CIDADES, Comunidades e Territórios

Urban SUNstainability: a multi-dimensional policy evaluation framework proposal

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Abstract

This paper discusses the concept of Urban SUNstainability and its importance for territorial sustainable development. Generically understood as a process for attaining sustainable development in urban areas, via the intense production and use of solar energy, Urban SUNstainability is presented as a convincing urban policy strategy for a greener, sustainable and prosperous world. Based on existing experiences in areas with abundant levels of solar radiation, it was found that, by now, the use and production of solar energy in urban areas starts to be economically viable, and should be regarded as an adequate solution to implement a greener and sustainable territorial development process in urban areas. As a way to assess the potential and current levels of Urban SUNstainability in urban areas, the paper proposes a multi-dimensional policy evaluation framework, based on five crucial aspects: the solar energy generation capacity, the direct and indirect environmental, economic and social benefits from implementing Urban SUNstainability strategies, and the soundness and effectiveness of the urban planning and governance processes related to the implementation of this process.

Keywords: SUNstainability, Sustainable Development, Territorial Development, Urban Development, Solar Energy.

1. Introduction

In an age of climate change and increasing vulnerability to extreme climate catastrophes, the choice for using renewable sources of energy, instead of fossil fuel energy sources, has become widely accepted as a concrete solution to promoting sustainable development (UN, 2016; Medeiros, 2018a). Indeed, how effectively a city plans and prepares for future potential environmental shocks is decisive in determining its prospects for environmental

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sustainability, as a key dimension both for territorial development (Medeiros, 2016a; 2017a; 2019a; Potter et al., 2008) and for achieving territorial cohesion (Faludi, 2010; Medeiros, 2016b; 2019b; Medeiros and Rauhut, 2018). Crucially, cities need to make choices about the use of green infrastructure in order to improve quality of life of their citizens, maximize economic opportunities, and minimize the impact of the population on the natural environment (Sachs, 2015).

Currently, the majority of carbon emissions and the bulk of energy consumption occur in urban areas (Vesco and Ferrero, 2015). Under this scenario, and amidst powerful social, technological and political forces that are compelling a shift towards a greener (Caprotti and Bailey, 2014) and circular economy (Bolger and Doyon, 2019), the use of solar energy is increasingly seen as a viable and clean energy source to power cities, through solar thermal systems (solar water heating, solar refrigeration) and photovoltaic (PV) systems (Govada et al., 2017).

According to the International Energy Agency, across all cities globally, “the technical potential for urban PV at 5,400 GW, is sufficient to provide approximately 30% of the urban electricity demand in 2050” (Steffen et al., 2019: 911). Indeed, in the past decade, the number of PV plants has been increasing rapidly, driven by a rapid decrease of production costs and by a strong support for green development policies (Trancik, 2014).

It is true that, like wind energy, solar energy is known to be a volatile and uncertain energy source (Spataru et al., 2015). However, as Kopp (1994) claims, and as the Giant Tesla Battery project in Australia has shown, solar energy can be stored in order to be used at night time or on cloudy days. Indeed, nowadays, it is possible that “an oversupply of renewable energy occurs during low demand-side load periods” (Praß, et al., 2017: 610) which can be stored and used when needed.

Under this scenario, the European Union (EU) energy policy aims to balance both the promotion of energy efficiency and the use of renewable energy (EC, 2019). In the end, this EU policy agenda intends to make a very significant contribution to improving security of energy supply, reducing emissions, and boosting competitiveness of technology innovation in renewable energy sectors (Park and Eissel, 2010). In particular, the European Commission (EC) has stimulated the energy performance of buildings via the EU Directive 2002/91 (2002), which had been supplemented by the incorporation into national law of Directive 2010/31/EU (2010). This Directive revises and improves the previous one on building energy performance, in order to ensure that “by 2020 all new buildings are so-called nearly zero-energy buildings” (Papamanolis, 2016: 815).

From a theoretical standpoint, this article is focused on the concept of SUNstainability which, in turn, offers a stronger contribution to a wide body of knowledge related with, for instance, the concepts of 'sustainability transitions', 'urban sustainability', 'sustainable urban systems', and 'urban sustainable energy development'. Crucially, according to Truffer & Coenen (2012), sustainability transitions can entail solar civic initiatives, as well as niche-innovations in the solar photovoltaic production (see Geels, 2019). From an urban sustainability perspective, there is an increasing awareness of the advantages of installing renewable energy plants in municipal and urban buildings (Haarstad, 2017) and sustainable development approaches advocating ideas such as, passive solar design (Hatuka et al., 2018), since the citizens’ acceptance of renewable energy forms and technologies is largely associated with both the risk-benefit perceptions and a general environmental concern (Vainio et al., 2019).

