to the export of logwood, the investment into logging process improvement is very limited. Between 2010 and 2016 the investment in wood industry from foreign companies achieved 150 mio. EUR per year in the North West Region of Romania, while the domestic wood industry is lagging behind in terms of technology innovation, innovation for new products and new market uptake.

4.2 Circular Nature-Based Energy Systems

Urban renewable energy sources – that is, renewable energy sources that lie predominantly within the urban boundaries or the near hinterland – are an option for all cities, particularly those at early stages of development where lower energy demands and a lack of distribution infrastructure may make local resources an attractive option. This chapter will focus specifically on the bioenergy, as major urban renewable energy source. Bioenergy sources are also of interest because they provide a unique link with the waste streams of urban areas, offering an opportunity to "close the loop" of a city's metabolism.

It is possible to consider the use of residues from forest maintenance, residues from livestock, the use of energy crops, and residuals from agro-industrial activities. Each region has its specificities, therefore, in order to define the types and quantities of available biomass, an analysis should be made about the agricultural, forestry, and zootechnical sectors, based on which viable scenarios should be considered.

4.2.1 Bioenergy Policies at European level

At European level energy initiatives have set high targets. In October 2014, the European Council established the EU's climate and energy policy for 2030, setting the target to reduce greenhouse gas emissions by at least 40% by 2030. In 2015, the Commission introduced the reform of the EU's trading scheme for emissions certificates to ensure that the energy sector meets the emission reduction target.

The Paris Agreement confirmed EU ambitions on climate change mitigation, the implementation of the 2030 climate and energy policy framework becoming a long-term priority (United Nations, 2015). In 2016, the Commission put forward proposals to accelerate the transition toward a low-carbon economy in other key sectors of the European economy.

Also, in 2016, the European Commission presented a new set of proposals for the transition to clean, consumer-oriented energy. The Clean Energy for All Europeans Package (European Commission, 2016) has legislative proposals addressing energy efficiency, renewable energy, and design of the electricity market, security of supply and governance rules for the Energy Union. The package includes actions to accelerate innovation in the field of clean energy and renovation of buildings, measures to encourage public and private investment and to promote the industrial competitiveness of the EU. The package also contains proposals to combat climate change and reduce the EU's dependence on fossil fuel imports.

With the Clean Energy for All Europeans Package, the EU aims to reduce its CO2 emissions with at least 40% by 2030, willing to demonstrate that the transition to clean energy is the main growth sector in the future.

In January 2018, the new amendments to the Clean Energy for All Europeans Package were debated by the European Parliament on 3 areas of interest (Renewable Energy, Energy Efficiency, Control Mechanisms). The following are the key outcomes of such debates:

- By 2030, the EU should increase energy efficiency by 35%;
- Renewable energy sources should account for 35% of gross final energy consumption;
- Support schemes for RES from biomass should be reassessed and designed to encourage sustainable use of biomass. For energy generation, priority should be given to waste and wood waste burning.

Drawing upon data from the National Renewable Energy Action Plans (NREAPs), Progress Reports from Member States (under Article 4 and Article 22 of the Directive 2009/28/EC), as well as from Eurostat energy statistics (2018a, 2018b) the following aspects on biomass for energy should be highlighted:

- Biomass for energy (bioenergy) continues to be the main source of renewable energy in the EU, with a share of almost 60%. The heating and cooling sector is the largest end-user, using about 75% of all bioenergy;
- Bioenergy contributes to the EU's energy security, as most of the demand is met from domestically produced biomass (about 96% in 2016);
- Forestry is the main source of biomass for energy (logging residues, wood-processing residues, fuelwood, etc.). Wood pellets, mainly for heating and electricity production, have become an important energy carrier.

Bioenergy can play a key role in achieving the EU's renewable energy targets for 2030 and beyond. However, biomass for energy must be produced, processed and used in a sustainable and efficient way in order to optimize greenhouse gas savings and maintain ecosystem services, all without causing deforestation or degradation of habitats or loss of biodiversity.

4.3 Bioenergy as Urban Renewable Energy

This section provides a thorough overview on the potential, application, and supply chain of bioenergy within an urban setting.

Paragraph 4.3.1 presents the biomass resource potentials in urban and peri-urban areas, providing a description of biomass typologies and characteristics, possible end-uses in energy and non-energy sectors, cost ranges, biomass processing and energy conversion technologies for urban energy systems.

Paragraph 4.3.2 reviews the bioenergy conversion technologies suitable to serve the heating, cooling and power demands of urban and peri-urban areas, and the opportunities for integrating these routes with existing energy systems and infrastructures.

Paragraph 4.3.3 addresses the aspects of the urban biomass supply chains. Some representative case studies of are also presented in this section.

Paragraph 4.3.4 summarises the lessons learnt on the topic.

4.3.1 Biomass Energy Sources and Potentials

One of the unique features of biomass energy sources is their diversity. Such sources can come from a range of different feedstocks and offer different energy densities and other characteristics. A broad classification of biomass feedstocks (primary, secondary, and tertiary) is proposed in Figure 10 and their supply chains. Specifically, Figure 10 provides a flow chart for biomass waste and residues available for energy production in developing countries and emerging economies across the globe. It focuses on biomass types that are secondary and tertiary outputs from production. Primary biomass sources for energy production (i.e. dedicated energy crops) are another option that can be economically or environmentally feasible in some situations.

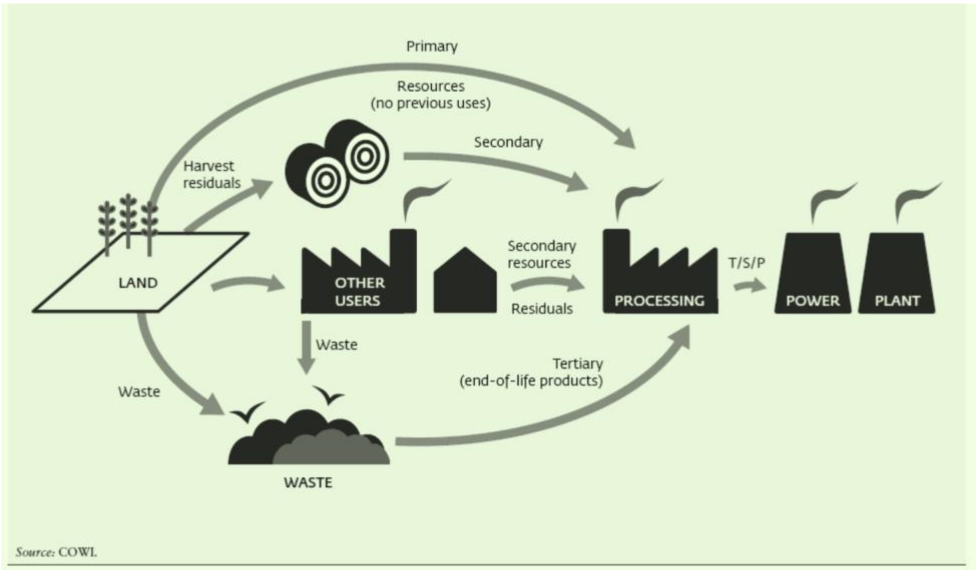

Figure 10 - Flow Chart of Biomass, from Field to Plant[17]

For each of the typical biomass types, this section provides the following information:

- Industry (agriculture, forestry, food production);
- Type (primary, secondary, tertiary);
- Feedstock (wood, agricultural);

[17] Source: COWL; International Finance Corporation, 2017

- Characteristics (calorific value, biogas potential, chemical composition, moisture content);
- Energy conversion process applicable (boiler, gasification).

Table 2 provides a cross-cutting overview of the different types of biomass available from primary, secondary, and tertiary sources.

Primary sources refer to energy crops harvested for the purpose of energy generation; no other use of the crop is foreseen. These include woody biomass, such as plantation trees (for example, eucalyptus), and herbaceous biomass, such as energy grass or grain (for example, for biofuel production).

Secondary crops refer to by-products used for energy production. As such, the main crop harvested (e.g. grain for food and feed) is not used for energy generation, but any residues (straw, husks, shells) are. Similarly, for woody biomass, the main crop is not used for energy generation (for example, wood is harvested for use as planks or in paper production), while logging by-products are used for energy generation. Secondary sources also refer to any by-products from production, such as black liquor from paper production.

Tertiary sources refer to end-of-life materials, such as discarded wood products or household waste and other kinds of biological waste.

	Woody biomass	Herbaceous Biomass	Biomass from Fruits and Seeds	Other (including mixtures)
	Wood fuels	**Agro-fuels**		
Primary (Energy crops)	• Energy forest trees • Energy plantation trees	• Energy grass • Energy whole cereal	• Energy grain	
Secondary (By-products)	• Thinning by-products • Logging by-products	**Crop production by-products** • Straw	• Stones, shells, husks	• Animal by-products • Horticultural by-products • Landscape management by-products • Bio-sludge • Slaughter by-products
	• Wood processing industry by-products • Black liquor	• Fiber crop processing by-products	• Food processing industry by-products	
Tertiary (End-use materials)	• Used wood	• Used fiber products	• Used products of fruits and seeds	

Table 2: Overview of the Types of Biomass Available[18]

The characterization of the biomass feedstock includes its chemical and physical properties, including trading form, calorific value, biogas potential, bulk density, ash content, and moisture content.

[18] Source: International Finance Corporation, 2017

Annex 1 provides a thorough characterization of the biomass feedstock, including biomass' detailed chemical composition (percentage of lignin, cellulose, hemi-cellulose, and extractives).

To decide on the type of a given biomass or feedstock, the key below may be used. It introduces a number of questions, mainly concerning alternative uses of the biomass and feedstock, that can help classify this material. All biomass and feedstock should first be evaluated posing the questions in Figure 11 below.

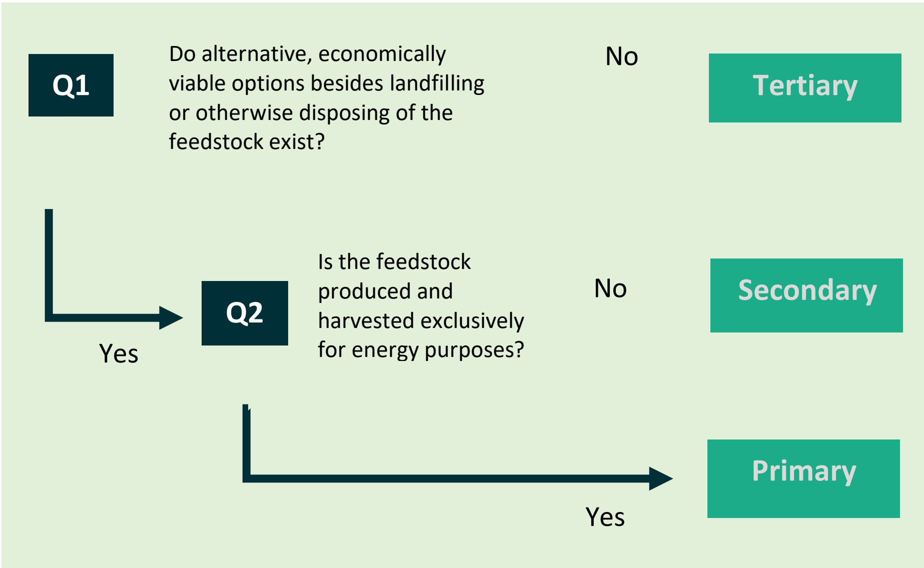

Figure 11 - Biomass Classification[19]

Table 3 provides a classification of urban biomass feedstocks.

Typology	Description
Urban biomass	
Biodegradable municipal wastes	
Organic fraction of municipal solid wastes	Paper/card, food/kitchen waste, textile/wood residues
Urban wood wastes	Stemwood, chips, branches, foliage from municipal trees and private gardens ("urban green"); demolition wood; industrial wood wastes
Waste vegetable oils	Waste cooking vegetable oils
Sewage sludge	By-products of wastewater treatment processes
Peri-urban biomass	
Energy crops	Short rotation forestry, herbaceous crops, silage crops, oleaginous crops
Forestry residues	Chips from branches, tips and stemwood
Agricultural residues	Straw from sewage crops, pruning residues
Wood residues	Clean and contaminated waste wood
Sawmill co-products	Chips, sawdust and bark
Agro-industrial residues	Wet fermentable wastes, lignocellulosic by-products
Zootechnical residues	Cattle, pigs, poultry manure
Landfill gas	Gas from decomposing biodegradable wastes in landfill sites

Table 3 - Classification of Urban Biomass Feedstocks [20]

4.3.2 Bioenergy Routes for Urban and Peri-Urban Areas

[19] Source: Adapted from International Finance Corporation (2017)
[20] Source: Keirstead and Shah (2013)

Bioenergy routes are essentially a three-stage process whereby different raw resources (biomass) are collected, before being upgraded and processed into biofuels and finally used in energy conversion systems to provide heating, cooling, or power.

Table 4 provides a classification of biomass resources, including those produced in urban environments and in the neighbouring areas (Jablonski et al., 2008; Wit and Faaij, 2010).

Because of the high energy intensity of urban areas in comparison to their biomass potentials, it is estimated that 5–10 percent of the total heat and power energy demand of urban areas could be reasonably served by urban biomass, while in the case of integration with peri-urban biomass and rural communities, this percentage could increase up to ranges of 30–50 percent.

