

# Industry 4.0 and Bioregional Development. Opportunities for the Production of a Sustainable Built Environment



Luciana Mastrodonardo and Matteo Clementi

**Abstract** The paper answers the question about how the technologies characteristic of industry 4.0 can support the bioregional development paradigm, focusing on local building production chains to support the energy retrofit of existing buildings. In particular it investigates design choices capable of activating supply chains that can intercept real and already existing spending flows and activate a workforce capable of evolving the anthropic system in the same direction characteristic of the natural systems. The paper focuses on the description of the features that industry 4.0 could assume in the field of building production to support energy requalification, reorienting urban metabolism of neighborhoods or small settlements towards local territories. It describes the characteristics of technologies adopted in the Industry 4.0 paradigm, in the context of open data, open-source software alongside low-cost microcomputers and sensors, and illustrates their potential in the possible activation of generative local microeconomies. Acceleration, digitization and automation of the construction sector are showing the relevance of having open real-time information to support decision-making processes. In particular the text focuses, on the one hand, on the applicability of such technologies and devices to areas characterized by very limited resources (such as for example the internal and more fragile areas in Italy); on the other hand, on how they enable community of prosumers and local cooperatives to complex productive activities characteristic of the energy communities.

**Keywords** Circular architecture · Data-driven design strategies · Real environmental performance-based design · Time digital representation and visualization · Enabling community

**United Nations' Sustainable Development Goals** 7. Ensure access to affordable, reliable, sustainable and modern energy for all · 8. Promote sustained, inclusive

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and sustainable economic growth, full and productive employment and decent work for all • 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation • 12. Ensure sustainable consumption and production patterns • 13. Take urgent action to combat climate change and its impacts

## 1 Industry 4.0 for the Bioregional Development

Industry 4.0 has been focusing on the use of integrated technologies for improved efficiency and flexibility in the production. Its role in Europe recently emerged and evolved in Industry 5.0 on the social, societal and environmental concept of:

- (1) Human-Centric Approach: involving human need in the production process adopting technology usage and the production process to the workers' needs;
- (2) Sustainability: technology should be used to optimize resource efficiency, minimize waste, reduce energy consumption and greenhouse emissions and use local renewable sources and develop circular processes.
- (3) Resiliency: industrial production should be adaptable in the times of crises, such as geopolitical shifts and natural calamities with resilient strategic value chains, adaptable production and flexible processes [1].

Industry 4.0 and the democratization of machines open up new possibilities and support the construction industry to implement Circular Economy standards and achievement of the S.D.G.s, promoting resource efficiency from project inception to end-of-life. By incorporating circular design requirements and innovation into the technologies, such as design for disassembly, deconstruction, and recycling, properly manage the waste stream, and close the materials loop and by increasing the efficiency in material use and reducing the use of non-renewable natural resources, promoting the use of renewable resources. The terms circular and renewable find an effective synthesis in bioregional development as man-made systems in which energy and matter demand and supply tend to meet on the same territory, increasing the efficiency of use of resources, using mainly locally available renewable ones. The same model finds support in the theories relating to a generative economy [2].

The need for sustainable communities (UN-SDG11) sees the model of bioregional development as the most eco efficient one, since it most closely reflects the characteristic dynamics of evolving living systems. That is, in accordance with the maximum empower principle, towards the maximum use efficiency of solar energy incidents on the local territory [3]. It constitutes a promising reference model that combines environmental sustainability and circular economic development [4–6].

The construction industry is facing the opportunity to benefit from the open availability of digital data and online digital access, to really interconnect physical and digital information. This evolution transforms the business models, enabling transitioning the current reactive to a predictive practice and reducing waste.

The link between Industry 4.0 and construction was primarily based on the potential of digitization and identified four key areas: digital data, automation, connectivity and digital access [7]. They are represented by a confluence of three main trends: industrial production and construction, cyber-physical systems and digital technologies. The increasing importance of concepts such as sustainability, human centric, resiliency and therefore bioregional development imposes tighter constraints based on the intensification and optimization of relations between the built environment and the territory. Open availability of digital data and online digital access can provide the communities inhabiting the territories with tools capable of creating new economies based on the optimal use of territorial metabolism starting from a theoretical basis already consolidated over time.

## 2 Bioregional System, Built Environment and Upcycling

Industry 4.0 is particularly interesting in its relationship with bioregions, defined through physical and environmental features, including watershed boundaries and soil and terrain characteristics and emphasizes local populations, knowledge, and solutions. Bioregion's environmental components (geography, climate, plant life, animal life, etc.) directly influence ways for human communities to act and interact with each other which are, in turn, optimal for those communities to thrive in their environment. As such, those ways to thrive in their totality—be they economic, cultural, spiritual, or political—will be distinctive in some capacity as being a product of their bioregional environment [8].

In a path towards local self-sustainability, the construction of informed and connected flows of energy and material, through technologies, defines the possibility of a low-tech sector at the service of its territory, perfectly integrated with agricultural resources (through sensors, constant evaluation of performance and robotization of production phases), to disused urban stocks and urban mining, and variables of local energy demand that can be defined through real-time evaluations of energy and sun light flows, as climatic conditions [4].

The Industry 4.0 model insists on system innovation related to robotization as an indispensable instrumental method for renewal of production processes. The integration of machine-to-machine communication and the internet of things (IoT) help to increase automation and improve communication and self-monitoring. Industry 4.0, when combined with the circular economy, represents an industrial paradigm enabling new strategies of natural resource use [7, 9]. In turn, the circular economy is driving more attention in support of innovative life cycle management, communication, and the development of smarter systems reconceptualizing waste as intrinsically valuable. This industrial revolution relies on digital technologies such as wireless connectivity and sensors that connect everything to everyone to gather data to analyze, visualize the entire production system, and provide applicable information to the business system [10].

Built environment is part of city metabolism as a palimpsest of urban stock, a record of human history partly erased and rewritten. The urban structure grows during time, through a succession of reactions and processes that develop from previous stages, a territorial morphology expresses a continuity of development, and a vital and unifying exchange with the environment. Thus, time appears as the great ‘master builder’ [11] to which human settlements owe their most durable, fittest configuration within a given environment: time becomes a key factor in this evolving system of resources, describing a variable configuration model, related on season, resilient capacity and region based. In Olgyay’s work, the term “region” relates to the solar altitude angle, and the regional characters of buildings are defined in terms of heat conservation, thermal demand, orientation, natural lighting and ventilation. Olgyay explained how basic building forms, in traditional architecture, answer to the needs of comfort and protection against the local environmental difficulties; yet there is no prosaic determinism in this approach.