The use of solar energy is not new. By and large, solar energy technology options have been used for decades, but their relatively high cost has limited their expansion in past decades. Even so, all around the world, solar energy is being utilised in buildings via rooftop PV cells and water-heating systems, in order to meet some energy demands of electricity, transport, and heating (Kar et al., 2017). So conceived, solar energy is the most suitable source to yield environmentally clean, stress-free and inexhaustible renewable energy provision (Mafimidiwo and Saha, 2017). With cities being responsible for up to 70% of energy-related carbon emissions, cities are becoming increasingly aware of their responsibility to act towards a greener economy (Steffen et al., 2019).

Substantially, solar energy is an important component of sustainable or green communities, and also one of the most promising climate-friendly energy sources (Zahran et al., 2008). Amongst other advantages, solar technologies: (i) can be efficient in large areas of the world; (ii) require no special skill set to generate or provision power; (iii) need no security measures (Stimmel, 2016); (iv) can perform without excessive maintenance costs for prolonged periods (Pelton and Singh, 2019); (v) can help to reinforce national security, economic growth, climate stewardship, sustainable land use, and economic development (Zahran et al., 2008); (vi) contribute to an urban energy transition towards experimentation in sustainability governance (Quirós et al., 2018); and (vii) have the potential for the creation of new green jobs (Park and Eissel, 2010). In addition to environmental and cost benefits, reducing demand for energy in buildings has three direct positive effects: (i) eliminating or requiring smaller mechanical service systems; (ii) making the buildings themselves more robust and resilient, in that they require less heating or cooling; and (iii) reducing the number of new power stations required to generate electricity (Bothwell, 2015).

In this regard, the use of solar energy can be viewed as an optimal sustainable development (SUNstainability) solution to be implemented in cities located in areas with significant levels of sun exposure all year round, as solar energy technologies can be incorporated into buildings and pathways (roads, sidewalks), large rooftop areas of commercial parks, vacant land at industrial sites, as well as on top of degraded or contaminated land (Steffen et al., 2019) etc., both by public and private entities, and by citizens. In the end, it should be expected that SUNstainable cities can be economically productive, socially inclusive, environmentally sustainable, and entail a sound governance system, in order to ensure that all citizens can benefit from them (Sachs, 2015).

In sum, SUNstainable cities can be seen as a concrete way of embracing zero carbon footprint green urban systems and zero carbon buildings (Govada et al, 2017); a vehicle to promote integrated sustainable urban development strategies (Medeiros and van der Zwet, 2019); and ultimately, sound territorial planning (Faludi, 2018; Medeiros, 2017b) and development (Medeiros, 2018b; Warf and Stutz, 2012). In order to be successful, however, SUNstainable cities should create partnerships with the academic and business arenas, and stimulate city dwellers in implementing solar energy solutions in their activities. From a governance standpoint, cities supported by solar energy systems can allow for the mitigation of over policy centralization, as they can become semi-independent in providing electrical power to the grid on an as-needed basis (Pelton and Singh, 2019).

As seen, the idea of ‘Urban SUNstainability’, generically understood as a ‘process of attaining sustainable development via the intense production and intense use of solar energy within urban areas’, entails a multi-dimensional and multi-governance development perspective. So conceived, the main goal of this article is to propose an innovative multi-dimensional conceptual policy evaluation framework, which can be applied to assess urban areas’ SUNstainability capacity. Methodologically speaking, this ‘Urban SUNstainability conceptual framework’ will be designed based on a wealth of literature, namely on sustainable and smart cities, and also on the use of solar energy in urban areas.