These ranges are also highly influenced by the energy demand typology of urban areas and their size, as discussed in following sections. Urban areas located near the premises of local biomass potentials (i.e. forestry or wood processing residues) can take advantage of this opportunities to develop biomass- fired district heating (DH) or combined heat and power (CHP) plants (Freppaz et al., 2004). In the case of biomass imports over long distances, the sustainability assessment of the whole bioenergy conversion chains is a crucial issue and is a specific eligibility requirement for subsidies in several countries (e.g. EU, 2009).

ID	Type	Resulting biofuel/usage
	Urban biomass	
1	Urban wood wastes	Chips and pellets
2	Waste vegetable oil	Biodiesel or refined bio-oil
3	Urban wet bio-wastes	Fermentable residues for AD processes
	Peri-Urban biomass	
4	Herbaceous residues and energy crops	Chips and pellets
5	Woody residues and energy crops	Chips and pellets
6	Herbaceous energy crops	Anaerobic Digestion (AD) processes
7	Lignocellulosic agro-industrial residues	Chips, pellets or direct thermochemical conversion
8	Agro-industrial residues for AD	Fermentable residues for AD processes
9	Oleaginous energy crops	Bio-oil production

Table 4 - Classification of Biomass Sources for Urban Energy Systems[21]

Table 5 describes the commercially available and most promising biomass treatment processes to produce solid biofuel.

ID	Biofuel	Treatment	Input biomass IDs
	Solid Biofuel		
1	Pellet	Chipping-drying-pelletization	1,4,5,7
2	TOP (torrefied pellet)	Torrefaction - pelletization	1,4,5,7
3	Chip	Chipping-drying	1,4,5,7
4	TOP (torrefied pellet)	Hydrotreatment-drying/dewatering (wet lignocell biomass)	3-5, 7, 8

Table 5 - Solid Biomass Treatment Processes[22]

Biofuels can be converted into energy by means of several technologies, as reported in Table 6. Heat production tends to be the cheapest and most profitable conversion system for solid

[21] Source: Pantaleo (2013)
[22] Source: Keirstead and Shah (2013)

biomass and in the absence of specific incentives for bioelectricity. The district heating option is interesting in the case of high heat density (IEA, 2008; Zinko et al., 2008), new buildings or refurbishment of existing ones, and possibly to increase the network load factors by district cooling with adsorption chillers (Rentizelas et al., 2008).

ID	Typology	Size range	Input biofuel IDs
	Heat technologies		
1	Multi-biomass boiler	0.02 – 20 MW	1-6, 10-11
2	Pellet stove boiler	0.02 – 20 MW	1,2,4
3	Biogas boiler	0.1 – 20 MW	10-13
4	Bioliquids boiler	0.5 – 20 MW	5-9
	CHP technologies		
5	OCR	0.5 – 2 MW_e /2-10 MW_{th}	1-8, 10-13

Table 6 - Conversion Technologies[23]

4.3.3 Urban Biomass Supply Chains and Logistics

Table 7 summarizes the most promising bioenergy routes for urban energy systems. For each option, the size range, conversion efficiency, and biofuel supply options are reported. Moreover, the possible configuration of the logistics of biomass upgrading and energy conversion, the main constraints when integrating into UES, the technology maturity level, and the typical urban areas suitable for each route are also described.

Route	Size	Efficiency (%)	Biofuel	Logistics	Constraints			Reliability	UES type / key factors
					T	S	E		
Pellet stoves/small boilers	20-100 kW_{th}	$75\text{-}85_{th}$	Pellets, TOP, chips	Centralized pellet/TOP plant + road distribution to small plants	+++	+++	+++	+++	Peri-urban rural / low heat density
Boilers + DH	0.1-5 MW_{th}	$80\text{-}90_{th}$	Solid biomass	Centralized pellet / TOP or biomass storage + road distribution to plants + heat distribution to loads	++	++	++	+++	High heat density / no gas available / existing DH networks
ORC+CHP+DH	0.25-1 MW_{th}	$15\text{-}25_e$	Solid biomass	Centralized storage / upgrading + road biofuel transport to plant + heat distribution to loads	++	++	++	+++	

Table 7 - Bioenergy Routes for Urban Energy Systems[24]

To conclude, bioenergy resources are widely available in urban areas and can be collected from urban waste streams which otherwise would incur in disposal costs. Such resources are highly diverse and can be used in a range of applications including the provision of heat, power, and transport. The choice of any bioenergy route will therefore depend on the specific technologies available, financial conditions, local environmental impacts, and many other factors.

[23] Source: Keirstead and Shah (2013)
[24] Source: Pantaleo (2013)

4.3.4 Lessons Learnt

This paragraph schematically provides the main lessons learnt with respect to the provisioning, processing, and application of biomass in urban energy systems.

The low-hanging fruit in biomass projects:

- Biomass processing industries or biomass producing companies, with biomass by-products and residues, a demand for process energy, and/or proximity to an external energy consumer, may have a good basis for a biomass-to-energy project. Many successful projects exist within industries such as pulp and paper, wood, palm oil, sugar, olives, coconuts, instant coffee, etc.
- Substitution of expensive fossil fuels with biomass residues may be beneficial for some industries and enhance their competitiveness.
- The use of local biomass as a fuel eliminates or reduces the reliance on a stable fossil fuel supply. At the same time, local production of energy is a catalyser for the local economy in terms of extra jobs in the fuel supply chain.
- In-house production of electricity and steam/heat from biomass may be a more reliable energy source than unstable external supplies, and production interruptions at the enterprise may be avoided.

Important lessons learned regarding biomass availability and supply chain:

- The most important question to ask is whether sufficient biomass residue of the proper quality is available from the industrial facility's own production, perhaps supplemented by local agricultural or forestry biomass wastes.
- For fuels sourced off-site, biomass must be secured by long-term contracts. The contracts must contain all relevant issues for the fuel supply, including quality requirements such as moisture range, sizing, and absence of foreign elements. In addition, the contract should specify all commercial aspects such as price terms, penalties, rejection right, and other conditions. The establishment of a stable and reliable supply chain for offsite fuels is one of the most critical and difficult aspects of the biomass project and requires careful analysis.
- When the energy production depends on agricultural or forestry production residues, the seasonal variation of biomass production becomes a determining factor for its availability (for example, delivery problems during the rainy season). It therefore is essential to map the seasonal variation for the most common crops that deliver the secondary or tertiary biomass for energy production. Furthermore, storage facilities may be established on-site at the plant or off-site at the premises of the biomass suppliers if storage is needed due to production or seasonal variations. In all cases, the

on-site storage capacity must be determined and approved. Typically, storage capacity at the biomass plant site of a minimum of three to four days is needed.

- It is important to consider biomass flexibility, in terms of supply, delivery, storage, preparation, and feeding. Better flexibility with alternative biomass types may increase the industry's operating time and availability if there is a shortage of the preferred fuel. In any case, it is important to identify a secondary biomass supply at an early stage of the project.

Regarding technology selection and design:

- If the moisture content in the fuel is above 60 to 65 percent, anaerobic digestion may be the choice of technology. For drier biomass wastes, a combustion technology will be more suitable.
- Proven technologies are essential, but in order to reduce capital costs, a local low-cost supplier may supply the technology in cooperation with an international, reliable, and experienced supplier who is responsible for the process design.
- The intended fuels will determine the combustion technology to use, but they also must be evaluated in terms of suitability for handling and storage at the site. The fuel sizing and content of potential corrosive elements will influence the selection of boiler technology and materials in the boiler parts. It must be verified that internationally proven equipment suppliers can accept the chosen type of biomass and that acceptable warranties can be guaranteed. Selection of unproven technology or unexperienced suppliers may easily lead to delays, operational problems, and budget overruns.
- If power production and export to the grid is foreseen, it is important at an early stage to check that a grid connection is possible at the right voltage and within close proximity. It also should be determined who should erect and finance the connection. It is important to check emission limitations at an early stage, as this may influence the choice of technology, especially in the flue gas cleaning system.
- Fuel flexibility is important in case of a lack of supply of the intended biomass fuel.
- Handling and disposal and/or reuse of residues (bottom ash and fly/boiler/flue gas cleaning ash) must be assessed carefully, as this can substantially influence the project economy.

This Chapter discussed the potential, application, and supply chain of bioenergy within an urban setting. The next Chapter narrows the focus and thoroughly explores how biomass could be employed in the production of energy- and construction-related materials, and assesses the efficiency gains of biomass-based cascading streams.

5. Biomass-based materials

Currently, most of the bio-economy strategies are developing value chains based on bioenergy and biofuel, while biomaterials are not yet considered at a wide scale, as their applicability is still missing a general acceptance. Several strategies were developed at European level in the field of eco-efficient innovation in the building sector, yet most of them are oriented towards energy efficiency, and only a limited part towards innovation in construction materials (Giglio, 2013). The value chain proposed by SPIRE aims at further developing and innovating such materials, thereby contributing to the achievement of the objectives foreseen by the EU Circular Economy package. The document has committed to increase the availability of secondary materials such as biowaste for future exploitation in conventional (composting, anaerobic digestion) and innovative ways. The innovation in the field is expected to support new markets for bio-based products, by interlinking industries through feed materials (when one industry's waste represents the raw material for another) (European Commission, 2018).

This Chapter discusses in detail the state-of-the-art and emerging trends in the development of both energy-related and construction-related materials and concludes assessing the efficiency gains of biomass-based cascading streams.

5.1 Energy-Related Materials

Since ages the forest sector as the main source of biomass has been an essential activity in many regions' economy. Forest industry in Maramureș Region has long historical roots: in the 1700s timber used to be acquired by individuals or small teams of workers who chopped trees down for their own use, be it for heat or construction. Early logging companies worked in the same area for years in the Carpathian Mountains, chopping down trees and transporting the logs down to the sawmills and wood manufacturing. Nowadays Maramures' wood industry nurtures and sustains communities from mountain and rural areas across the region and forestry revenues help to finance a wide range of public services that the inhabitants rely on every day. The citizens in Romania can take pride in their forests because this region is home to the biggest share of remaining virgin forests in Europe.

Research, technology and innovation can develop the higher added value furniture industry or provide the next generation wood products development. Under-utilized species, smaller stems, dead trees, mill residue, and debris from silviculture or harvesting, now have new value as raw materials for next generation forest products as well as fuel for bioenergy production.

The dramatic expansion of new products and services that promise to generate new wealth, more skilled jobs, and greater stability for communities and workers. Furthermore, the potential of forest residues and wood industry by-products, previously dismissed as waste, can strengthen the regional energy sector, providing heat-and power for locals. This promise can be met with a clear vision and targeted actions for further wood manufacturing. The overarching goal is to generate, on a consistent and sustainable basis, the greatest possible economic benefits per hectare of harvested forest land.

5.1.1 Energy-Related Materials from Solid Biomass

According to the estimative global calculation, forestry and forest-based industry are generating an annual 90.000 tonnes of wood waste in Maramureș county, having an estimative 7 mio. EUR economic value (AMEMM, 2012). Most of these wood residuals are converted into biomass and used as fuel at big wood manufacturing factories, at biomass boilers or on household level producing heat. Additionally they can also be used to generate power energy for domestic use, energy supply to factories, as well as to provide electricity to the national power system. Most of the wood by-products produced at sawmills and pre-processing of wood is already used as biomass fuel, while the forest residuals at the logging process is not harvested efficiently. According to the local stakeholders, there is huge space for improvement in this area.

The cultivation of energy willow in Romania started in 2008, and according to Romanian experts, the local agroclimate is suitable for energy willow plantations in Baia Mare (Domokos A, 2019).

In order to implement the cascading concept in valorisation of solid biomass materials, collaboration between forest owners, wood harvesting companies, big sawmill companies, local furniture producers, domestic bioenergy technology producers and bioenergy consumers is ongoing. One of the most relevant example for this is the Erpek IND Srl: a member of Green Energy Cluster that installed more than 170 biomass boilers with total nominal capacity of 22 MW across the whole Romania In doing so the company used sawdust, wood by products, green wastes from urban public areas, energy willow and all kind of wood residuals from forest management activity, first converted into wood chips and then into thermal energy. These biomass-to-energy facilities use the local wood biomass residuals from local sawmills, collection of branches, forest residuals, etc.

5.1.2 Industrial Hemp as a Potential Bioenergy Crop

Recent studies investigated the potential of industrial hemp as a bioenergy crop. Following Kumar (2017) concludes that “phytoremediation is a eco-friendly process to remediate heavy metal and other forms of contamination in the contaminated land. The feasibility of this approach must be supported by those crops which have the potential to produce economic benefits. In current scenario, the fastest growing source of renewable energy is bio- energy. The cultivation of energy crops on arable land can decrease our dependency on continuously depleting fossil resources. Further, it could also mitigate climate change. Hemp is an annual herbaceous crop that has been used by human civilization for several years for its seeds and fibres. Hemp (*C. sativa*) has also been proved as an efficient phytoremediator for heavy metal-contaminated sites. Apart from phytoremediation, hemp produces high biomass which have been used for production of bioenergy such as bioethanol, biodiesel, biogas, biomethanol, etc. Using hemp as a remediation agent, the sustainability and applicability of the phytoremediation approach could be managed well by the profitable income generated through the production of bioenergy" (Kumar, 2017, p.281).

Additionally, "agronomy data suggest that the per hectare yield (5437 kg) of industrial hemp stem alone was at a similar level with switchgrass and sorghum; while the hemp plants require reduced inputs. Field trial also showed that ~1230 kg/ha hemp grain can be harvested in addition to stems. Results show a predicted ethanol yield of ~82 gallons/dry ton hemp stems, which is comparable to the other three tested feedstocks. A comparative cost analysis indicates that industrial hemp could generate higher per hectare gross profit than the other crops if both hemp grains and biofuels from hemp stem were counted" (Das et al, 2017, p.641).