Upcycle principles encourage designers—and anyone interested in this new approach—to see everything on Earth as having potential to be something else. Realize that there is not a garbage can, forget the concept of “trash” and consider that everything has to go somewhere and become useful [12]. The challenges we face are multifarious—population pressure, climate change, energy security, environmental degradation, water and food availability—to name a few. To address them we will have to change our business and production processes, become significantly more energy and resource efficient, and minimize waste. Advanced technologies will accelerate this process of transformation and will play a pivotal role in addressing the immediate need of resource conservation and climate change concerns. Technology supports in utilizing renewable energy resources, developing smart grid systems, making efficient public infrastructure producing environmentally friendly materials and products will be crucial to achieve the overall goal of sustainability.

### **3 A Method from Big Data to Territorial Metabolism GeoData**

#### ***3.1 The Informed Open Source Material/Energy Databases***

The text presents a method and specific tools aimed at creating open source databases to support the development of integrated material/energy systems for the production of building material and energy from locally available resources. The proposed methodology was developed starting from the open data available on Italian territory, with the intention of allowing local communities to implement this information with self-detected data. The objective is enabling the local community to trigger processes aimed at bioregional development, activating local economies and transferring existing good practices, through an information platform. This objective is achieving through:

1. The preparation of a georeferenced information system starting from open data currently available to all minor municipalities throughout the country.
2. The implementation of geodatabase with data made available to the local community through self-detection activities using low-cost sensors.

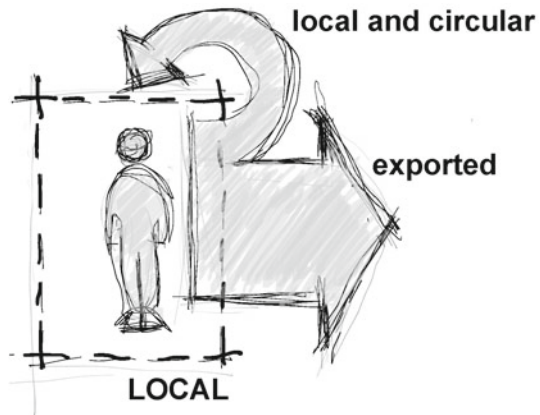
The final result would constitute a Territorial Metabolism Geodatabase (TMG) to support the development and application of design strategies. In order to meet the emerging role of Industry 4.0 on Human-Centric Approach, Sustainability and Resiliency, the method aims to map specific information on the same IT medium.

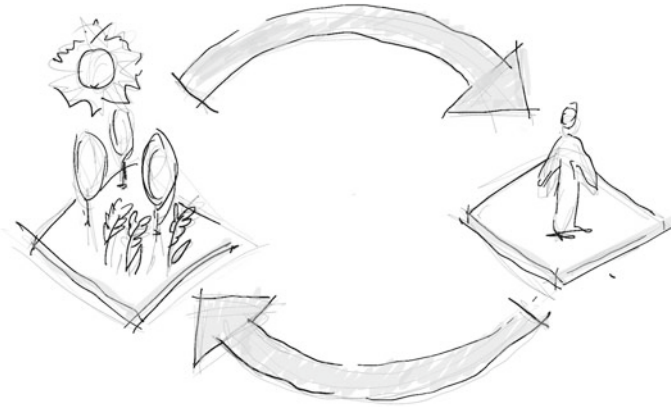
With regard to the Human Centric Approach, the methodology arises from the awareness that in order to trigger new circular and local economies in small settlements, it is necessary to intercept the local expenditure flows starting from the expenditure flows manageable by the public initiative. The provision of this information allows to identify and quantify the money leaving an area and therefore formulate a solution for a sustainable local development processes. Housing, food and transport make up the main spending streams of the settled population [5] (Fig. 1).

The pursuit of environmental sustainability, together with the need to activate circular economies at the local scale, imply matching local demand for energy and material and available resources, in compliance with the regenerative cycles of ecosystems. For example in the sustainable retrofit of existing buildings [13, 14], in order to redesign integrated supply chains of energy and building materials that intercept the largest share of expenditure flows, it is essential to supplement the data relating to the local demand for energy and materials, with the outflows from the system and the renewable resources available and not used (Fig. 2).

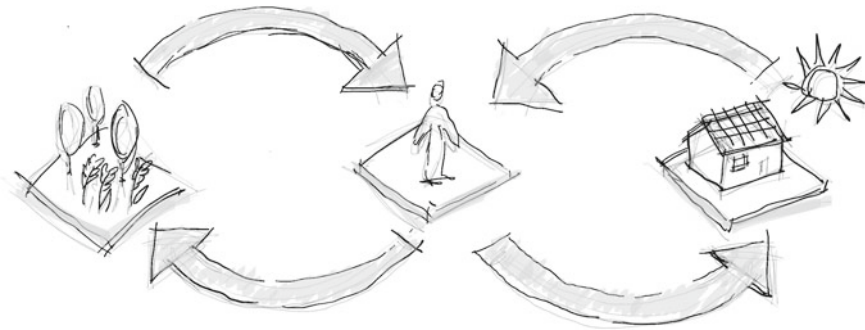
The increase in Resiliency is instead closely linked to the possibilities offered by the method in managing the temporal variability of the data. In fact, the information associated with the demand for energy and matter allows us to understand its variability over time and that the same happens for the mapping of flows leaving the system in the form of waste and other renewable resources available locally. For example, this type of data availability allows the easy passage from one supply

**Fig. 1** Human centric approach for circular economies associated with spending flows





**Fig. 2** Sustainability for circular economies



**Fig. 3** Resiliency and temporal variability for circular economies

source to another simultaneously available, increasing the resilience level of the supply system. In order to have useful data available to understand the variability of the territorial metabolism in different periods of the year and over several years, it is essential to define appropriate time intervals to describe the complexity of the territorial system and at the same time predict the possible effectiveness of improvement practices. The time intervals considered refer to the monthly, annual and five-year average. The monthly average figure is a useful compromise in order to make such complexity manageable (Fig. 3).