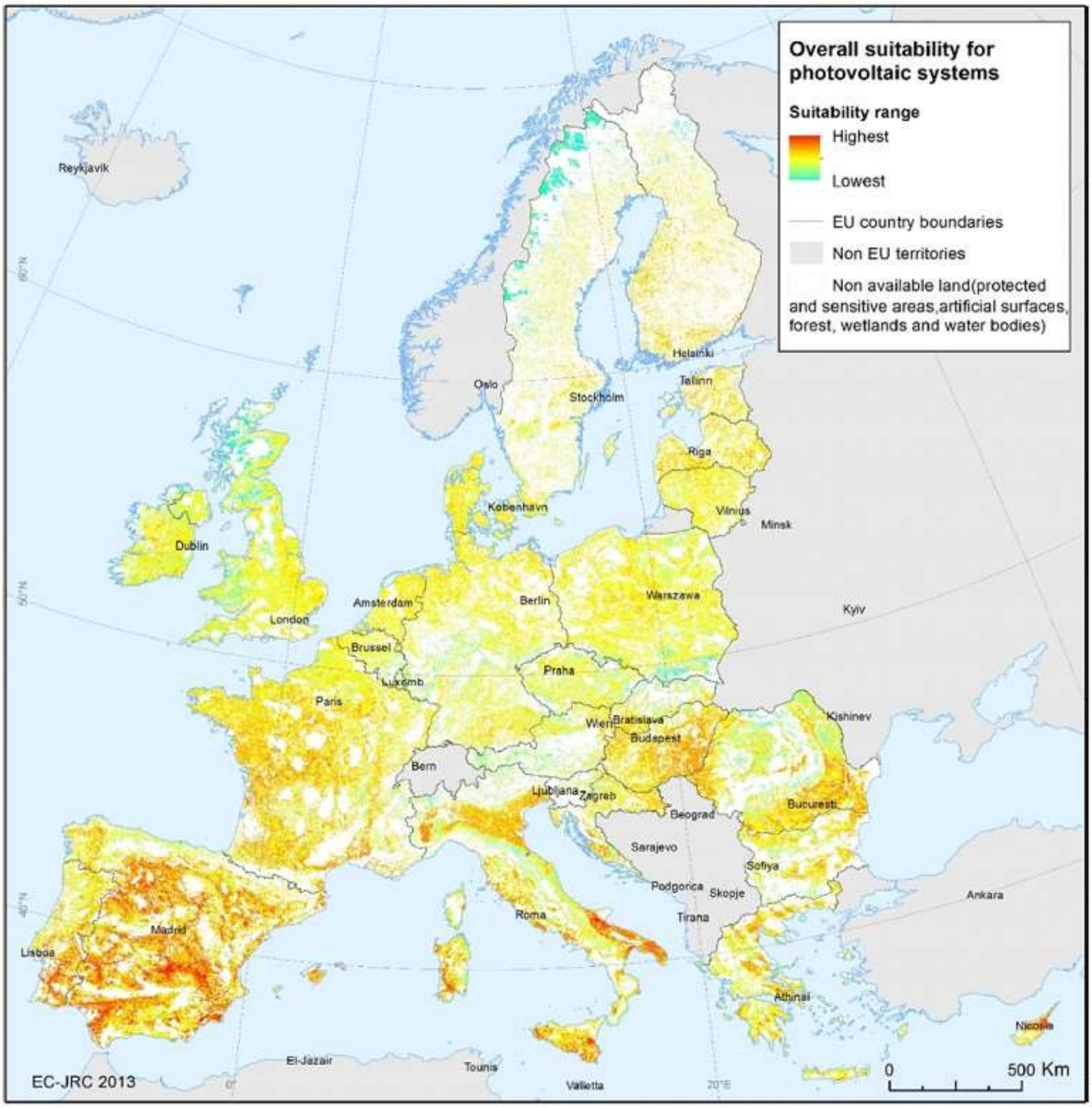
The article is organized as follows. The next section will address the potential advantages and disadvantages of producing and using solar energy in urban areas, as a vehicle to promoting sustainable territorial development. The third section will then elaborate on how the notion of Urban SUNstainability is integrated into the main World and EU territorial and urban development strategies. The fourth section will debate the above mentioned Urban SUNstainability conceptual framework.