"In summary, hemp has great potential to become a promising commodity crop for producing both biofuels and value-added products that can improve the stigma surrounding its applications" (ibid, p. 646).

5.2 Construction-Related Materials

Studies have shown that the cement industry is responsible for approximately 5-8% of the CO2 emissions around the world, thus having an important environmental impact. The pollution resulting from this activity is caused by both energy consumption and the high number of residues produced (Gonzalez-Kunz, 2016). On the other hand, a lot of waste is produced by biomass direct burning for energy production. One resulting waste stream is biomass fly ash (BFA), usually used in agriculture, and the other one is called biomass bottom ash (BBA), usually deposited in landfills. Literature states that considering the growing trends of obtaining energy from biomass, the residues from this process will soon be comparable to the fly ashes produced by burning fossil fuels (González-López, 2014). Furthermore, it has been proven that there are environmental risks associated with BBA, as ashes containing heavy metals that leach into underground and surface waters, ultimately threatening human health (Gonzalez-Kunz, 2016).

In a 2018 study on bio-economy, the European Commission declared that the demand for industrial biotechnologies is likely to double in the next ten years, as the need for innovation in bio-products production is absolutely necessary in order to decrease the pollution resulting from the current practices. The same document highlights the need for strengthening the relation between economic, social and environmental issues. Thus, finding possible uses for this waste should be a top priority for future sustainable strategies, and linking these usages with the construction industry would be a great achievement. The investigation of agro-industrial waste for construction materials is gaining popularity, as an ecological, organic alternative building material to replace cement in the future (Frias, 2017). Both biomass bottom ash and vegetal fibres were tested and declared suitable for partially replacing raw materials in cementitious materials (da Costa Correia, 2017; Frias, 2017).

5.2.1 Upcycling of Agricultural Waste and Biomass

According to Gonzalez-Kunz et al. (2016), several researchers studied the applicability of plants waste in construction materials. Aprianti et al. (2015) studied the potential uses of several agricultural wastes for cementitious materials, such as rice husk ash, palm oil fuel ash, bagasse ash, wood waste ash, bamboo leaf ash, olive fly ash, all of them being responsible for huge amount of waste disposals every year. On the other hand, Brás and Faustino (2016) studied the possibility of adding biomass ash in concrete and mortar compositions (for CEM-I and CEM-II, with a 20% of sand replaced with BBA), while Madurwar et al. (2013) reviewed the application of agro-waste in sustainable construction materials. In what concerns the vegetal fibres from agro-industrial resources, their application as reinforcement in cementitious materials in macro, micro and nanometric scales was tested. Fibres coming from banana, sisal, hemp, green coconut, sugarcane bagasse, curaua, bamboo pulp, pine and eucalyptus were tested by a group of researchers as reinforcement for cementitious materials (da Costa Correia, 2017). Furthermore, at the end of the 20th century researchers started studying the use of vegetal fibres for obtaining sustainable fibre cement composites (ibid.), while Vo (2016) mentions *miscanthus x giganteus* (a well-known biomass energy crop) as an ecological alternative for construction materials such as isolation panels and bio-concrete blocks. A more comprehensive description for the inclusion of waste in construction materials can be found for the production of pozzolans with sugarcane wastes, considered an alternative construction material for countries with developing economies (especially in Asian and Latin American countries). As fibres, sugarcane waste can be used for the fibres manufacture and fibre-reinforced composite materials, while as ashes it can be used for refractory materials, supplementary materials in cement, etc (González-López, 2014).

Additionally, Brümmer et al. (2020), discussed the potential of hemp concrete as a high-performance material for green building and retrofitting:

"Currently about 5,000 tons of hemp material is yearly employed for construction purposes in France, the country that started to develop in insulating building materials from hemp in the early years 90 followed by other European countries and developing in the last 15 years towards a global interest, undertaken by a growing research on this field. The materials are based on the two main components of the hemp stem: fibre (about a third part of the stem material) and the more abundant woody core (historically often considered as waste product of hemp fibre de-cortication), transformed mainly into particles of 2-25 mm length, called hemp hurds or shives. Hemp is naturally free of nutrients for parasites, it doesn't need to get protected, like wood and some other plant-based materials and is difficult flammable (classification B1 or B2). Construction materials based on hemp range from loose wool (100% hemp) or thermo-welded insulating panels (85% hemp fibre or 80% hemp fibre and hurds) and non woven felts for acoustic damping or leveling (100% hemp fiber) to particle boards for dry walls and ceilings (up to 100% hemp), pellets for slabs (pressed dust, by product of hemp fiber decortication), hemp fiber reinforced polymers for façade panels and curtain walls and hemp oil based varnishes. Hemp insulation panels replace non renewable

resourced and energy consuming insulation materials like glass and rock wool, that show the same or very similar thermal conductivities. […] the most versatile insulation material is hemp concrete. Mixed e.g. with hemp hurds, lime (or other natural binders) and water, this material allows a consumption of up to one cubic meter hemp hurds per constructed square meter. the whole building envelope can be done with it, since its mechanical strength and fire classification are more favorable then in hemp wool insulators and even an important fire resistance (more than 120 minutes) can be achieved in load-bearing concretes, without reducing the hemp content. Its aptitude for inside applications and its water vapor diffusivity makes it very interesting not only for bioclimatic architecture but also for retrofitting of vernacular architecture. Furthermore a un-rendered 30 cm thick hemp concrete wall enables a storage of 36.08 kg of CO_2 per m^2 (Kennet and Miller, 2012)".

(Brümmer et al., 2020)

Overall, vegetal fibres and bio bottom ashes have demonstrated benefits on multiple levels. From an economical point of view, their use implies lower costs for raw materials and thereby low production costs, which may contribute to keep lightweight fibre cement in the market (da Costa Correia, 2018). In what concerns the environmental benefits, their use contributes to reduce both fibre cement sheets impact, as well as land and underground water pollution caused by disposing BBA on landfills. Furthermore, these materials have been proven to be beneficial for human health. Despite the growing interest shown by researchers in the partial replacement of cementitious materials with vegetal waste, and even if their environmental, economic and health benefits have already been proven and their chemical and physical properties were certified, their commercial use is still limited. SPIRE will nonetheless aim at testing and improving the performance of innovative bio-based materials in Baia Mare, with the ultimate goal of upscaling the experimentations' results to larger contexts.

5.2.2 Production process

In what concerns the production process, the main action to be undertaken when partially replacing cementitious materials with plant-based waste is to verify if the chemical properties are suitable for construction materials, and in what proportions should plant-based materials be used in order to assure proper physical properties.

For the chemical properties for instance, the pozzolanic activity of bio bottom ashes was tested by using an accelerated chemical method: replacing 20% of raw material for cement paste with bio-ashes proved to be sufficient to develop pozzolanic cements (Frias, 2017). In what concerns the physical properties of cementitious materials, complying to EN 459-1 standards defined by the European Committee for Standardization (2001), only time and volume stability should be determined, therefore the calculation of the water content in cement pastes. Yet, Spanish researchers highlighted additional characteristics which should be monitored, such as the type and amount of impurities in the waste, as it modifies material's viability and performance (Frias, 2017). Furthermore, mechanical properties such as porosity, flexural strength, density and compressive strength are considered important (Beltrán, 2015). In what concerns fibre cement manufacturing, the first method was invented by Hatschek in the 1890s, who mixed cellulose pulp, reinforcing fibres, Portland cement and mineral additions in water (da Costa Correia, 2018). According to Vo (2016), usually biomass materials are used in the raw condition, and the preparation process of cement paste is very similar to the usual concrete mix, but it is carried out against different standards. Sometimes, washing and chemical pre-treatment stages are necessary if vegetal waste is contaminated (Vo, 2016). To conclude, it has been proven that cementitious materials that include plant-based replacements provide the following benefits (Vo, 2016):

- Reduced density in concrete;
- Proper strength achieved in structural lightweight concrete (which raises its marketability);
- Enhanced flexural strength, ductility and fracture energy;
- Energy savings;
- Enhanced indoor air quality;
- Good thermal insulation and acoustical absorbency.

5.3 Cascading Streams' Efficiency Gains

Keegan et al. (2013) thoroughly discussed the efficiency gains of cascading streams:

"The concept of cascading the use of biomass is applicable when there is a linear system in which biomass progresses through a series of material uses, by reuse and recycling, before finally being used for energy recovery. The concept has been traditionally applied in the forestry sector to allocate wood resource into pulp and paper, wood processing, and energy industries. These different sectors are connected as part of a cascade, as well as by recycling loops between different steps, such as the use of sawmill residues in the pulp and paper sector and the recycling of paper.

Cascading biomass use offers significant efficiency gains, maximizing the value extracted from a given amount of biomass by fulfilling both material and energy needs from the same feedstock.

Biomaterials and bioenergy share the common potential to reduce GHG emissions and, as such, it is undesirable for the development of either to be hindered by, inevitable, competition for biomass resources. In theory, applying the cascading use principle more widely would allow material and energy uses of biomass to be achieved in a complementary way, allowing the benefits of both biomaterials and bioenergy to be realized. By preferentially directing virgin biomass toward material uses over energy, cascading use maximizes the amount of carbon sequestered in biomaterials. The Commission's consultation (European Commission, 2011) on the bio-based economy found consensus among respondents that significant improvements in efficiency in the use of renewable resources can be obtained through cascading use. The time dimension of cascading use of biomass is also worth of consideration: biomass employed in construction, for example, sequesters significant volumes of carbon, postponing its emission into the atmosphere, but also results in this biomass being unavailable for energy use for decades or more at a time.

Having collated the results of various lifecycle analyses comparing potential GHG emission savings on a per hectare basis, Carus et al. (2010) conclude that savings derived from material biomass uses are at least in the order of magnitude of savings from first-generation biofuels and in most cases higher than that. Biomaterial use does not seem to unambiguously outperform solid and gaseous biomass use for electricity and heat production but the authors indicate that when biomass is used in a cascading way, an additional 10 to 20 tonnes CO2-equivalent/hectare can be abated on average, making a rather clear case for the preference of material use with subsequent energy recovery.

Against this background, a support framework based on the principle of maximizing GHG mitigation would have important implications for the bioenergy sector. This does not necessarily imply that bioenergy pathways would become generally untenable, but it might necessitate a restructuring of the resource base of bioenergy generation towards increased *use of waste products and advanced conversion technologies. A regulatory framework adhering to resource efficiency standards and seeking to maximize the contribution of biomass use to GHG mitigation would steer biomass into those pathways with the highest GHG mitigation potential"*

(Keegan et al., 2013, p. 5).

6. Digital technologies and instruments

This Chapter introduces a set of emerging digital technologies and tools that are increasingly contributing to the transition towards the smart city under many strands. In particular, these include blockchain technologies, local digital currencies, and geographic information systems.

The beginnings of Blockchain technology date back to 2008 when Satoshi Nakamoto launched on the Internet the first white paper. 2008 is the root of the peer-to-peer decentralized cryptocurrency called the Bitcoin protocol. The basic idea of cryptocurrencies was developed in 1990 by the academic entrepreneur David Chaum, but it only gained momentum in the aftermath of the 2008 financial crisis. So far, this technology is of Interest due to the advantages it presents in front of traditional currencies, such as the exclusion of third parties from trading transaction, thus resulting a reduction of trading costs, more confidential transactions, stronger security, and increased transparency. Below is a detailed description of all the advantages that a virtual currency comes with.

Local currencies are generally designed to encourage local economy and increase sales of goods and services within local communities and among local businesses. This generally leads to a reduction of the carbon footprint (due to transportation reduction) and a boost of the local economy thanks to capital being kept locally. Another relevant advantage for local business is promotion as part of the scheme's promotion material. The main disadvantage of local currencies is that users do not benefit from the same level of consumer protection, as the currency is not backed by legislation or a national bank. In terms of Digital Currencies, these are even less reliable, due to the high volatility of the whole process, lack of financial or assets backup for the emitted coin, etc.

A local currency can be defined as a currency that can be spent in a particular geographical area, by participating organizations and citizens. (Naqvi and Southgate, 2013)

Some countries, Romania included, prohibit the creation of local coins in a physical form, as the Central Bank is, by legislation, the only one entitled to produce coin. However, electronic coins are legally acceptable if created by banks and local authorities, in a well-regulated framework. Cryptographic currencies are unregulated, since they are based on trust amongst participants.

Geographic Information Systems (GIS) are more and more present in everyday life. Starting from simple maps (such as OpenStreetMap, build by crowdsourcing), to satellite imagery (such as Google Maps), or from simple cadastre data (parcel based and up-to-date land information system) to city digital twins (digital replica of a city), such initiatives support everyday activities for citizens, business and authorities. They enhance transportation, help reduce costs and time, empower cities to better manage infrastructure, monitor the progress of works, etc.

Vegetation monitoring is conducted through remote sensing, and specific indices, such as NDVI (Normalized Differenced Vegetation Index), which enables a distinction between vegetation and other types of land cover and gives important clues on the vegetation quality and quantity. Other Pigment specific calculations (e.g. PSRI - Plant Senescence Reflectance Index) indicate plant senescence and health state. A major advancement in using Earth Observation data was provided by the European Space Agency's Copernicus programme, which provides 10m spatial resolution data for free usage.

Commercial satellite data is available for resolutions up to 0,5 meters, while 0,3 meters are expected to be commercially available before the end of 2021, providing observations almost as good as on-demand drone or aircraft flights, but at significantly lower costs.