### **3.2 The Local Territorial Metabolism Data Analytics**

The elaboration of thematic maps and the publication on a shared portal make it possible to relate the estimated data to each other [15], and to integrate such assessment with the data actually collected. By integrating new methods of data collection and analysis, stakeholders would be able to take evidence-based decisions on

resources allocation and product use and query their processes to meet the local energy necessity. Open source tools, low sensors and microcomputers give the possibility to map the punctual availability of underutilized resources, such as the amount of solar energy on the ground and on buildings envelope, of biomass or other resources such as hydro and wind power (including in the same dataset agricultural wastes, municipal solid waste, and waste heat in the sewage system). In summary, the scope of Big Data Analytics would turn into Local Territorial Metabolism Data Analytics [4, 9] and is closely linked to the local community's ability to produce and self-manage open information oriented towards the generative use of local resources.

The proposed methodology and application tools are divided into the following phases (Fig. 4):

1. LDEM—Mapping the local demand for energy and matter, and therefore the availability of expenditure of the settled community.
2. LR—Mapping local renewable energy potential.
3. EF—(Exported flows) Mapping material flows out of buildings/open spaces.
4. AW—Mapping the potential workforce and skills available locally.
5. DB—Sharing a database of local closing cycles practices.
6. Defining parameters to verify the transferability of best practices; starting from the information mapped and collected in a single open source Geographic Information System.

### ***3.3 Open Tools and Open Data***

The current development of the open source software allows operations of big complexity and it gives the possibility of using complex data even to actors who cannot purchase proprietary software such as local administrations, especially minor ones, and designers who are not directly involved in urban planning. These tools represent an important opportunity to process and communicate information to support decisions aimed at designers, planners, and local communities. The open source feature of these tools meant possible to merged some tools into specific platforms and the creation of specific institutions and related websites that report news relating to the current level of development of such tools, such as the Open Geospatial Foundation. Among the open source GIS tools made available, the elaborations of this work used Quantum GIS (QGIS) and GRASS-GIS.

The method starts from the information normally made available to citizens to create support tools for decisions that can be managed from below. Therefore, to ensure the replicability of the procedure to a wide audience the research relies exclusively on open data provided by government and institutions. The open-access data used for the development of the present case study are described in Table 1. In order to be able to create a common geo-referenced database and correlate the information, the data on the geometry of the buildings available or other data relating to smaller areas, have been aggregated by the census block.

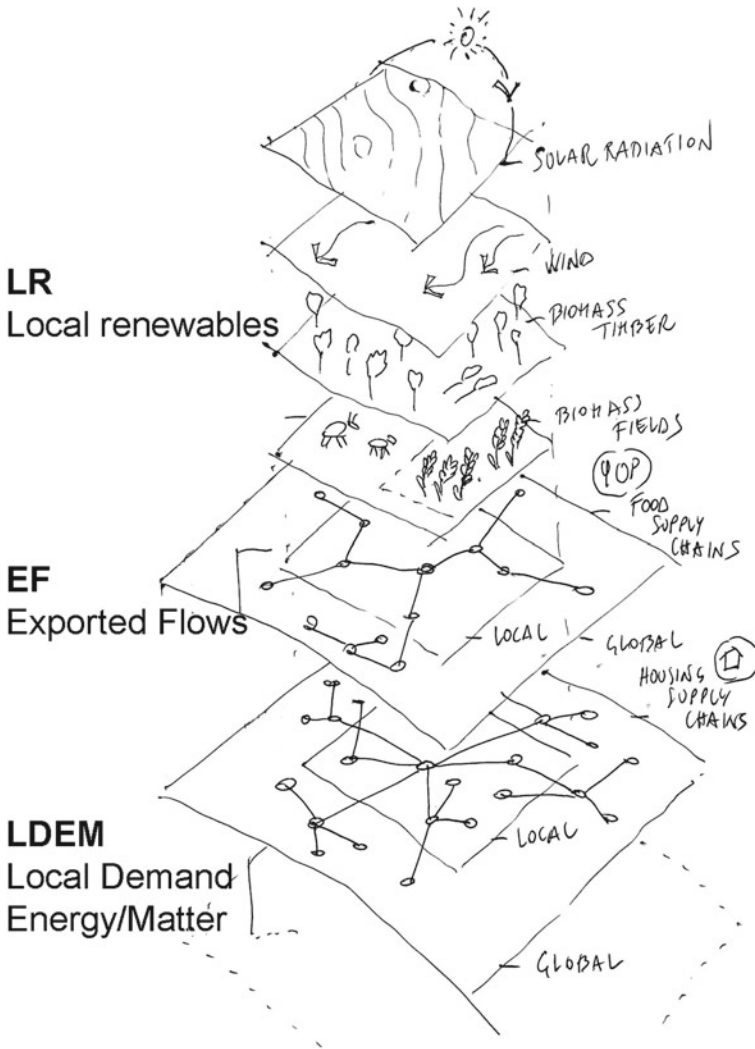


Fig. 4 Phases of methodology and application tools

## 4 The Case Study

### 4.1 Local Territory

To test the effectiveness of the methodology, an internal area of the Abruzzo region representative of the Italian minor municipalities was chosen as a case study: San Valentino in Abruzzo Citeriore (Pe). The smaller municipalities of inland areas are



**Table 1** Source data table

Data	Data type	Source
Populations, households, industry, services	These datasets include information on the height of the buildings, the number of dwellings, the construction system and period together with population age group and number of inhabitants	Italian National Institute of Statistics [16]
Regional data consumption	Data on household consumption in the Abruzzo region	CRESA [17]
Urban waste flows	Data from the regional urban waste observatory	Regional observatory [18]
Energy	Preliminary assessment of possible energy consumption, divided by different consumption categories in the municipality of San Valentino	SEAP San Valentino [19]
Land use	Productive land available, using the Copernicus georeferenced database which publishes the different land use destinations and the related geometric configuration for the entire European territory	CLC [20]