2. Solar energy and sustainable territorial development

More than 50% of the population around the world dwell in urban areas. Close to 80% of humanity’s greenhouse gas emissions are produced in cities, whilst around 70% of the energy is consumed in cities (Siemens, 2009). Consequently, cities play a major role in implementing the United Nations (UN) 2030 Agenda for Sustainable Development (UN, 2016). This Agenda recognizes that “sustainable urban development and management are crucial to the quality of life of our people” and that, amongst other things, this requires “more efficient use of water and energy” in order “to minimize the impact of cities on the global climate system”. Alongside, it proposes to ‘increase substantially the share of renewable energy in the global energy mix’, and the promotion of ‘investment in energy infrastructure and clean energy technology’, so that ‘all human beings can enjoy prosperous and fulfilling lives and that economic, social and technological progress occurs in harmony with nature’. In this context, and especially in territories with abundant exposure to sunshine, such as the south of Europe (Quirós et al., 2018)

(Figure 1), the use of solar energy can provide a critical and fundamental response to address the UN 2030 Agenda for Sustainable Development.

Figure 1. Spatial distribution at grid cell level (1km resolution) of the suitability for the installation of large-scale PV systems in Europe



Source: Castillon et al., 2016: 91.

A wealth of literature has debated the importance of urban sustainable development processes and the promotion of ‘smart cities’ (Battarra et al., 2016; Maltese et al., 2016) towards more green and resilient cities. Conversely, only a limited amount of research work has been produced on Urban SUNstainability processes – if and how solar energy can provide 100%, or close, of a city’s energy needs in a sustainable manner all year round. Even so, a few examples are found in the literature, on the role of solar energy in promoting SUNstainability processes in several urban areas: Helsinki - Finland (Dahal et al., 2017); Virginia – USA (Pitt et al., 2018); San Francisco – USA (Ko et al., 2017); Toronto – Canada (Chow et al., 2016); Osmaniye – Turkey (Kara and Ozalp, 2017); and Cáceres – Spain (Quirós et al., 2018).

These experiences are particularly important since the combustion of fossil fuels is largely responsible for the problems of climate change, air pollution, and energy insecurity. As such, renewable energy sources, such as solar energy, have near-zero emissions of greenhouse gases and other air pollutants, no long-term waste disposal problems, and no risks of catastrophic accidents, whilst it can meet 100 percent of the world's energy needs (Delucchi and Jacobson, 2013). This is especially true for urban areas where solar energy systems can be easily implemented in buildings and other places. Thus, the importance of assessing cities' Urban SUNstainability, as a concrete solution, is imperative, not only for achieving environmental sustainability, but also as a means to supporting a sustained transaction to a greener economy and a more inclusive society (Sachs, 2015).

Solar energy production can be exploited via a smart grid infrastructure, in which the customer becomes part of a network with bidirectional energy flows. In essence, solar-energy intakes enable energy providers to develop and to use tools to reduce grid power demand when solar power can supply the total demand (Tamburini et al., 2015). One positive outcome is that the smart grid strengthens the role of the consumer and transforms passive consumers into active prosumers, thus promoting an active citizenship model (Koutitas, 2018). More pointedly, energy displays that give feedback on energy consumption in real time make it possible to save energy on the basis of the information supplied by the smart meter (Battarra, 2016). Curiously, in general, on-site solar energy generation would benefit from a lower density environment since sparsely built forms allow larger rooftop areas per capita and less obstruction for solar panels. In contrast, compact urban settings are likely to have more shade on the rooftops from neighbouring structures and provide less rooftop area per capita (Ko et al., 2017). In addition, there are a few other barriers to Urban SUNstainability processes:

• In several cases, solar panels still cannot compete with fossil fuels when it comes to generating electricity relatively cheaply (Park and Eissel, 2010). Even so, the cost of photovoltaic power is dropping rapidly. Hence, if those trends continue, and if the photovoltaic industry continues to grow and improve technologically, by 2020 the cost will be comparable to the cost of conventional power, as will the cost of solar thermal power (Jacobson et al., 2013). More recent (2019) analysis conclude that "wind and solar farms have become cheap enough, in many instances, to outcompete even gas" (TE, 2019: 31). Then again, for any energy option, the total cost to society is the private cost of generating power plus additional environmental or system-wide costs. "For wind, water, and solar power, these additional costs include the costs of extra generation capacity, transmission, or storage needed to ensure that demand can be satisfied reliably" (Delucchi and Jacobson, 2013: 34);

• Sometimes, investment in solar energy creates costs that must be passed on to other electric ratepayers, since "net-metered PV owners do not pay their share of the fixed costs for the generation, transmission, and distribution infrastructure that make grid-based electricity available to them when they need it" (Pitt et al., 2018: 2032-3);