This Chapter discusses in depth the potential of these tools and technologies as well as the conditions for their adoption and the expected results in the framework of SPIRE.

6.1 Virtual currencies and Sustainable Development

There is no one agreed-upon definition of Virtual Coins. Some relevant European bodies have provided their own definitions, such as the European Banking Authority (EBA) which defines a Virtual Coin as a "digital representation of value that is neither issued by a central bank or public authority nor necessarily attached to a fiat (conventional) currency, but is accepted by natural or legal persons as a means of exchange and can be transferred, stored or traded electronically" (EBA, 2014, p. 7). The European Central Bank (ECB) defines a Virtual Coin as a "type of unregulated, digital money, which is issued and usually controlled by its developers, and used and accepted among the members of a specific virtual community".

One of the most important features of Virtual Coins is that they can be sent directly from one place / user to another, without the support of an intermediary (like bank). This is possible because Virtual Coins are supported by its users through a peer-to-peer computer network. Because the third part of the trading process is missing, namely the intermediary between the sender and the recipient, the total costs of payments will be reduced, and the efficiency of the financial world will increase. (Lee and Chuen, 2015)

Units or tokens are stored in electronic wallets, identified by unique addresses (one or more). The term "wallet" is use as a more user-friendly way to name actually a software which run on your own computer to manage your virtual coin.

This address is randomly generated and consists of a combination of letters and numbers. When a unique address is generated the user is not required to provide personal Information.

The transaction is possible due to key system. Each Virtual Coin address contains a private key and a public key. First key is the private one, which ensure the security of the virtual wallet. With the help of this key the wallet can be unlocked. After the process of unlock, the wallet can receive or send Virtual Coins. The second is public key, which confirm all payment process send from a specific address. The address can be finding by anyone, but no one can access the wallet to allow receiving and sending coins without the private key. (Baker, Filbeck and Harris, 2018).

The data that is stored when a transaction occurs:

- Input address or sender (can be one or multiple senders)
- Output address or recipient (can be also one or multiple)
- Number of coins send to the receiver
- Time at which the transaction was added to the network

Data about all transactions are stored in a public decentralised ledger (blockchain) which are the main technological innovation of every Virtual Coin.

The blockchain is maintained by a community of "miners". The role of miners is to provide computational power for transaction processing. More exactly, the miners add new blocks (digital information consisting of several transactions) to blockchain (every 10 minutes). The blocks are added to the blockchain in a linear, chronological order. Anyone can view blocks added to the blockchain and also, anyone have the possibility to connect their computer to the blockchain network as node. After a computer is linked to the network, it receives a copy of the whole blockchain that Is updated automatically in real time. In this way, computers make the information more difficult to manipulate ensuring added security in front of hackers. A hacker needs to manipulate every copy of the blockchain on the network. This explains the feature of the blockchain: distributed ledger.

Most blockchain developers pay miners a reward for the processing power. Transactions are validated through cryptographical means. There are mainly two forms of reward for miners: fees and coins created in the process of validating the transactions.

Miners, or more specifically, the nodes that are part of the blockchain network, validate payments and record them in a newly created block by solving a computationally demanding mathematical problem that is created and specified by the Cryptographic Protocol". Only the first miner to solve the problem is rewarded.

One of the challenging issues regarding cryptocurrencies is that it usually involves a high degree of anonymity. Users are only identified by their cryptographic address, not real identification, raising thereby suspicions of money laundering or financing illegal activities.

The most relevant crypto currencies in circulation are Bitcoin (the first and most popular currency), Ethereum (a crowd funded initiative that encourages user involvement rather than large pool mining), Ripple (aiming at being used by the banking sector to replace SWIFT transactions), Bitcoin and Litecoin. However, more than 1500 crypto currencies exist.

6.1.1 The Need for Digital Currency

In the beginning, in important to mention that the real author of Bitcoin is an unknown person or entity which use the name Satoshi Nakamoto. Bitcoin was created as a reward for computational processing work, known as mining, in which all users participating in the great Bitcoin network offer their computing power to verify and record payments into the public ledger.

The first studies and implementation of a virtual coin (cryptocurrency) was conducted by Satoshi Nakamoto, the creator of Bitcoin. He proposes through the white paper launched on the Internet In 2008, the year of word crisis, a purely peer-to-peer version of electronic cash which works through the Internet and which completely excludes the intervention of a financial institution in carrying out a transaction.

The concept started after identifying two of the most important downsides of the financial institution serving as trusted third parties to process electronic payments, respectively the fact that completely non-reversible transactions are not entirely possible and the costs for transactions and the mediation. Transactions that are computationally impractical to reverse would protect sellers from fraud, and routine escrow mechanisms could easily be implemented to protect buyers. (Nakamoto, 2008)

6.1.2 Expectations

The specialized literature presents the Internet as being a great technological achievement managing to connect people from all over the earth. It also believes that the blockchain will have a much sharper growth in the world, accepting this innovative technology much faster than the Internet has accepted. Blockchain aims to be a continuation of the process of connecting. Like Internet of Things (IoT) connects machines, the blockchain may become "Internet of Money", connecting finances.

“With revolutionary potential equal to that of the Internet, blockchain technology could be deployed and adopted much more quickly than the internet was, given the network effects of current widespread global Internet and cellular connectivity”. (Swan, 2015, p. xi)

6.1.3 Technology Behind a Cryptocurrency

The definition of the coin in Satoshi Nakamoto’s view is: "We define an electronic coin as a chain of digital signatures. Each owner transfers the coin to the next by digitally signing a hash of the previous transaction and the public key of the next owner and adding these to the end of the coin. A payee can verify the signatures to verify the chain of ownership." (Nakamoto, 2008, p. 2)

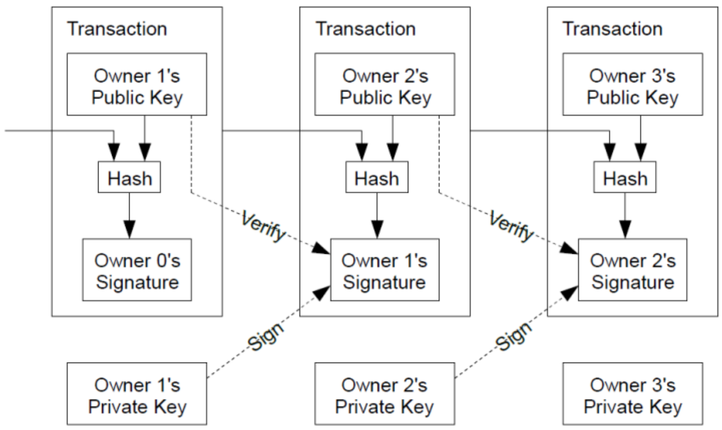

Figure 12 - Transaction flow[25]

A challenge in his initial model is that a payee cannot verify that the coin was not double spent by one of the previous owners, thereby some additional type of validation is required. This could be solved by a centralized system, but that would require everyone to trust that central system (also referred to as "mint"). In this model, all transactions are public, and the *mint* decides the order for processing, thereby discarding invalid ones (double spending), and all participants need to agree upon the order in which transactions are being processed.

The solution comes from using two key functions: hashing and timestamping. Hashing is running a computer algorithm over any content file and the result of which is a compressed string of alphanumeric 64-character. This string is a unique and private identifier which content cannot be back computed into the original content. The has is short enough to be included as text in a blockchain transaction, which thus provides the secure timestamping function of when a specific attestation transaction occurred. Timestamping server, that has the role to register the precise time of each transaction.

More exactly, the blockchain solve this problem by combining BitTorrent peer-to-peer file sharing technology with public-key cryptography.

As the technology is based on distributed computing, and proof of the fact that a transaction existed at the moment of the timestamp, a proof-of-work system was designed, so that the average required work (CPU processing) to redo a transaction exponentially increases as the block gets older. This was achieved through adding a nonce (variable) that is added to each block that is further used in a cryptographic process with an increased difficulty, in order to validate the correctness of the block and its transactions.

[25] Source: Nakamoto (2008)

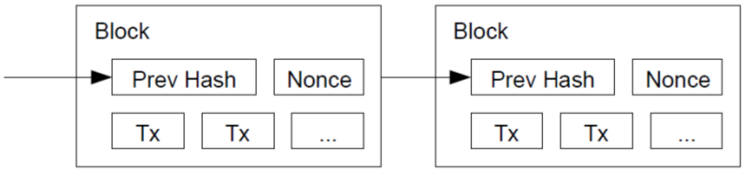

Figure 13 - Distributed Timestamp Server[26]

Blockchain is based on a network of processors (CPU) that performs calculus and validates blocks. The correct blockchain is the longest set of blocks (or the greatest proof-of-work invested in it). To modify an older block, an attacker would have to perform all work computed by all network nodes and surpass the work of all honest nodes, which in terms of cryptography is very unprobeable.

How the network of nodes works:

- New transactions are broadcast to all nodes
- Each node collects new transactions into a block
- Each node works on finding a difficult proof-of-work for Its block
- When a node finds a proof-of-work, it broadcast the block to all nodes
- Nodes accept the block only If all transactions in it are valid and not already spent
- Nodes express their acceptance of the block by working on creating the next block in the chain, using the hash of the accepted block as the previous hash

"Nodes always consider the longest chain is the correct one and all will keep working on expanding it". (Nakamoto, 2008, p. 3). In case two versions of the same block are broadcasted to the network, the correct one is considered the first received. However, both versions are kept until a new block is created.

An important challenge comes from getting nodes into the network. For this reason, a coin (reward) is created as the first transaction in a block. The first node to deliver the block receives the reward (coin). This aims to keep the nodes interested in validating transactions AND use their computing power to get the reward, rather than attempting to fake transactions.

A secondary challenge regards disk space, as described in the bitcoin whitepaper:

[26] Source: Nakamoto (2008)

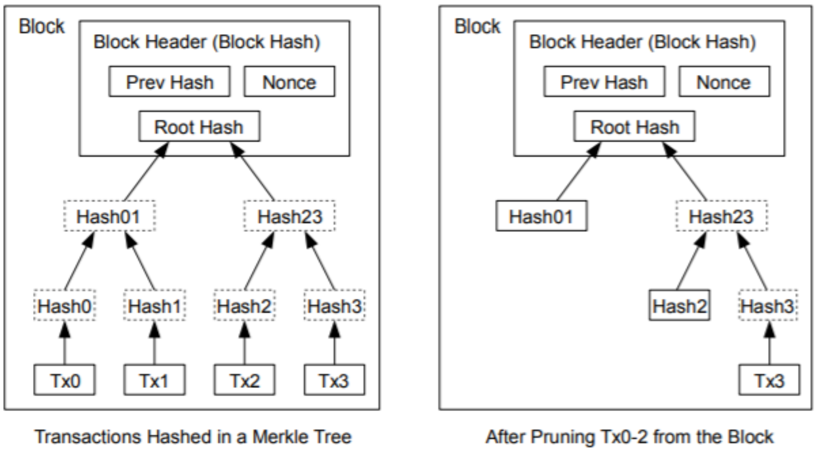

Figure 14 - Reclaiming Disk Space[27]

Payment validation does not require running a full node, but is feasible from using the block headers for the longest chain:

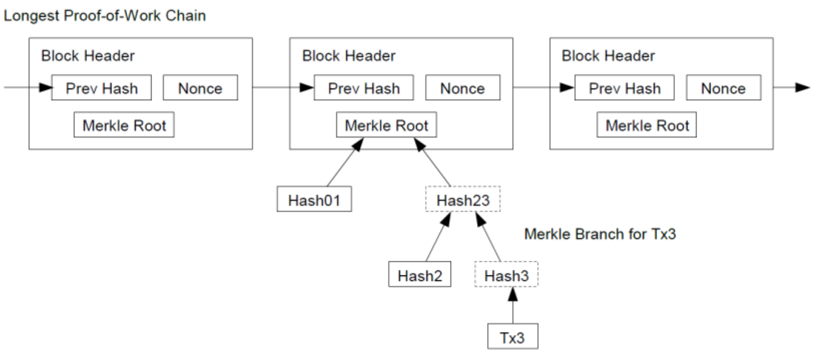

Figure 15 - Simplified Payment Verification[28]

6.1.4 Sustainability Through Local Currencies

Over the course of the last two decades, there has been extraordinary demand for the use of local currencies, and today we know of 2,500 different local currencies. Is a global trend which seems to be very beneficial and useful for both the citizens and the environment of a region. (DeMeulenaere, 2000).

Complementary currency - is used as a complement to a national currency (Robert Costanza et al., 2003) , as a medium of exchange, which is usually not legal tender. (Lietaer and Hallsmith, 2006)

Community currency - a complementary currency used by a group with a common bond, such as residents of a locality, association, or members of a business or online community.

[27] Source: Nakamoto (2008)
[28] Source: Nakamoto (2008)

Local currency - a complementary currency used in a locality. (Naqvi and Mona, 2013)

Regional currency - a local currency where the locality is a larger region.

Auxiliary currency, microcurrency, Eco-Money - less common synonyms for community or local currency. (Douthwaite & Wagman, 1999)

Private currency - a currency issued by an individual, business or non-governmental organization. Complementary currencies are a type of private currency.

Sectoral currency - a complementary currency used within one economic sector, such as education or health care.

Alternative currency - generally, a synonym for complementary currency, referring to a currency designed to work in conjunction with the national currency; less often refers to a type of private currency which attempts to supplant or circumvent the national currency.