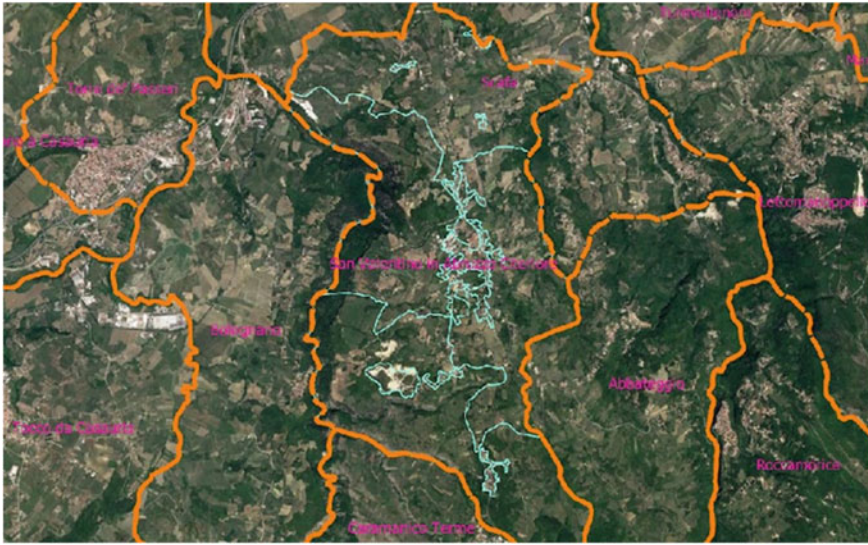
**Table 2** Comparison with average national data

	Total productive land (sqm/inhab)	Agricultural (sqm/inhab)	Woodland (sqm/inhab)	Pasture (sqm/inhab)
Italy	4.362	2.540	1.519	303
Abruzzo	7.682	3.675	2.322	1.685

characterized by a large availability of resources per capita and allow for experimental alternative models of local development. The availability of natural capital per capita is in fact higher than the Italian average. The data in the Table 2 constitute comforting information on the vocation to sustainability of the minor municipalities of the Abruzzo area and make it a candidate for possible experiments oriented towards bioregional development (Fig. 5).

## 4.2 *LDEM Mapping of the Main Spending Flows of the Local Community*

The results associated with the progress of the geodatabase are developed in the municipal area of San Valentino with the mapping of the main expenditure flows. With 1922 inhabitants, the energy needs in 2008 was estimated at 31,053.21 MWh/y and probably a small negligible part comes from biomass (in particular wood). Otherwise the municipality depends on petroleum products, natural gas and electricity. Petroleum with 18,735.38 MWh/y is the most substantial part (60%) of the total



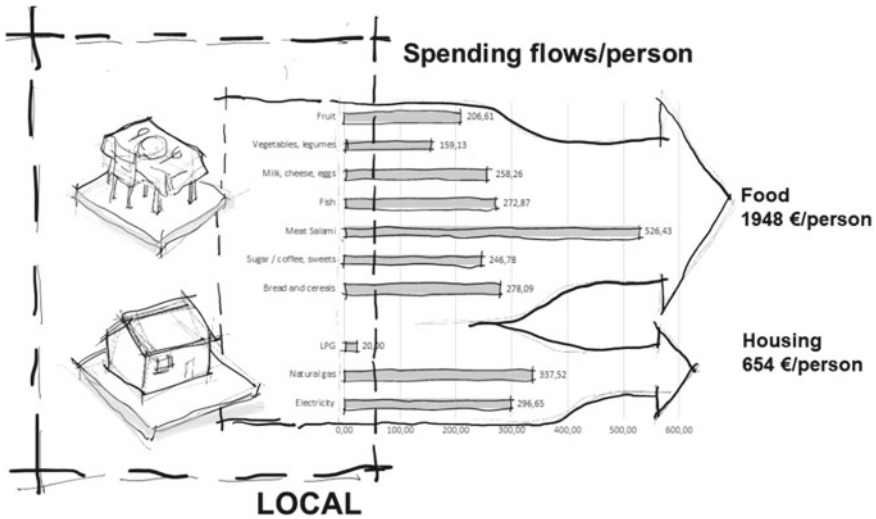
**Fig. 5** Profiles of the municipality of San Valentino and neighboring ones (in orange) superimposed on the profiles of the census blocks of the municipality (in light blue)

energy of which diesel—among the by-products—reaches the primacy of the overall supply with 12,458.59 MWh/y (40%) followed by natural gas with 8,504.65 MWh/y (28%), gasoline with 6,267.64 (20%) and electricity with 3,715.54 MWh/a (12%). The LPG does not represent an important part at the percentage level. The data below can be integrated with information relating to food costs, which together with housing and transport costs represent the main consumption categories of a community (Table 3).

By associating the unit costs of fuels with the main energy consumptions reported in the SEAP [19], it was possible to quantify the costs related to household utilities and transport and compare them with food costs. In particular, the graph in Fig. 6 compares the consumption categories that are most suitable for an experimental use of local resources and for the activation of possible synergies for housing. The interceptable dynamics that require the least investments are related to the supply chain of cereal products, vegetables and legumes and the supply of fuel for winter heating. However, this assumption is not sufficient and it is necessary on the one hand to map information useful for verifying the effectiveness of these strategies, and on the other hand to understand the local weight of public initiative in promoting strategies oriented towards integrated supply chain planning.

**Table 3** Energy use by sectors in San Valentino

Sector	Transport	Residential	Tertiary	Agriculture	Public
Energy use	54%	29%	5%	4%	3%



**Fig. 6** Main spending flows associated with a San Valentino inhabitant and relating to the categories of consumption, food and home

Once the data on the resident population and on the physical configuration of the urban space have been collected, the geolocation of the information associated with the expenses of the local community can be carried out in two specific ways. A first preliminary assessment associates the data on household expenses with the individual census blocks information, as the number of inhabitants. A second method associated some items of consumption refined with a specific assessment of the energy consumption of buildings, with the different building shapes and technological features. At the current state of research, the assessment of the expenditure flows of the settled community was conducted using the first method. Among the energy costs associated with housing, the main one is related to winter heating followed by electricity consumption: it gives indications on the possible willingness to pay for alternative solutions, or the willingness to face an investment beyond the public incentive systems.