• Often times, "an excess of distributed solar PV systems could cause technical problems for the electrical distribution grid" (Pitt et al., 2018: 2033);

• The amount of solar energy that can be generated by a solar panel depends largely on location, the weather, and the time duration involved in receiving solar radiation, since it is a function of the amount of available irradiance that falls on the solar panel (Mafimidiwo and Saha, 2017: 217). Indeed, a "reasonably accurate knowledge of the availability of the solar resources at any place is required by solar engineers" (Kara and Ozalp, 2017: 765);

• The shortage of empirical data remains a barrier when it comes to the implementation of solar energy solutions in cities (Ko et al., 2017).

3. Urban SUNstainability and territorial development agendas

Sustainable development is a holistic approach that emphasizes economic, social, environmental, and spatial planning/governance objectives in shaping policy. Existing literature also highlights the fundamental role of environmental sustainability as a pillar to achieving the policy goal of territorial cohesion (Medeiros, 2016b). Reflecting the general mood of present times, the global rise in the production of energy via renewable sources, devises a brighter way forward in building a more sustainable world economy for a global society that is interconnected as never before. This calls for concerted policy actions on a global scale and new forms of global governance to meet the new UN Sustainable Development Goals (SDGs). Hence, it goes without saying that the fundamental idea of sharing best practices in implementing green economy polices, between two of the most economic dynamic regions of the world (EU and USA), makes more sense than ever before.

Indeed, sustainable development is a central concept for our age (Sachs, 2015), as the gigantic world economy is creating a gigantic environmental crisis, threatening billions of people across the word. In this context, the production of renewable sources of energy can be seen both as a direct solution for mitigating global warming and other environmental threats, and as the basis for novel economic activities, in the context of a prosperous, socially inclusive, and environmentally sustainable world. Indeed, the world economy has become very large, relative to the finite planetary resources, and human beings are exceeding the planetary boundaries in several critical areas. Under this pessimistic scenario for the future of our planet, sustainable territorial development strategies offer a range of answers to define the objectives of a more cohesive and well-functioning society, one that delivers wellbeing for its citizens today and for future generations.

3.1. Worldwide: United Nations (UN)

The support for a sustainable development agenda has been at the forefront of the UN political agenda for decades. Indeed, in 1987, the Brundtland Report placed the goal of uniting countries to pursue a sustainable development path on the global political agenda, due to an increasing realization of the persistent deterioration of the human environment and natural resources. This was meant as a development process to meet the needs of the present, without compromising the ability of future generations to meet their own needs. Throughout its 300 pages, the report recognised that "future development crucially depends on its long-term availability in increasing quantities from sources that are dependable, safe, and environmentally sound" (UN, 1987: 141). Further on, the same report singles out the untapped potential of renewable sources of energy that could, in theory, provide enough energy to cover the global energy consumption.

As regards solar energy, this report mentions its relatively small use globally. Nevertheless, it highlights the potential advantages of using solar water and household heating systems, and the use of photovoltaic equipment, which, by then, already provided cheaper electricity to remote places than conventional power lines. In conclusion, the Brundtland Report sustains that "every effort should be made to develop the potential for renewable energy, which should form the foundation of the global energy structure during the 21st Century", and that "a much more concerted effort must be mounted if this potential is to be realized" (UN, 1987: 163). All these goals played out well in the environmental sustainability mainstream political discourse. However, they bear witness to a lack of deeper and stronger policy action towards the use of solar energy in urban areas, mostly likely because of the costs involved, namely in the production of PV solar panels at the time.

Over the years, solar energy has become increasing competitive within the energy production market (Koutitas, 2018). However, the recent UN 2030 Agenda for Sustainable Development does not mention, even once, the term 'solar energy'. Even so, it dedicates a main policy goal (7) to "ensure access to affordable, reliable, sustainable and modern energy for all". Evidently, this requires an increasing share of renewable sources of energy in the global energy mix. No mention whatsoever, however, was made of the need for urban areas to became fully independent in electricity production, in particular via solar energy.