In 1932, during the "Great Depression", the municipality of Worgl, Austria performed an experiment designed to help the local economy, based on "The natural economic order" study of Silvio Gesell from 1919 – a 20th century economist. They created a first "local coin" (a stamp scrip). Though extremely successful, the experiment was abruptly terminated by the Austrian Central Bank in 1933. The small city's population included 500 unemployed people and an estimate of 1000 close to unemployment. The mayor Michael Unterguggenberger had several projects that he wanted implemented in the city, such as paving streets, water distribution, planting trees and other infrastructure works). The city's financial reserves were limited to 40.000 Austrian schillings, by far insufficient for both social protection and investments. He used the amount as guarantee in a secured bank account and issued stamp scrip's worth of the same amount and used the issued stamp scrip to pay for works. A stamp needed to be put on the scrip each month (at 1% face value), so everybody paid with stamp scrip made sure they were spending it rapidly, thereby providing work for others. Eventually people needed new usage for the stamp, inherently getting to pay their taxes (surprisingly, in advance). This has led to a swift reduction in unemployment. They not only re-paved the streets and rebuilt the water system and all of the other projects on Mayor Unterguggenberger's long list, they even built new houses, a ski jump and a bridge with a plaque. Every one of the schillings in stamp scrip created between 12 and 14 times more employment than the normal schillings circulating in parallel.

Each region can adopt a local currency (virtual or not) that meets its needs. Both, local and virtual currency, help the community in development process. More exactly, this type of currency encourages the spending of money locally for regional economic development.

The main objective is to expand employment of local people on a permanent, long-term basis by helping them to create their own small business and by creating local markets for locally produced goods and services.

Another good reason to adopt one of the forms of local currency is because it can participate in CO2 reduction by rewarding citizens for action that protect the environment. As a secondary result in this endeavour to reducing gas emission would be traffic decongestion and the reduction of accidents at the local level.

These are just a few examples that can lead to a major effect on the wellbeing of citizens thus increasing the standard of living by creating a healthy and safe environment.

6.1.5 Usability of Blockchain in SPIRE Project

Blockchain, by its technological definition is a connector. In its raw form it connects a block to another block and so on, in its basic form it is intended to be a financial connector representing the "Internet of Money" but through SPIRE it is desired to take these technologies to another level.

SPIRE aims to link one good deed to another to form a giant chain of activities for the benefit of community. Blockchain is a new innovative technological tool with which SPIRE wants to create a united community that will participate in the good of development of the city.

With the help of blockchain, a rewards system will be created for citizens and commercial entities. This rewards system is created to stimulate ecological activities and to increase the internal economy of the city.

Because SPIRE aims to be a project close to the citizens that will increase their standard of living, trust and safety in the community, blockchain is the most appropriate technology. SPIRE through the rewards system, called iLEU does not copy Bitcoin. This currency used worldwide is an inspiration that confirms the good functionality and openness of people to this kind of rewards. The most important feature of Bitcoin is the security it has. All good security practices will be adapted and used to create the iLEU. An important difference, in security area, is that iLEU cannot be mined. By deduction, the verification nodes of a new transaction will not be represented by the citizens' personal computers, but the iLEU developer will make available to the citizens a suitable number of nodes that will ensure the maximum security of the rewards system.

This technology will be integrated into a user-friendly application that will help them track their transactions and the available amount in the electronic wallet.

6.2 GIS and Earth Observation in cities

Observation of the Earth began in 1960 when the TIROS satellite was launched mainly for meteorological reasons. After this important event was opened an era of applications of remote sensing data for a wide variety of themes. Now there is a lot of satellites like TIROS which provide valuable data for resource management and scientific understanding of the Earth. (George Joseph, 2015)

Europe leads this sensing revolution in space through the Copernicus initiative and the corresponding development of a family of Sentinel missions. This has enabled the global monitoring of our planet across the whole electromagnetic spectrum on an operational and sustained basis.

Nowadays, maps and globes are things that belong to the field of the past. Experts studying the surface of the earth used such materials long ago. With the evolution of technology have been found ways to transpose the surface of the earth into digital information that can be processed through the computer. This information about Earth which now is on computer, along with the tools for analysing them, make up a Geographic Information System (GIS).

GIS is a revolutionary tools in the study of the Earth, because with the help of GIS it is possible to evaluate not just map, is possible to evaluate whatever you want: land, elevation, climate zones, forest, political boundaries, population density, per capital income, land use, energy consumption, mineral resource, and a thousand of other things - in whatever part of the word interest you.

In more technical words GIS is a major spatial data handling tools for natural resources inventory and management.

6.2.1 Urban Planning with GIS and Earth Observation

Cities are constantly changing, and authorities face immense challenges in obtaining accurate and timely data to effectively manage urban areas. This is particularly problematic in the developing world where municipal records are often unavailable or not updated.

One way to solve all these issues which can appear at the city level is through introduction of tools like GIS (a system designed to capture, store, manipulate, analyse, manage, and present all types of spatial or geographical data) or like DIAS (platform which facilitates access to Copernicus Sentinel data and information products within the six Copernicus operational services) combined with other statistical data, help local administration or the urban specialist to understand and solve certain problems easier and faster.

The application of Earth Observation (EO) for addressing urban sustainability issues has gained significant momentum during the last decade. Nowadays we can enjoy a high resolution, multi-sensor system which combined with the latest technological upgrades such as:

computer speed and graphics capability, provides very high accuracy information that can be used by urbanism planning application.

There is a set of indicators which can be evaluated based on EO products. The raw Earth Observation data consists of multispectral radiance records. Applying an analysis method over these raw data will results different specific digital information helpful for evaluating land, density of forest, density of urban area, quantity of water, air quality, urban heat island and the list can go on. Some uses of Earth Observation (EO) in urban planning:

- EO can be applied in monitoring the urban environment by providing scientifically verifiable measurements of physical properties and their changes which are crucial to achieving sustainable urban development. These include air, vegetation cover studies, and the impacts of urban structure on microclimate.
- EO can be shown to be useful in population studies and for estimating population size between censuses.
- EO data have been extensively used for land use and land cover
- mapping in urban areas.
- EO data are a cost- and time-effective alternative to conventional methods for obtaining buildings data, and it allows planners to monitor changes in the number, size and area, density, layout, height, and volume of buildings.
- EO can help in planning new urbane zone. Green spaces, roads and bridges can be difficult to place but with EO a good analysing of city area is possible and all new investment in infrastructure can have a minimal negative effect on the environment or even lead to improvement of living level of citizens.
- EO data can monitor natural disasters - for example, inundation, can be monitored with EO-based indicators. With the help of environmental monitoring through EO, the management of difficult situations, which arise due to climate change throughout the year, become much easier to manage.

6.2.2 Earth Observation and Internet of Things

All new global data sets from space lead to a far more comprehensive picture of Earth. This picture Is now even more refined via data from billions of smart and Inter-connected sensors referred to as the Internet of Things (IoT).

In this modern word, IoT is the next big step of the Internet, representing a great advantage in gathering, analysing and distributing data that can be transformed into useful information. These sensors can be used Individually or, as is increasingly the case, in tandem with multiple devices, sensors are changing our world for the better.

Combining satellite data such weather, vegetation changes, land, sea temperature with data gathering on the ground that refers to temperature and pollution, these together can provide a much clearer picture of climate changes and the Impact of humans on our planet. (Mathieu and Aubrecht, 2015)

6.2.3 Earth Observation and Machine Learning

As a broad subfield of artificial intelligence (AI), machine learning is concerned with algorithms and techniques that allow computers to “learn” by example.

To provide relevant results, an application that uses machine learning must first go through the training process. This training process requires information that the application can process regarding the object of study. The more information provided, the more accurate the predictions made by machine learning will be.

Coming as an extension of remote sensing, machine learning provides immense help in a wide variety of applications such as: science, business, health care and engineering. Usually, machine learning works with data in different form (image, video, sensor, health records, etc.). It can be used in understanding this data and crating predictive and classification tools. In this way numerous decisions at the urban level can be taken without Introducing human errors.

Some applications of machine learning:

- Vegetation Indices - measurement of global trends in vegetation
- Agriculture - estimating crop yield, disease detection in crops
- Level of an urban area - mapping settlements and buildings to estimate poverty in developing countries

6.2.4 Earth Observation, Agriculture and Smart farming

Climate change is becoming a growing problem worldwide. These changes can impact urban climate, traffic, social and economic considerations, which are inherently spatial in nature. Earth Observation manages to provide information that can help both, to improve the situation and to keep under control these types of problems.

These climate problems can affect also the agricultural area. With help of the red a near-infrared bands which are provided by remote sensors are used for studying vegetation. Agricultural efficiency and competitiveness can be enhanced through the practical application of data products that are derived from reflectance measurements taken in these spectral regions (International Space Station, 2009).

EO has been used for agriculture since the 80th of the last century, however the availability and quality of the satellite data has increased drastically since 2015 with the Copernicus program. "Especially Sentinel-2 and -1 are providing excellent time series of data about crop types, biomass development, calamities and farming practices (ploughing, seeding, etc.) can be derived with high accuracy. More accuracy means lower production costs, as resources such as water, seeds and fertilizer are not wasted". (Mathieu and Aubrecht, 2015, p. 261)

For sustainable agriculture and smart farming need data driven information services. These support sustainable and cost-effective agriculture combining EO and navigation satellites input with information from ground sensors to help farmers decide how, when and where to allocate resources for the best economic and ecological results.

All in all, smart farming supports ecologically and economically sound agricultural management via site-specific application - an Important step to a sustainable agriculture.

6.2.5 iGIS

"intelligent" Geographic Information System (iGIS) is a framework which provides scientific and technological solutions for a wide range of highly demanded task such as monitoring and decision-making support at the level of the objects and situations as well as tools and means of artificial intelligence (Vodyaho and Zhukova, 2014).

The components that iGIS platform incorporates:

- An inference machine and expert system
- A knowledge base system
- Visual environment for developing classes and objects of subjects' domain
- Visual environment for developing models(script) of the object behaviour in GIS
- System for scenario implementation in real time or/and user-defined arbitrary scale with visual display of symbols or Images on the background of electronic maps
- A decision-making support system that provides recommendations during the scenarios playing

iGIS is an important component in the SPIRE Project. It is used for education, gamification, assessment and measuring of project KPI. The platform itself leverages on Remote sensed data, ground truth, scientific indexes and Artificial Intelligence (AI) in order to provide a complete overview of the intervention area, as well simulations of impact of replication in further areas using AI. Multimedia tools will enable visualization for students and local stakeholders, enabling them to simulate effects of actions and understand specific NBS and processes.

In conclusion, all the technologies that have been presented above, represent an important pillar in the construction of the SPIRE project. The advanced technology we have in the 21th century is an opportunity for every city to transform into a smart city capable of offering its inhabitants a better, friendlier living environment. The ecosystem in which we live and the people who are part of a certain community is forced to evolve with technology, all these three components growing together, form a total balance that ensures good functioning and good coexistence.

7. Case studies

This Chapter provides a collection of best practices and model examples across Europe on the domains of brownfields regeneration, bioenergy, digital currencies, and GIS/Earth Observation.

7.1 Brownfield Regeneration Case Studies

This Paragraph provides a selection of model examples of brownfield regeneration initiatives carried out in different European Regions. The case studies are described paying particular attention to the new land-use of the target areas, as well as to the management instruments and governance arrangements adopted.

7.1.1 Coresi Business Park – Brasov, Romania

Key Facts	
Location	Brașov, Romania
Brownfield Size	120 ha
Original Function	Tractor production facility
Instruments	Masterplan, Real estate investments
Stakeholders	Immochan Romania Municipality of Brasov
Partnership	Avantgarden Immo Invest Ascenta Management
Project Cost	Ca. 350.000.000 euro


source: Property Forum[29]

Table 8 - Coresi Business Park – Project Key Facts

Located in the North-East side of Brasov, the development site covers approximately 8% of the city's building area and will be completed over the next 10 years.

Originally opened in 1925 as an airplane factory, it has been reconverted into a successful tractor production facility during the Russian occupation at the end of World War II in 1946. The factory kept working until 1990, when a period of continuous decline started. In 2007 the company's assets were sold to an investment funds managed by a UK-based advisor: Cheyne Capital.

The redevelopment of the brownfield started in 2012, when Immochan Romania invested in the development of a shopping centre in the area.

In 2016 Immochan Romania decided to further expand its business spheres and to invest in residential housing and office development. Avantgarden Immo Invest and Ascenta Management partnerships were created ad-hoc in order to manage the residential and office branches, respectively.

[29] https://www.property-forum.eu/news/brasovs-coresi-business-park-expands/273

Currently, Coresi District Park is a self-sustainable ecosystem that integrates three main components: a shopping centre - Coresi Shopping Resort, a residential compound - Coresi Avantgarden, and an office district - Coresi Business Park.

7.1.2 Manufaktura – Łódź, Poland

Key Facts	
Location	Łódź, Poland
Brownfield Size	18,5 ha
Original Function	Cotton products company
Instruments	Private Investments
Stakeholders	Poltex's board Apsys Polska
Project Cost	200.000.000 euro

source: Wikimedia[30]

Table 9 - Maufaktura – Project Key Facts

Located at the edge of Łódź's city centre, the project site extends over a total surface of 18,5 hectares.

Before World War I the complex hosted a huge factory, the "I.K. Poznański Cotton Products Company", inclusive of a (at the time avant-gardist) multi-storey housing estate for workers. After the war, the owner family lost its fortune and the factory remained closed until it was nationalised at the end of World War II.

In the early 2000s, the complex has been established as a national monument and the president of the factory's board (Poltex) started the search for potential investors willing to reinvent and regenerate this post-industrial space.