Future developments intend to refine the current development status of the TMG with specific data used for further processing. Data mapped by census block and based on estimates of needs and statistical regional data have to be implemented with the direct contribution of the inhabitants with a participating monitoring. In particular, the data made available to the SEAP [17] are associable to the consumption in a specific year (2008) to each polygon relating to publicly owned buildings. The continuous updating of these spending flows in the TMG itself would be extremely useful.

### 4.3 LR: Mapping Unused Renewable Energy and Material Potential

According to the various land use destinations that characterize the local area of reference, this phase of the methodology aims to assess and map the type and amount of renewable energy available. Whereas it is not a very densely inhabited area, the research project maps the solar renewable energy potential together with the possible production of energy and materials from renewable sources obtainable from types of territory such as arable land, pasture and wood. In San Valentino the municipal area amounts to 16.39 km<sup>2</sup>, the availability of land per person is 8531.56 m<sup>2</sup>. The productive area per person is equal to 8.332 m<sup>2</sup> (of which 7.129 for agricultural use and 1.203 forest) [20] (Fig. 7).

The availability of productive land present in the municipal boundaries divided by the number of inhabitants. The potentially usable area for the installation of solar collection devices is a percentage of the built up area, and gives indications on the amount of land made biologically unproductive usable for the collection and use of solar energy. The topographic database (RTDB) allows to enrich the TMG with information on the geometry of buildings. It associates the eaves height to the building's polygons. That information, together with the street level contour lines, allows for generating high-resolution digital elevation models (DEM-1 pixel/50 cm) useful for mapping solar radiation incidents on open spaces and roofs, thanks to tools such as the one proposed by Hofierka [1]. If accompanied by isopleths, these maps can be consulted using common web services such as Google Earth (Fig. 8). The quantities relating to solar radiation, thus included in the TMG, would indicate the precise conditions of solar radiation representative of the monthly average associated with diffuse and direct solar radiation, and to distinguish the portion that affects the roofs from the one related to the open spaces (Figs. 9 and 10). These themes, superimposed on the mapping of publicly owned buildings, are able to identify those census blocks in which the availability of incident solar radiation on roofs or open spaces of public management is greater [21].

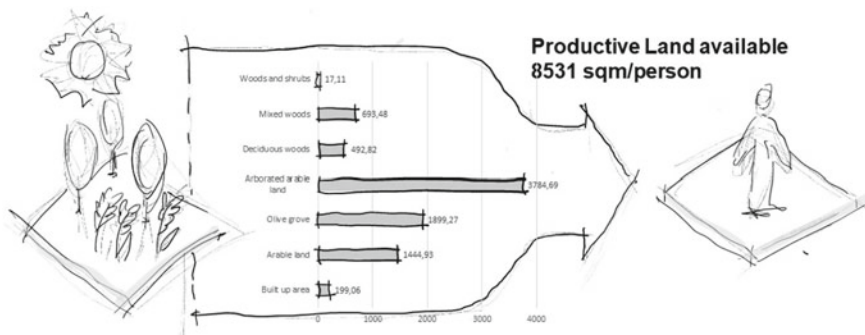
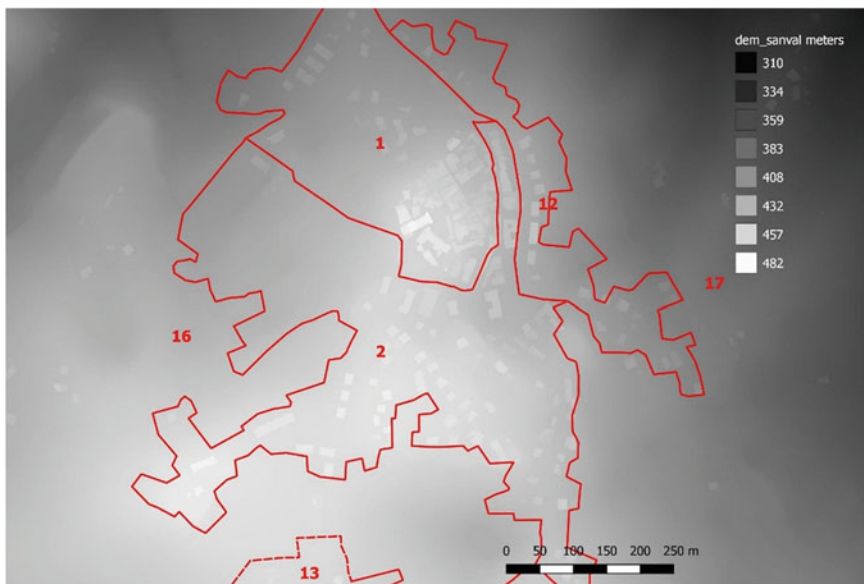
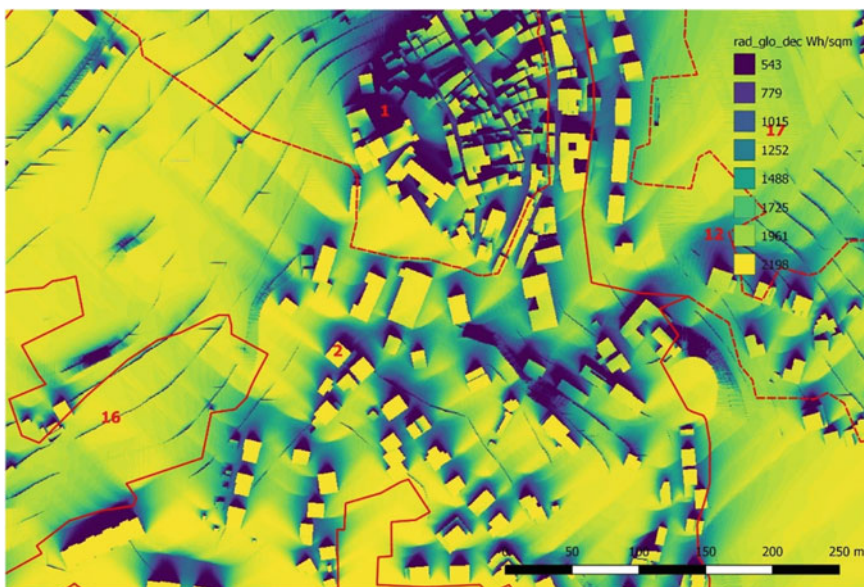


Fig. 7 Surface of production area available per person in the municipal area of San Valentino