3.2. Europe: The European Union (EU) policy agendas

The reading of the first EU treaties (Rome, Maastricht, Amsterdam) shows a clear absence of policy goals aiming to support the use of renewable energy sources. It is only by 2010 that the Lisbon Treaty dedicates an Article

(176A) which invokes the need to "promote energy efficiency and energy saving and the development of new and renewable forms of energy". In the same year (2010), the EC published the EUROPE 2020 policy agenda, which clearly and unequivocally supported the shift towards a low carbon economy and the increased use of renewable energy sources (EC, 2010: 7).

Nevertheless, the Europe 2020 agenda does not advance a specific energy policy goal dedicated to urban areas. Seen from this angle, three years earlier, the Leipzig Charter on Sustainable European Cities (LC, 2007), invokes the need for improving the energy efficiency in cites. However, not a single word is used to highlight the need for renewable sources of energy in European cities. Conversely, both Territorial Agendas (Territorial Agenda, 2007; Territorial Agenda 2020, 2011) highlighted the need to promote renewable and local energy production. Likewise, the more recent Urban Agenda for the EU (Pact of Amsterdam) invokes a strong shift towards renewable energy and energy efficiency. Moreover, this Agenda adds a fundamental goal, expressed in the need to apply energy efficiency in buildings, and to foster "innovative approaches for energy supply (e.g. local systems) and increasing the local production of renewable energy" (Urban Agenda, 2016: 27). A major concern is that the concrete mention of the term 'solar energy' is absent in all mentioned documents.

Despite that, the EU has an Energy Strategy (EC, 2015a), which was adopted on 25 February, 2015. In short, this strategy "is focused on boosting energy security, creating a fully integrated internal energy market, improving energy efficiency, decarbonising the economy – not least by using more renewable energy – and supporting research, innovation and competitiveness. Since its launch in 2015, the EC has published several packages of measures and regular progress reports, which monitor the implementation of this key priority of the Juncker Commission to ensure that the strategy is achieved. On 9 April 2019, the Commission published the fourth State of the energy union report, which takes stock of the progress made towards building the energy union and highlights the issues where further attention is needed. It brings together a series of Commission reports and initiatives related to the energy union in an integrated way"[2].

As regards concrete measures for urban areas, the EU Energy Strategy proposes a full integration of electric vehicles in urban mobility policies. Furthermore, the EU Clean energy for all Europeans package[3], consisting of eight legislative acts, was agreed by the Council and the European Parliament in 2018 and early 2019, and requires that EU countries have 1-2 years to transpose the new directives into national law. Some of the most relevant for Urban SUNstainability are:

(i) the 'Energy performance in buildings' package: based on the EU Directive 2018/844 (amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency), it mentions the need for integrating renewables to smart grids and smart-ready buildings;
(ii) the 'Renewable energy' package: based on the recast Renewable Energy Directive (2018/2001) on the promotion of the use of energy, entered into force in December 2018, it mentions the relevance of solar thermal technologies and rooftop solar installations.

In a more generic perspective, and for several years now, the EU has been taking pro-active measures with the goal to support a greener economy, by helping citizens and governments to green their activities, through better management of resources, and the use of economic instruments that are good for the environment. More recently, the concept of the 'circular economy' has gradually been adopted by the EU[4]. This was done via the implementation of the Circular Economy Action Plan in 2015 (EC, 2015b). But here, the key emphasis on energy is on improving energy efficiency, rather than on the need for using renewable sources of energy, and in particular solar energy.

[2] https://ec.europa.eu/energy/en/topics/energy-strategy/overview
[3] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
[4] https://ec.europa.eu/environment/circular-economy/index_en.htm

3.3. European Urban SUNstainability experiences

Amid these ever-growing green development flavour trends, it is expected there will be a rise in initiatives which gather and share urban experiences in implementing Urban SUNstainability development strategies. One of these initiatives is the POLIS project, which joins six European cities (Lisbon-PT, Vitoria-ES, Lyon-FR, Paris-FR, Munich-GE, and Malmö-SE), in a quest to implement strategic town planning and local policy measures to utilize the solar energy capability of structures. In sum, the aim of the POLIS project is to "identify and evaluate current practices in solar urban planning, and unite the key responsible parties of this process to create a more cohesive planning and legislation practice for solar developments. The physical structure of a building and its position within the urban pattern is clearly integral to its solar energy capabilities. Availability and orientation of external surface area is a crucial factor in the design of active solar systems and also important for the reception of passive solar energy. More than any other renewable energy, integrated solar energy relies on the qualification of the built environment".[5]