The private company Apsys Polska started construction works in 2003, restructuring the 9 hectares of the factory's abandoned premises and developing new multifunctional buildings on a further 9,5 ha neighbouring plot of land.

As a result, nowadays the former Izraela Poznańskiego factory became *Manufaktura*: a key attraction for both for tourists and residents, offering a shopping centre alongside cultural public spaces and an entertainment centre.

[30] Photo by HuBar - Praca własna, CC BY-SA 2.5, https://commons.wikimedia.org/w/index.php?curid=790797

7.1.3 King's Cross – London, United Kingdom

Key Facts	
Location	London, United Kingdom
Brownfield Size	27 ha
Original Function	Rail and industrial facilities
Instruments	Masterplan, private investments
Stakeholders	U.K. property developer Argent U.K. state-owned London and Continental Railways Limited (LCR) DHL Supply Chain (formerly Exel) London development agency (LDA)
Partnership	King's Cross Central Limited Partnership (KCCLP)
Project Cost	£2.200.000.000 (private investments)

source: Wikimedia[31]

Table 10 - King's Cross – Project Key Facts

Probably the largest plot of run-down and under used land in central London, the brownfield extends over an area of 27 hectares.

Even though King's Cross has been a thriving industrial transport hub during the Victorian era, by the 1970s its logistic buildings and warehouses had fallen into dereliction and the area became one of the least profitable of the whole centre of London.

The project site is owned by KCCLP: a joint venture partnership among U.K. Property Developer Argent, the U.K. state-owned London and Continental Railways Limited (LCR), and DHL Supply Chain (formerly Exel).

The project involved turning 27 hectares of brownfield land into offices, retail space and 2,000 homes, all organized around a 10.5 ha public open space. It also included the enlargement of the station's western concourse with 2,800m² of retail floor space for shopping and dining and a new King's Cross Square that boasts a food market, pop-up events, and public art.

Sustainability is a very important aspect of this intervention, which aims at reducing carbon emissions by at least 50% relative to 2005 levels. For this purpose, the project developed its own Energy Centre with a Combined Heat and Power Plant (CHP). Each building at King's Cross is connected to the Energy Centre through a hot water distribution network. Moreover, thanks to an optimal orientation and the to the use of dense materials, it has been possible to maximise the energy efficiency and minimise the environmental impact of all new residential buildings, towards the achievement of the BREEAM certification.

[31] Photo by Crookesmoor - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=76751893

7.1.4 The Gasometers – Vienna, Austria

Key Facts	
Location	Vienna, Austria
Brownfield Size	2,2 ha
Original Function	Gas storage tanks
Instruments	Plan to limit pollution; Architectural competition
Stakeholders	Municipality of Vienna
Project Cost	150.000.000 euro

source: Wikimedia[32]

Table 11 - The Gasometers – Project Key Facts

Causing serious contamination of soil and groundwater, Simmering Gasworks was one of the first historically contaminated sites to be listed in the national remediation program in 1990. The Gasometers have been operational between 1899 and 1966, when they were finally closed because the fission of natural gas become the primary technology of producing "city gas";

Before starting to think about the reuse of buildings, it was necessary to solve the problem of pollutant sources and contaminated groundwater. It was elaborated a comprehensive remediation project to prevent and limit groundwater pollution with 4 lines of action:

- Controls of contaminated water, construction of a water treatment plant nearby;
- Removal of primary contamination sources;
- Clean-up of hot spots;
- Recycling of brownfields.

In parallel to the remediation activities at the hazardous site, the location of the former Simmering Gasworks has been developed as a new city quarter. In 1996 the City of Vienna decided to hold an architectural competition to gather ideas for the subsequent mixed use of the gas holders;

Well-known architects designed the transformation of the gas holders and nowadays they are as city within the city. Each gasometer has been divided into several zones for living (apartments in the top), working (offices in the middle floors) and entertainment and shopping (shopping malls in the ground floors).

[32] Photo by Bwag - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=42853989

7.1.5 Park of Nations – Lisbon, Portugal

Key Facts	
Location	Lisbon, Portugal
Brownfield Size	330 ha
Original Function	Industrial district (oil refinery; oil and fuel storage; industrial slaughterhouse)
Instruments	Masterplan, Urbanization plan (UP); Environmental monitoring Plan
Stakeholders	Municipality of Lisbon

source: Wikimedia[33]

Table 12 - Park of Nations – Project Key Facts

Located in the North Eastern edge of Lisbon, the 330 hectares project area was originally occupied by several heavy industries and infrastructures including an oil refinery, oil and fuel storage facilities and an industrial slaughterhouse.

With deindustrialisation the area rapidly felt into dereliction until a regeneration process was started in 1992, when Lisbon was bestowed the hosting of 1998 World Expo.

The principle underlying the intervention was to combine permanence with ephemerality, and the strategy for the requalification of the area included the use of an Urbanization Plan (UP) aiming at "the urban renovation and reconversion of the Redevelopment Area and the priority development of Expo'98";

Specifically, the following actions were taken:

- Demolition of the existing industrial structures, and where necessary, their deactivation;
- Recycling of the materials;
- Soil and water decontamination;
- Recovering of landfill;
- installation of a waste-water treatment moving plant.

Furthermore, the exhibition site was integrated into the daily-life urban fabric: the layout of the exhibition site was changed into an authentic urban structure inclusive of a system of streets and squares. In particular, residential areas, public facilities and financial groups' head offices and services were incorporated in the project; and new network systems of accessibility and communication were implemented.

[33] Photo by René Bongard, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=85002904

7.1.6 Landschaftspark – Duisburg, Germany

Key Facts	
Location	Duisburg, Germany
Brownfield Size	180 ha
Original Function	Industrial buildings
Instruments	Policy of preservation; International Building Exhibition Emscher Park (IBA)
Stakeholders	State of North Rhine-Westphalia; Citizens; Ruhr Regional Association; Municipality of Duisburg
Partnership	German Industrial Heritage Association Nordpark Interest Group

source: Wikimedia [34]

Table 13 - Landshaftspark – Project Key Facts

The decommissioned Thyssen ironworks is located at the centre of a ca. 180 hectares area in Duisburg-Meiderich. The factory produced pig iron from 1901 until its closure in 1985 with the last tapping of Blast Furnace 5 on 1985.

Local politicians were inclined to demolish the old industrial buildings, but a group of local citizens and experts joined forces to resist to the demolition of the ironworks. This commitment led to the establishment of the German Industrial Heritage Association and the Nordpark Interest Group.

Meiderich ironworks were finally saved in 1988 with the foundation of the International Building Exhibition Emscher Park (IBA), which allowed to convert the old factory into the centrepiece of this major industrial and cultural project.

Additionally, the foundation of the IBA also led to the creation of the Emscher Landschaftspark (landscape park) between the cities of Duisburg and Dortmund

As a first step the State of North-Rhine-Westphalia acquired the site of the Landschaftspark with the aim of developing a large park on the former industrial wasteland, and in 1989 launched an international design competition for landscape architects. The winning project, designed by Prof. Peter Latz, aimed not only at preserving the industrial buildings, but also the flora and fauna that have spontaneously developed and grown since the factory ceased its activities.

Currently, the Landschaftspark is a globally renowned recreational area offering sport and leisure opportunities to the people of Duisburg in a unique setting that is at the same time home to more than 700 plant species as well as a living testimony of the history of ironworks technologies.

[34] Photo by Sch0p3nh4u3r - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=79741604

7.2 Bioenergy Case Studies

7.2.1 Bioenergy Villages

A bioenergy village is a village, municipality, settlement or community – or a part of it – which produces and uses most of its energy demand from local biomass or from other renewable energy sources. BIOVILL project was implemented by a consortium of nine organizations working to establish bioenergy villages in south-eastern Europe.

The first Bioenergy Villages were established in Denmark, Austria and Germany in the 1990s. But between 2005 and 2015 more than 170 Bioenergy Villages were established in Germany. Of course, the bioenergy villages use different technologies of different sizes, - based on local circumstances, - such as wood heat boilers, biogas plants, combined heat -and power plants with additional solar plans and windmills. The installations produce electricity and heat. The electricity is delivered by local electricity grids, while the heat is distributed by the local district heating network. The idea development was started with the citizens, and they wished to change their daily routine, the bioenergy village concept was about locals who want to work together for their well-being, for stronger local community and better environment. The citizens understood that the local biomass value chain has to be built. In each location wood is harvested and processed in the local centers and wood residuals but also agricultural residuals can be used to cover local energy demand of the community. In Bavarian bioenergy villages organization structure is ready, technology is installed and financing models employed but they all have the common goals to ensure the future sustainability and affordability of energy supply. In the meantime, they circulate money in the local economy to provide sustainable jobs and living. The energy cooperatives allow citizens to contribute financially to the development of bioenergy villages by equal voting rights and ensure the influence of the citizens. Local public utilities or public companies act as the developer of the infrastructure and operator of the bioenergy villages. In Germany and Austria there are several companies whose business model is to build and run bioenergy villages on a commercial basis. The benefits of living in a bioenergy village decrease the dependency on fossil fuels and regional development. The expenses on energy do not go abroad or out of the region, but contribute to the local economy, supporting local economic development, the money goes to local farmers, foresters, bioenergy plant operators and back and forth. Local small and medium-sized enterprises, such as forestry SMEs, wood processors, and plumbing and heating companies, are heavily involved in the projects either as service providers or as partners in the future implementation and management of the energy schemes.

Within the Bioenergy Village - Biovill project all the partner countries from South-Eastern Europe learned that the Bioenergy Village is not science fiction or a future concept, it is functional even in different countries in Europe. One of the most relevant best-practice about Mureck, Austria is presented in the following table.

Key Facts	
Concept	New bioenergy value chains based on regional energy and material cycles ensures self-sufficiency in heat, power and transportation
Energy technologies	wood-fired district heating plant, biogas CHP, biofuels & photovoltaic
Type of biomass used	wood chips, waste cooking oil, oilseed, energy plants, manure
Installation year	1991 Biofuels, 1998 (Biomass heating), 2005 (Biogas), 2010 (Photovoltaic)
Added Value	16 mil EUR/year
Supplied users	300 district heat connections
Heat supply rate	90%
Heat generated per year	14 GWh/a
Grid	14 km
Power use	self-supply of facility owner and feed in to the grid
Power supply rate	>100%
Power generated per year	12 GWh/a
Owners	inter alia local farmers and foresters, municipalities and citizens

Table 14 - Mureck Bioenergy Village – Project Key Facts

7.2.2 PROMOBIO

The objective of the PromoBio project is to provide support to the regional bioenergy initiatives and to facilitate new bioenergy business projects in Eastern European countries where potentials in particular of forest and agricultural biomass, have been utilised unsufficiently as renewable energy sources. Best bioenergy practices and successful business models from the partner countries Finland and Austria will be tested and transferred to the target regions: Plock county in Poland, Centru region in Romania and Banska Bystricá region in Slovakia. The aim is to provide the local stakeholders with the grounds to make informed decisions in developing the bioenergy markets of their region. North Karelia in Finland and Lower Austria are considered as benchmarks of well-developed bioenergy markets. The project will provide concrete supporting actions both to decision makers and to companies starting or developing bioenergy business. Important objective is also to increase the capacity of trainers giving professional or continuous education in bioenergy issues, in order to distribute the identified good practices and gained knowledge to a wider audience. (PromoBio, 2014)

The Romanian PromoBio partners selected several bioenergy initiatives from Centru region for technical support which have been developed as pilot projects at regional/national levels.

Key Facts		
	Business Incubator House in Sfantu Gheorghe	**Dalia Greenhouses in Sfantu Gheorghe**
Concept	New bioenergy value chain based on local greenwaste cycles ensures self-sufficiency in heat	New bioenergy value chain based on local greenwaste, agrobiomass, SRCs such as energy willow, and forest residuals ensures self-sufficiency in heating of more than 2 ha greenhouses
Energy technologies	wood-chips fired heating boiler	wood-chips fired heating plant
Type of biomass used	wood chips, green-waste from public areas, industrial wood waste	wood chips, energy willow,forest -and industrial wood waste
Installation year	2014	2007-2008
Added Value	16 mil EUR/year	
Supplied users	1 large consumer	>10 greenhouses
Heat supply rate	95%	100%
Heat generated per year	270 MWh/a	17 GWh/a
Grid	no	2 km

Table 15 - Business Incubator House and Dalia Greenhouses – Project Key Facts

7.2.3 Business Incubator House, Sfantu Gheorghe

Incubatorul de Afaceri Sfantu Gheorghe is an office building for 46 local SMEs and professional associations. The building refurbishment was financed by a national programme for SMEs' support and completed in 2010.

Initially, the heating system used natural gas as fuel; the heating costs rose annually due to increase of the natural gas price. COVIMM Company responsible for managing the building decided to replace existent heating system with a new biomass boiler.

This project consisted of installing a biomass boiler producing 135 kW for operation only in the winter period (1,800 hours at maximum heat load). This boiler uses 426 m3 biomass (sawdust and wood chips) to produce 243 MWh/a. The investment calculated in the feasibility study is €37,400 and the operating costs are €6,669 resulting in a heating cost of €0.0363 /kW hours (kWh), in comparison with the existent heat cost of about €0.047 /kWh.

7.2.4 Estelnic Biomass Project

Estelnic is a rural municipality in Carpathian Curve with 1190 inhabitants in Romania. Estelnic is one of the oldest localities of Covasna County in Romania. The old settlement was formed around the Franciscan monastery and along the brook Estelnic. It was first mentioned in an official document in 1332, under the name Iskulnuk.