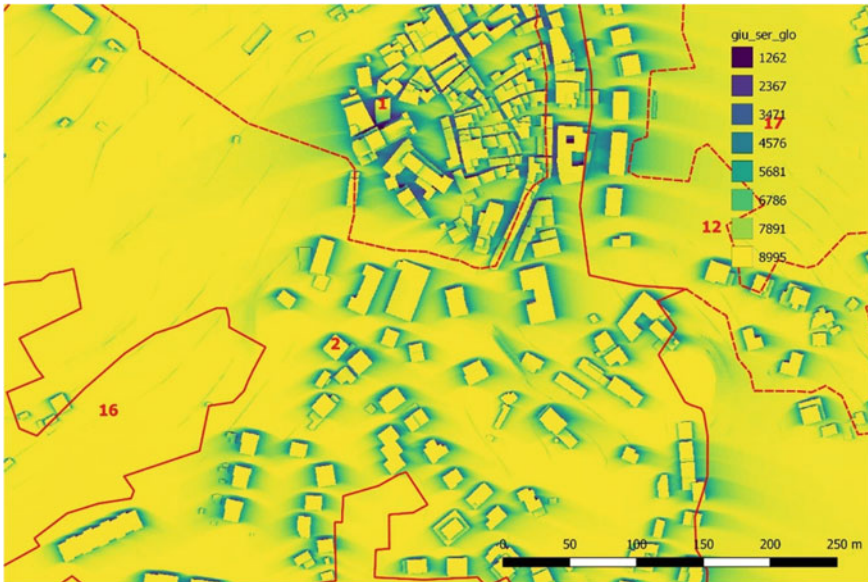


**Fig. 8** Digital elevation model of a portion of the urban area of San Valentino (resolution 1 pixel side: 0.5 m) with in red the profiles of the census blocks



**Fig. 9** Map of direct solar radiation representative of clear sky day of December (unit of measurement Wh/sqm \* day), in the red profile of the census blocks





**Fig. 10** Map of direct solar radiation representative of clear sky day of June (unit of measurement Wh/sqm \* day), in the red profile of the census blocks

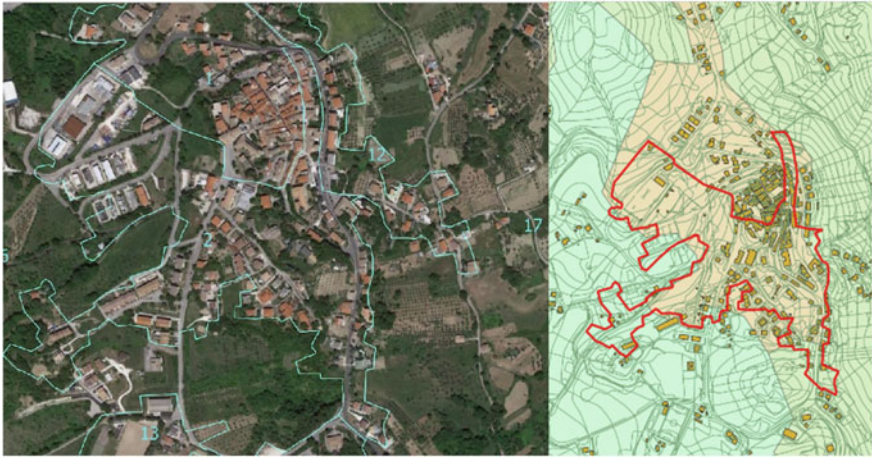
#### ***4.4 EF—(Exported Flows) Mapping Material Flows Out of Buildings/Open Spaces***

The mapping of outgoing material flows as solid urban waste was carried out by associating the per capita yearly flows and associate outgoing household waste material flows for the area. By multiplying the quantities of waste generated with the number of residents, the total amount of MSW generated within the area can be obtained.

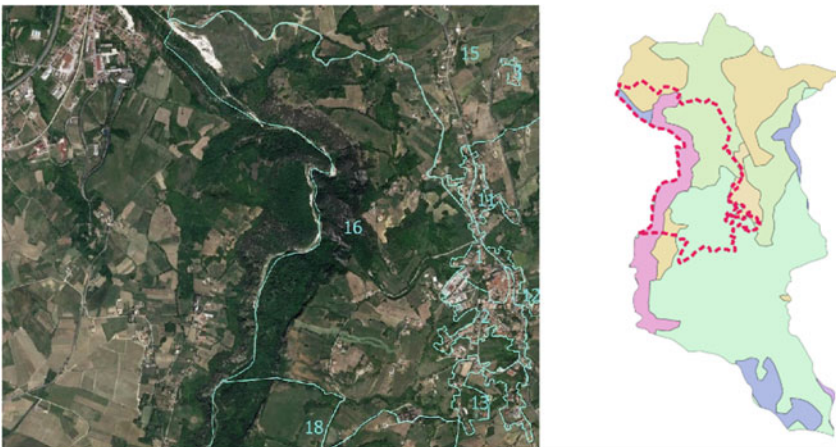
The current level of resolution of the TMG allows to visualize:

- information on the geometry of the surfaces occupied by different land use destinations;
- maps of the relative solar irradiation representative of the monthly average that take into account the geometry of the buildings;
- the flows of waste emissions by census block.

The use of low-cost sensors and facilitated forms of database self-compilation would make it possible to refine the database by inserting information on future crop planning in advance. In the case of solar irradiation maps, sensors positioned on some roofs allow to compare the data relating to the monthly statistical average with the real irradiation data. Finally, as regards the emission flows of TMG waste, it could include the flows actually conferred by individual users, through the weighing of the tubs (Figs. 11 and 12).