In Estelnic, a new woodchip boiler exists since March 2016, with an installed capacity of 150 kW. This woodchip boiler supplies the local public institutions with heat: the mayor's office, Angustia Leader's Office, and the Youth and Cultural Centre. This project was coordinated by Green Energy Romanian Innovative Biomass Cluster and Oxford Research AS from Norway. The main goal of this demonstration project was to establish a new green energy project focusing on energy self-sufficiency, called" Biomass - a new green business!", financed by a Norwegian Grant for the Green Industry Innovation Programme for Romania. The local stakeholders and decision makers reacted positively to the new concept. Within the frame of the project, 3 ha of energy willow have been planted to supply the feedstock needed for the heating of the public building within the next 25 year.

Key Facts	
Concept	New bioenergy value chain based on local green waste from public areas and SRCs cycles ensures self-sufficiency in heat
Energy technologies	woodchips fired heating boiler
Type of biomass used	wood chips, green-waste from public areas, SRCs - energy willow
Installation year	2016
Added Value	150 k EUR/year
Supplied users	3 consumers: Mayoralty, Angustia Office, Cultural Center
Heat supply rate	95%
Heat generated per year	300 MWh/a
Grid	150 m

Table 16 - Estelnic Biomass Project – Project Key Facts

7.2.5 Dalia Biomass Boiler

DALIA is a floricultural producer located in Valea Crisului Village in Covasna County. Dalia Company was set up in 1993 and has continuously developed. Now, Dalia has more than 1 ha of greenhouses. The greenhouse heat demand is produced by inbuilt energy sources equipped with wood stoves using sawdust and firewood. The existent wood stoves are obsolete and not energy efficient. A part of raw material used as fuel (sawdust) for existent stoves is supplied by the beneficiary using the residues from floricultural activities. Before burning, this residue is transported from a wood processing company to obtain the fuel (sawdust). The rest of the biomass quantity needed for greenhouses heating is firewood bought from local suppliers.

Due to low efficiency equipment Dalia had great biomass consumption with high heat generation costs and increased final price of products. In this situation Dalia decided to develop a project to decrease the energy costs. The project goal was the installation of a new biomass boiler, replacing the existing low efficiency stoves to cover the heat demand of Dalia greenhouses.

This project consisted of installing a biomass boiler of 750 kW capacity for 2,500 hours of operation at the maximum heat load. This boiler uses 5,200 m3 biomass (sawdust) to produce 1,875 MWh/a. The investment calculated in the feasibility study is €71,500 and the operating costs are €53,548 resulting in a heat cost of €0.0308 /kWh in comparison with the existent heat cost of about €0.0345 /kWh. The needed biomass quantity is supplied by the beneficiary. The forest and agricultural residues provided by the beneficiary are processed by a local biomass processor to obtain the sawdust used as fuel in the new heating plant. The beneficiary transports raw material (sawdust) to and from the local biomass processor its own trucks.

7.3 Local Currencies Case Studies

One of the important trends in sustainable development throughout Europe is the creation and usage of local currencies. The aim of these currencies is to encourage spending within a local community and preferably towards locally owned business. Regulations across Europe are highly different regarding the issuance and usage of local currencies, often depending on their form. Romania, for instance, states that the only authority that can emit currency is the National Bank. However, specific laws enable the emittance of electronic currencies, in certain conditions, while virtual currencies are unregulated.

Local currencies emerged throughout the world and provide good practice examples for developing the iLEU:

7.3.1 Torekes – community involvement

Name	Torekes
Type	Physical
Timeframe	2010 - 2017
Location	Rabot-Blaisantvest in Ghent, Belgium
Scope	Stimulating community involvement in environmental and social activities

Table 17 - Torekes Key Facts

Torekes were introduced in 2010, and the popularity of this local currency has increased every year. In 2015, approximately 1289 volunteers participated in the project.

Torekes is earned by dedicating yourself to the Rabot-Blaisantvest neighbourhood, as an individual, resident group or as a volunteer at an organization in the area. Initiatives that contribute to a better neighbourhood are eligible for Torekes. These can be very diverse activities, ranging from reading to children in a school, offering free sports lessons, cleaning up litter, helping during the working days in the various allotments in the neighbourhood. One of the reasons for its success is that Torekes can be spend in local businesses. The coin has a fixed value of 10 EuroCents. Torekes can be redeemed in several shops and counters in the neighbourhood and even outside it, as cash or products.

This experiment is very important for the public administration, bringing a big plus to it due to:

- land rent as the principal source of public revenue;
- debt-free money issued by the government to fund public expenditure.

Summarizing all this, the main advantage that the new local currency offers is stimulation of the local economy without Increasing the debt of the city government.

7.3.2 Berkshares

Name	Berkshares
Type	Physical
Timeframe	2006 - present
Location	Berkshires region of Massachusetts, US
Scope	Stimulate local and sustainable consumption

Table 18 - Berkshares Key Facts

BerkShares is a local currency that circulates in The Berkshires region of Massachusetts. It was launched on September 29, 2006. This project promotes the idea to buying from local producers and assure that a high percentage of each dollar spent will remain circulating in the community. In this way The Berkshare community want to increase the following branches of activity: local economy, ecology and sustainability.

BerkShares can be obtained at any of the following local bank branches in exchange for U.S. dollars at a rate of 95 cents per BerkShare. The federal dollars remain on deposit at the BerkShares Exchange Banks in order to allow citizens to redeem BerkShares for dollars at the same exchange rate. At the bank, 95 dollars will yield 100 BerkShares and 100 BerkShares will yield 95 dollars. The list on the virtual currency website contains around 400 business in Berkshire Country that accept the currency.

BerkShares can be spent at face value with participating businesses—for example, 10 BerkShares can be used for a $10 purchase. There are 400 businesses in the Berkshire region that accept BerkShares and four banks provide BerkShares with 16 brick-and-mortar offices where residents can exchange for BerkShares and receive more Information on the project.

6.2.3 Calgary Dollar

Name	Calgary Dollar
Type	Physical

Timeframe	1995 - present
Location	Calgary, Alberta, Canada
Scope	Stimulate community economic development

Table 19 – Calgary Dollar Key Facts

Calgary Dollars is a local currency in Calgary, Alberta, Canda. In 2018 Calgary Dollars launched a new digital component with an online platform, app for iOS and android and a new website.

This local currency, which operates as a limited form of currency In Calgary, is not a legal tender and Is not supported by a national government. Calgary dollars are part of an initiative to inspire local consumers to shop close to home, to personalize economic relations, to nurture a sense of community and to increase both local self-sufficiency and bioregionalism. It comes in denominations od 1, 5, 10 ,25 and 50 Calgary Dollars, which are printed on plastic material In the same dimension as the Canadian dollar.

Business and users of Calgary can accept any amount of Calgary Dollars for any goods or services, from 10 percent to 100 percent. For example, a customer might pay for a $20 purchase with $5 Calgary dollars and $15 in Canadian dollars at a business that accepts 25 percent Calgary dollars. This amount can be change at any time and can also be adjusted for specific days and promotions.

Any business based in and located in Calgary can spend and accept Calgary Dollars.

7.3.4 Bristol Pound

Name	Bristol
Type	Physical
Timeframe	2012 - present
Location	Bristol, UK
Scope	Encourage people to spend their money with local, independent businesses

Table 20 – Bristol Pound Key Facts

Bristol Pound was launched in Bristol, UK on 19 September 2012. Its objectives is to encourage community to spend their money with local, independent business In Bristol and the former Country of Avon.

The Bristol Pound is managed by the non-profit Bristol Pound Community Interest Company In collaboration with the local financial Institution, The Bristol Credit Union. The Bristol Union ensures that every £1 sterling converted to a printed 1 Bristol Pound is backed in a secure trust fund.

Account holders can convert Bristol Pound to and from pounds sterling at a 1:1 ratio. Both paper and electronic version exist.

Bristol City council, among other organizations, offer their employees the option to take part of their salaries in Bristol Pounds. Former mayor Ferguson accepted his entire salary (51.000 lire) in the local currency.

Bristol is the first city in the UK in which taxes and business rates can be paid in a regional currency. Energy bills, since June 2015, can be paid In Bristol Punds to the 100% renewable energy provider, Good Energy. Some businesses apply discounts for customers paying in Bristol Pounds.

There is a map on the app and an online directory to help you find participating businesses.

7.3.5 SCEC

Name	SCEC - Solidarity ChECamine
Type	Virtual
Timeframe	2008 - present
Location	Italy
Scope	SCEC is fighting to stop the degradation of local communities, to support families and businesses through mutual rediscovery and mutual solidarity.

Table 21 - SCEC Key Facts

ŠCEC works in a very simple way.

It is a percentage of the price of goods and services freely chosen by those who sell. ŠCEC represents a discount which, however, passes from hand to hand and can be reused indefinitely (Solidarity ChE Walk). It is distributed free of charge, so it is an integration of income for those who use it and those who accept it in turn reuse it in other activities of the circuit by circulating and maintaining wealth in the territory.

ŠCEC is an act of mutual Solidarity because those who accept it offer a discounted price to their community who choose it instead of going shopping at the GDO. In turn, those who receive it and want to reuse it will do the same with their fellow entrepreneurs and go back up their supply chain by involving suppliers.

ŠCEC is unique throughout Italy and can be used anywhere.

In a circular economy and mutual aid logic, ŠCEC can also be accepted by individuals to offer occasional services in the community with a high percentage of ŠCEC.

For occasional services, the law provides that these are characterized by the absence of habituality, professionalism, continuity and coordination and take place with an annual remuneration of no more than 5000 euros.

In the case of time banks and voluntary activities, acceptance of the ŠCECs can reach 100% of the price.

Example: fee of the doctor who accepts 20% of Š:

total € 100 = € 80 + 20 Š. The doctor uses it to pay his accountant, the cleaning company or by going to the restaurant

Restaurant account that accepts 25% of Š:

total € 50 = € 37.50 + 12.50 Š. the restaurant owner can purchase raw materials from a local producer and so on.

From a tax point of view, ŠCEC is an Unconditional Discount and does not enter the taxable amount, however it must be entered in the receipt or invoice.

7.4 Domain Specific Virtual Currencies

Some relevant crypto currencies target specific domains or objectives, such as increasing health, rewarding customers, rewarding positive action, etc.

Below are some examples.

7.4.2 Sardex

Name	Sardex
Type	Virtual
Timeframe	2012 - present
Location	Sardinia, Italy
Scope	Sardex focused on developed a business network

Table 22- Sardex Key Facts

Sardex is a regional business-to-business (B2B) and it was launched during the financial crisis in 2008. In this project are involve several thousand small and medium-sized business on the Italian island of Sardinia so, the main objective is very simple, to give the opportunity to participate in a system of mutual credit and do business with other local companies.

Ex: A dentist, for example, can offer to fix the teeth of a carpenter and be paid in Sardex credits. The dentist can then use Sardex credits she's earned to buy groceries from a grocer. The grocer, in turn, can use the Sardex credits he's earned to pay the carpenter to build some new shelving for his store. (1 Sardex credit is equivalent to 1 Euro)

Participating SMEs pay a flat annual fee to join. Once members, they gain access to new prospective customers and suppliers. The fee is individually negotiated. After this, they can post trade offers on Sardex's web platform.

Sardex wanted transparency, so, the solution was blockchain. Blockchain is real help in the fight against tax evasion in public finance due to transparency.

Due to the success of Sardex, it has been replicated in several regions of Italy, such as: Lombardy and Sicily.

7.4.3 WELL

Name	WELL
Type	Virtual
Timeframe	2009 - present
Location	Worldwide
Scope	Increasing the globalization of medical services and bridging the healthcare gaps created by natural geography and international borders

Table 23 - WELL Key Facts

WELL blockchain and app allow its users generate cryptocurrency through proof of “walk” and other wellness behaviour. All that is required is a smart phone with an internal step counter and commitment to be healthy by walking. Users earn cryptocurrency by walking, biking and other activities. Additionally, users can connect various devices to the app. Beta version of the app is available in both Google Play and Apple App Store. Earned cryptocurrency can be exchanged for rewards and discounts in WELL marketplace that will include products and services from various consumer facing brands and insurance companies.

WELL also helps consumers get recognized and paid for their data and healthy behaviour. WELL developed a proprietary protocol focused on wellness and is in discussions with several potential partners to join its blockchain to motivate and reward partner constituents including employees and patients for their healthy behaviour. WELL branded bracelet, watch and weight scales are available at affordable prices while providing cutting edge functionality such as ECG, sleep quality, step counter, calorie counter, heart rate, BMI, fat %, etc. WELL app is also compatible with many third party fitness and medical devices and is finalizing integration with Fitbit and Apple watch to allow everyone to mine and get paid for staying active by joining WELL.

7.4.4 MOBILIO

Name	Mobilio
Type	Virtual
Timeframe	2013 - present
Location	Worldwide
Scope	Motivate drivers to stop using their phones while driving and thus drastically reduce the number of road accidents, injuries and deaths

Table 24 - Mobilio Key Facts

Mobilio was launched in 2013. With the Mobilio app – available for Apple and Android smartphones – drivers collect points for distraction-free driving that can be exchanged for a cryptocurrency called MOBILIO. It is a currency that is minted strictly by drivers who have proven (automatically through the app) that they are driving distraction free.