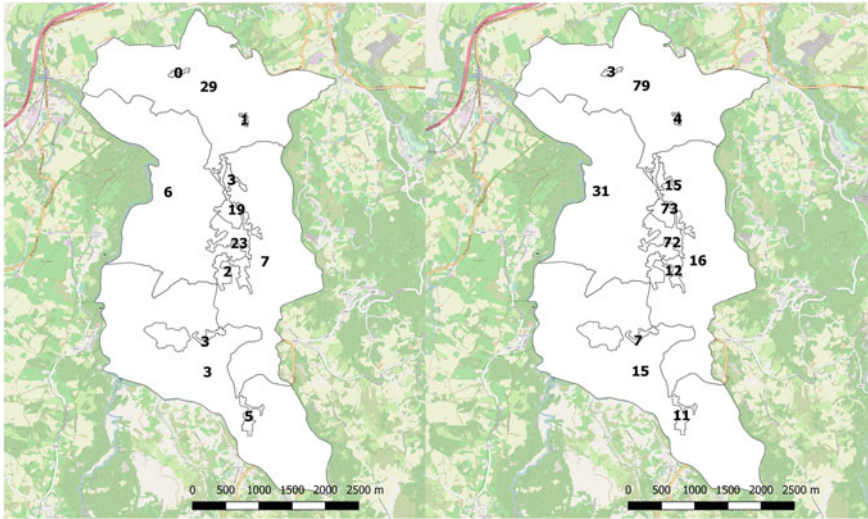
**Fig. 11** Geometric configuration of some of the census blocks of the more urbanized area of San Valentino; CB2, in the center, records the presence of publicly owned high-level solar roofs



**Fig. 12** Geometric configuration of some of the census blocks of the San Valentino area most suited to plant production. The west boundary of block 16 is covered by publicly owned woodland

#### 4.4.1 AW: Mapping the Potential Workforce and Skills Available Locally

Among the unused local resources, person-hours are a fundamental component. The real possibility of triggering local prosuming processes depends on local availability of human resources. Useful information on the available person-hours are obtainable by crossing age-groups with employment status within the census data (Fig. 13).



**Fig. 13** The map on the left illustrates the number of unemployed by census block, the map on the right illustrates the number of unemployed and housewives by census block

For the present case-study the following categories were selected:

- Total resident population more than 15, unemployed seeking new employment
- Total resident population aged 15 and over, non-labor force
- Total resident population aged 15 and over, house husbands and housewives
- Total resident population aged 15 and over students.

Due to the restrictions associated with the current pandemic emergency, the data relating to the presence of unemployed are changing considerably. It is therefore of fundamental importance to integrate the data already mapped with what will be detected by the current census activity at the end of 2021 [22].

## 5 Closing Local Loops: Abacus of Best Practices

### 5.1 Defining Scenarios

The data stored in the TMG constitute an information base aimed at becoming a collaborative platform, updated in real time through sensors, and associated with further quantitative community data. The update is in real time through algorithms shared with the community that intervenes on some categories of data:



**Table 4** Good reference practices

Group	Product	Uses	Level of tech	Case study
<i>Energy</i>				
Timber	Pellet or wood chips	Heat, electricity generation	Medium	Trentino forest management
Photovoltaic	Electric energy	Public building or private facilities	Low	Energetic communities
Local energy	Biogas	Heat or electric generation	Low	Local farm
<i>Material</i>				
Cellulose	Recycled cellulose	Insulation, cardboard, construction	Medium to high	Applied CleanTech
Hemp	Shives (woody bark)	Building materials (blocks, insulation panel)	Low to medium	Edilcanapa in Abruzzo
<i>Data</i>	Public dataset	Collaborative platform	Theoretical	–

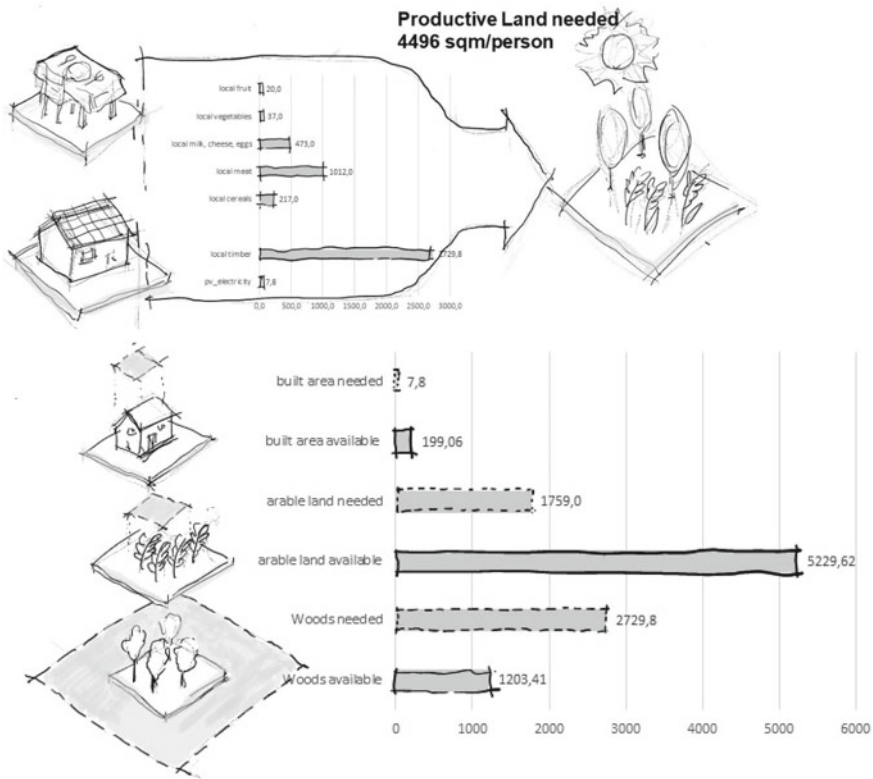
- through sensors associated with cultivation, buildings, production activities
- through manual data implementation methods.

Starting from existing good practices, different scenarios are simulated aimed at bringing together local expenditure flows with the potential local production. The identified expenditure flows are related to the resources available locally and respond to local needs by making materials and energy available, focusing on the seasonality of local resources. The table shows some good reference practices which refer to the possible circularity of resources and highlight connections that intercept the potential for local triggering of entrepreneurship or the availability of public goods capable of hosting production at km.0 (Table 4).

## 5.2 Example Scenarios

This paragraph briefly presents two examples that illustrate the potential use of the data stored in the TMG to verify the transferability of some good practices by developing simplified scenarios. In particular, scenario 1 works on the possible transfer of the good practices comparing them with strategies aimed at local food production (Fig. 14):

- BP1—use of woody biomass from forest maintenance to cover the thermal needs for winter heating of buildings;
- BP2—use of photovoltaic roof systems, connected to the conventional grid, to produce electricity from solar sources.



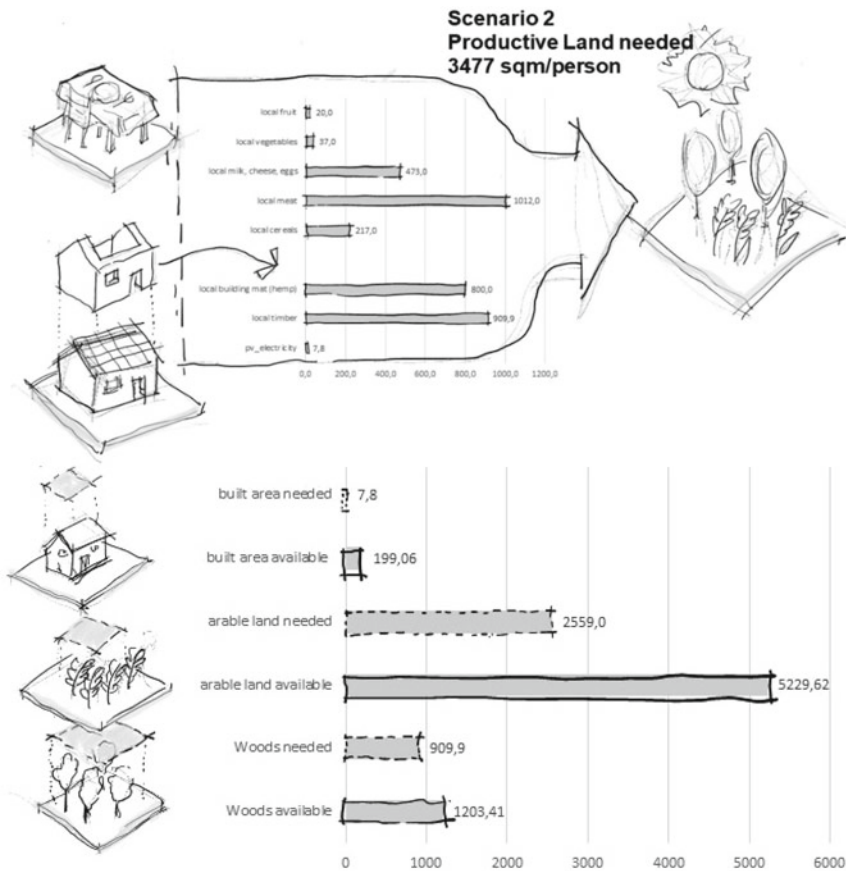
**Fig. 14** Productive land necessary to locally cover energy and material needs and data relating to the production area available per person and the area necessary to cover energy and material needs (Scenario 1)

From the comparison between the TMG data and relating to the extension of production area needed and actually available, it emerges that the energy needs relating to winter consumption for heating homes exceeds the actual local availability of woody biomass (considering with the local regenerative cycles). The activation of possible local micro-economies aimed at intercepting the flows of expenditure associated with the energy needs for heating homes will therefore have to develop integrated supply chain projects. They will be oriented on the one hand to cover local energy needs with locally available resources, on the other hand to activate useful strategies to increase the energy efficiency of the homes. The local production of insulating material such as hemp, thanks to the availability of arable land has high potential for success.

Scenario 2 provides for the possibility of growing hemp to be used as an insulating material, in particular the graph in the Fig. 15 shows how a reduction in the thermal transmittance of the building envelope equal to 0.17 W/sqm\*K, would correspond to a reduction in consumption energy equal to 2/3 of the initial value. The implementation

of activities aimed at the integrated development of the energy supply chain and the insulating material would involve a remodeling of the surfaces of the necessary production area. Optimistically hypothesizing to produce the insulating material in an annual cultivation cycle, the production land balance would see an increase in the arable land component equal to 800 sqm/person, to the advantage of a reduction in the extension of woods useful for producing energy of about 1700 m<sup>2</sup> (Fig. 15).

The comparison between available productive land and necessary land in Scenario 2 shows that the needed surfaces do not exceed the amount of available areas (Table 5).



**Fig. 15** Scenario 2: Above, surface of the production area necessary using hemp to improve the energy performance of the existing buildings. Below: data relating to the production area available per person and the area necessary to cover the energy and material

**Table 5** Available productive land and necessary land in Scenario 2

Practice	Energy/Material	Unit	Productive land	Area (m <sup>2</sup> )	Source
BP1 woody biomass	Thermal energy	sqm/kWh*y	Woods	0.763	[1]
BP2 rooftop pv	Electricity	sqm/kWh*y	Rooftop area	0.00714	[16]
BP3 hemp mat	Insulating material	sqm/kg	Arable land	1.33	[18]

## 6 Conclusions

New emergent technologies and methodologies generate new enabling possibilities for local self-sustainability. Technologies 4.0 is not only an evolution of the sector, but also pleads for its radical transformation based on three concepts: re-industrialization, digitization and sustainability. Three concepts directly bomb a sector that is recognized as a non-industrialized sector (only the production and manufacturing of its materials and products can be considered as factory-made, so under the usual lean management philosophy), and then, industrialized construction is strictly part of the new paradigm [10]. The simplified assessments proposed in the scenarios give a rough idea of how to use the data mapped in the TMG for an informed platform, and exchange information with sensors for giving time response energy and material solution. The coexistence in the same georeferenced database of information on land features and on the population allows to relate data to the expenditure flows of a community with data that can be associated with the production capacities of a territory in compliance with the regenerative cycles of local ecosystems. The georeferencing of this information allows the data to be expressed in general terms or per capita terms, providing clear information on the possible strategies that can be pursued. The TMG itself gives the possibility to include information on the metabolism associated with public properties, i.e. both data related to the demand for energy and matter and information associated with the potential renewable supply. This data availability is fundamental for planning triggering activities of local microeconomies, it will in fact be in the census blocks where public ownership is most present that the start of the first experimental activities will be expected.

In this local systemic design the governance of local production with computerized systems, digital manufacturing, collaborative platforms, self-assembly, robotization of production, Communities 4.0, can provide answers to the economic circularity of the construction sector oriented towards the systemic sustainability of the territories, focusing on humans and social sustainability and enabling local communities in data management to increase their production capacities.

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