The business model involves insurance companies that should reduce rates or enable the usage of Mobilio for insurance. For an insurance customer to actively avoid a possible risk, a reward may sometimes be necessary in addition to the information. In this case it makes sense to use a remuneration concept such as Mobilio instead of a complicated integration into existing ERP systems. On the one hand, customers can be remunerated directly with tokens, and on the other hand, the insurance company can offer services that in turn can be purchased with MOB tokens.

The value of Mobilio depends initially on the number of participants and their driving behaviour so, so an increase in the Mobilio price is expected each year.

With driving being the most dangerous activity engaged in by most people on a daily basis, the adoption of Mobilio has huge potential to make the word a safer place.

7.4.5 EvergreenCoin

Name	EverGreenCoin
Type	Virtual
Timeframe	2015 - present
Location	Worldwide
Scope	Stimulates concern for our environment and the world we live in by helping to raise funds for environmental green projects

Table 25 - EverGreenCoin Key Facts

EverGreenCoin was launched in 2015 and now, conversion between EverGreenCoin (EGC) and USD is 1 EGC = $ 0.011713 USD.

Proof of Environment is a program from EverGreenCointo:

a) motivate individuals to do environmentally responsible tasks, and

b) raise awareness of EverGreenCoin while doing so.

Proof of Environment is not a technical process: it is a human process that is positive for the environment. Everyone is welcome to participate, and there is no technical knowledge or special equipment required. All users need is a picture or video of an environmentally friendly task being completed (i.e. planting, trash clean-up, recycling, anything demonstrating responsible care for our planet) and an EverGreenCoin address for EverGreen to send the reward to at the end of that month. Users also need give permission to use the image or video submitted for educational purposes. A "work share" is any event, be it collecting trash on a stroll through the park, installing some new solar equipment, recycling, planting trees, or even potting a house plant!

EverGreenCoin is organized into 'branches'. Each branch focuses on its area of expertise while coordinating with the other branches and sharing resources to work towards EverGreenCoin's goals.

The end-goal being a network of like-minded people, each focused on areas they are most knowledgeable and passionate about, becoming a towering organization of environmental efforts and success.

7.4.6 MOBI

Name	MOBI - Mobility Open Blockchain Initiative
Type	Virtual
Timeframe	2018 - present

Location	Worldwide
Scope	Building mobility services more efficient, affordable, greener and safer

Table 26 - MOBI Key Facts

Launched in 2008, MOBI's mission is to explore Blockchain and related technologies, promote standards and accelerate adoption for the benefit of the industry, consumers and communities. Blockchain technologies to improving people's lives by making mobility more efficient and affordable, to reduce congestion and pollution and to improve safety. MOBI is used for:

- Recognize cars on the road
- Allow drivers to automatically pay tools or parking fees without the need for cash or cards
- Registration of ownership and vehicle history.

MOBI Is an open, inclusive, global non-profit organization with corporate partners from diverse industries working with governments, NGOs, academics and private foundations. MOBI's diverse membership reflects a variety of benefits afforded by participation In the MOBI community.

A partial list of members includes: GM, Ford, Daimler Benz, BMW, Renault, VW, IBM, Accenture, Bosch, Denso, Word Economic Forum, IOTA, Hyperledger.

MOBI's use cases for blockchain span the entire mobility services value chain. Use cases are not limited to vehicle digital identity and history, location in space and time, supply chain, autonomous machine payments, mobility commerce platforms, data markets, emissions tracking, car and ride sharing, usage-based insurance, usage/congestion/pollution based taxes. MOBI has active projects in several of these areas and will launch several more projects by year-end. Currently the conversion rate is 1 MOBI = $ 0.002772 USD.

7.5 Earth Observation Case Studies

7.5.1 NERUS – Network of European Regions Using Space Technologies

NERUS offers a dynamic platform to all Regions aiming at making a better use of space applications for the delivery of efficient public policies benefiting citizens.

NEREUS' work can be summarised in 3 pillars of activities:

- political dialogue,
- interregional collaboration and partnerships,
- communication and public outreach.

As Europe's flagship space programs, Copernicus and EGNOS/Galileo, have entered the stage of operability, they provide data and signals which can be transformed into useful information for Regions across Europe.

At the regional level, NERUS work can be summarize is:

- Improve the awareness and understanding of space technologies in member regions;
- Fully exploit the potential of space applications in support of public policies for a better-informed decision-making;
- Bridge EU space policies and programs to regional strategies, to better anchor space uses to the needs of territories and citizens;
- Strengthen and develop local space communities;
- Raise the profile and visibility of space-related activities and capabilities;
- Integrate the space dimension in regional innovation and SME programs and policies.

At the interregional level:

- Support local politicians, entrepreneurs, researchers, and students in grasping relevant opportunities at European level;
- Build strong European partnerships and mobilize solid initiatives in a broad range of sectors;
- Enhance cross-sectorial exchanges amongst operators from different economic sectors, such as agriculture, digital, tourism, maritime, etc.

At the European level:

- Advocate the key role of regions in developing the space market, by recognizing them as drivers of the demand for space-based services and products;
- Relay the regional dimension of European space policies and programs towards the European institutions;
- Provide members with timely information on the latest developments of European space policies and programs related to regional space uses in relevant application domains.

7.5.2 KERMAP – Our green cities

KERMAP is a spinoff of the University of Rennes 2 and the LETG laboratory set up by the French National Centre for Scientific Research (CNRS). The company, founded in 2016, provides solutions to support cities in their ecological transition, offering a broad range of services, such as vegetation and air quality monitoring, and carbon storage estimation, among others.

KERMAP offers for the first time a comparison of the proportion of tree vegetation in the different municipalities of mainland France. Their platform mapped the tree vegetation visible on the photographs acquired by the planes of the National Geographic Institute (IGN) this leads to the possibility to study the urban green fabric.

The satellite-based map will help the City of Rennes to monitor the evolution of the vegetation, the increasing of house units to the detriment of green areas and climate change issues. The map will allow city authorities to understand which trees need to be cut and to decide on where they will be replanted and on which species are more suitable for different areas of the city. The information on the vegetation cover collected through satellite imagery will also help the city to prepare its future Local Plan of Urbanism (PLU). Indeed, according to the PLU, each neighbour of the city needs to have a mandatory percentage of green areas.

7.5.3 GEODAN - Amsterdam Digital Twin

Digital twins hold promise to improve decision making and investment for a broad spectrum of stakeholders, from city-scale transport planners to individual building owners. Potential benefits include everything from better health and wellness in office environments to improved air quality in our dense urban environments. With the digital and social landscapes converging in terms of modelling, sensing and inclusivity, digital twins may be the technology to help deliver on these challenges.

The company used publicly available data to create a virtual model of the city. Using smart models, processes and plans for future development can be calculated and visualized there. As examples, Geodan cites environmental effects of building a new apartment complex or what changes will be made to traffic by a detour. Authorities and city planners can assess processes faster and more precisely that way.

Geodan collects, combines, visualizes and analyses data such as company data, current file information, or historical data. By creating the right cross-connections between these data, Geodan create new, spatial insights. Insights that allow users to make the right decisions in arranging their country. That is the connecting power of location intelligence. If you combine the power of location data with innovative technology, that’s what Geodan calls Location intelligence.

conclusions

The challenge ahead of SPIRE is as ambitious as making Baia Mare to the new green and sustainable capital of Romania. For this purpose, it is crucial to implement a successful, nature-based strategy for the regeneration of Baia Mare's brownfields based on the following key principles.

1) To regenerate a brownfield requires an **integrated territorial approach**, that is:
    a. Pluralistic decision-making planning process (multi-stakeholders/horizontal governance);
    b. Multidisciplinary planning process (professionals with different backgrounds to be involved, not just architects and engineers);
    c. Multi-level governance activation on/in the intervention area (activating multi-scalar competence and facilitating cross-sectorial policies coordination);
    d. Area based approach (commitment to community empowerment, and community capacity, limiting and precisely identifying the intervention area);
    e. Time based approach (setting clear and realistic timeframes for the regeneration planning process).
2) To regenerate a brownfield requires to use the right **toolbox**, that is:
    a. Avoiding simplistic top-down, command and control approaches (they could maybe work for regenerating objects/small scale stuff, but not for proper land use transformations);
    b. Replacing the logic of business plans with the logic of business strategy (a long-term plan of action designed to achieve a particular goal or set of goals or objectives);
    c. Prepare a local strategic master plan for the intervention areas and surroundings;
    d. Have a clear strategic plan at city scale (…where brownfield regeneration is a clear planning domain);
3) To regenerate a brownfield requires to **think out of the box**, that is:
    a. To Switch from a project's logic to a logic of process (it is not just a question of designing and realizing new buildings for serving group of interests or new spaces for private/public services);
    b. To move from the mere technical management of interventions to one putting at the centre the process of urban/metropolitan/territorial governance;

c. To promote instruments that are promoting/facilitating the private investments (providing clear strategic business plans), but under precise conditions in respect of general and public interest;

d. To guarantee flexibility in the use of strictly normative urban planning instruments (public administration as a driver in adapting land use management for brownfield areas).

Accordingly, SPIRE is a complex project that brings innovative approaches and technologies from different disciplinary fields in order to implement a ground-breaking, integrated regeneration strategy for the city.

This Report is a multidisciplinary overview of the theories and experiences underlying the approach fostered by SPIRE. It chiefly explored the state of the art in ecosystem services for the bioremediation and sustainable regeneration of brownfields and analysed the potential of circular/cascading value streams and digital technologies in sustainable local development.

This collection ideally represents the starting point of SPIRE’s preparatory research work, and as such the project will rely and draw upon this body of academic and empirical knowledge in the design and implementation of its activities and initiatives throughout its lifetime.

Additionally – and more importantly – with its experimentations SPIRE aims at significantly contributing to the advancement of research and practice on its intervention fields. In particular, its main added value lays in a new way of integrating land-use policies, bioremediation techniques, bio-based cascading value systems and digital technologies towards a multiple-speed circular strategy at urban level.

SPIRE’s experimentations will therefore bring a new wealth of empirical evidence on how the intertwined, integrated and cross-cutting implementation of the concepts, approaches, and tools adopted is capable of impacting on the social, environmental, economic, and strategic planning spheres of a city.

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Annex 1. Characterization of Biomass

Feedstock	Most Common Trading Form	Conversion Technology	Net Calorific Value (MJ/kg)	Bulk Density (kg/m³)	Ash content (% dry bulk)	Chemical Composition					
						Elementary Analysis (w% dry)			Lignocellulosic Constituents (w% dry)		
						Carbon	Hydrogen	Oxygen	Hemi-cellulose	Cellulose	Lignin
Coniferous stem wood, without bark	chips	combustion	19.1 (18.5–20.5)	300 (270–360)	3 (1–10)	50 (48–52)	6.1 (5.7–6.2)	40 (38–44)	25–25	40–45	24–33
Logging residues, coniferous	chips	combustion	18.5–20.5	300 (270–360)	3 (1–10)	50 (48–52)	6.1 (5.7–6.2)	40 (38–44)	25–25	40–45	24–33
Wheat straw	bales	combustion/ fermentation	16.6–20.1	20–40 (loose) 20–80 (chopped) 110–200 (baled) 560–710 (pelletized)	2–10	48 (41–50)	5.5 (5.4–6.5)	39 (36–45)	23–30	34–38	16–21
Used wood (recycled wood, untreated)	hog fuel	combustion	18.6–18.9	200 (140–260)	0.5–2	49–52	5.9–6.4	38–44	25–30	40–45	20–30
Bark, coniferous (debarking residues)	shredded	combustion	17.5–20.5	240–360	1–5	50 (48–55)	5.9 (5.5–6.4)	38 (34–42)	10–15	20–30	10–25
Broadleaved stem wood with bark	chips	combustion	15.0–19.2	220–260	0.3–1.5	42.6–52.0	5.7–6.4	41.4–51.1	21–32	28–49	30–32
Poplar	chips	combustion	18 (17.3–20.9)	340 (320–400)	1.2 (0.2–2.7)	49.7 (44.8–52.0)	6.0 (5.6–6.3)	43.9 (41.6–48.6)	25.3 (12.7–39.8)	44.4 (35.2–50.8)	22.9 (15.5–31.9)
Cereal straw	bales	combustion/ fermentation	14.8–20.5	20–40 (loose) 20–80 (chopped) 110–200 (baled) 560–710 (pelletized)	6.7 (1.3–13.5)	48.9 (43.7–52.6)	5.9 (3.2–6.6)	43.9 (39.4–50.1)	25.0 (7.2–39.1	37.0 (14.8–51.5)	17.5 (5.0–30.0)
Paulownia	chips	combustion	18.6 (18–20)	250 (220–260)	1.1 (0.5–3.5)	49.5 (47.9–50.0)	6.4 (5.8–6.7)	43.8 (43.2–45.0)	19.6 (19–25)	41.6 (40–49)	22 (21–23)
Willow (Salix)	chips	combustion	19.8 (19 – 21)	330 (300–390)	1.5 (1–3)	49 (47.1–50.3)	6 (5.8–6.2)	43 (41.3–45.3)	27 (23–32)	41.0 (38–45)	25 (23–29)
Barley straw	bales	combustion/ fermentation	18.9	20–40 (loose) 20–80 (chopped) 110–200 (baled) 560–710 (pelletized)	4.5–9	45.4 (39.9–47.5)	5.6 (5.3–5.9)	42.1 (41.2–43.8)	24–29	31–34	14–15

Corn cobs	chopped	fermentation / combustion	14	160–210	15 (1–40)	47.1	5.8	40	31–33	40–44	16–18

Source: DTI & Biowaste4SP (International Finance Corporation, 2017)