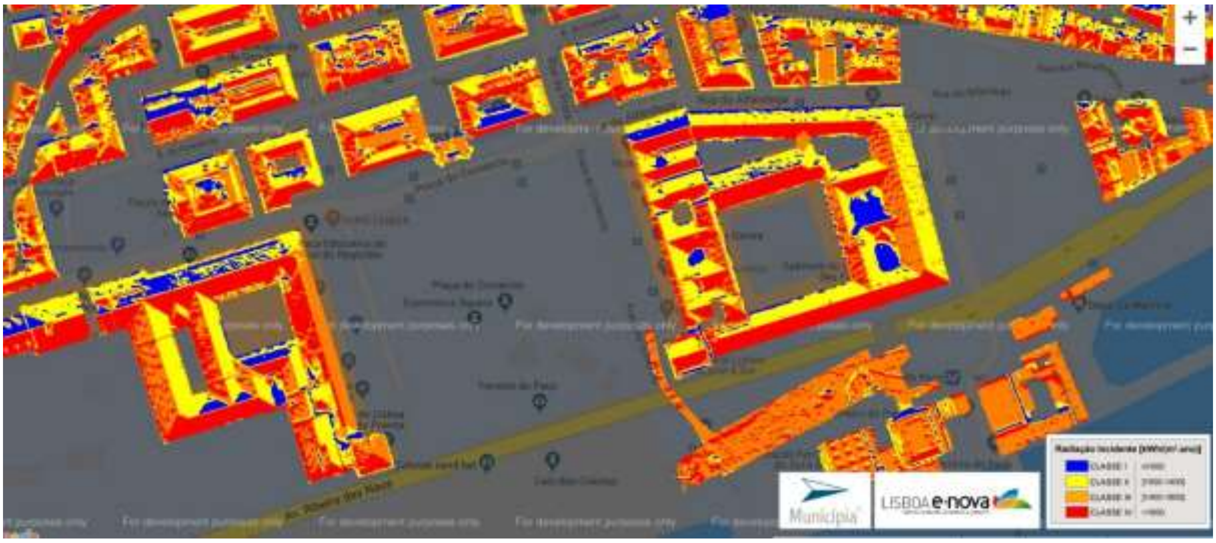
This POLIS project is particularly interesting since it makes available to all interested stakeholders several instruments to promote solar energy in urban areas, such as: (i) municipal agreements or private law commitments; (ii) a best practice guide for solar urban planning in Europe; (iii) the presentation of solar action plans; and (iv) the presentation of several software programmes for analysing and simulating sun irradiation in a given urban area. In the end, the promotion and mobilisation of solar urban potential is engaged through the cooperation of cities that are currently engaged in solar urban planning.

Lisbon, as one of the cities integrated in the POLIS project, has created an Energy and Environment Agency (Lisboa E-Nova), which "seeks to contribute to sustainable development of Lisbon by mainstreaming good practices among political decision makers, major urban stakeholders and citizens. Lisboa E-Nova's objectives are met through projects and communication actions that promote the adoption of innovative concepts and actively contribute to the definition of new policies and development frameworks. By incorporating measures to adapt to climate change and actions to mitigate it, as well as supporting innovation and the development of projects that enable greenhouse gas (GHG) emissions to be reduced, Lisboa E-Nova is working towards achieving a low carbon city and one that is less vulnerable to the effects of the future climate. A city that is an example to follow on the path to decarbonization, while focusing on the welfare of the citizen[s] and future generations. Lisboa E-Nova is a key player in the city in the pursuit of national and international energy and climate goals for 2030 and 2050, and is active in three broad areas[6]".

Most importantly, however, from this E-Nova initiative, was the creation of the SOLIS instrument, which includes the development of a two-component platform: (i) the update and improvement of a solar potential chart for Lisbon (Figure 2); (ii) and the development of a virtual space, capable of gathering and sharing technological solutions associated with the production of solar energy. In synthesis, the solar potential chart for Lisbon was developed in 2012, and serves as a support tool to assess the solar potential of edifices and other surfaces in Lisbon. With this chart, the city of Lisbon expects to establish appropriate goals and policies when it comes to the adoption of solar energy. Additionally, this tool will allow the owners of the buildings and other spaces to compare their electric consumption profile with the photovoltaic potential of their location, in order to obtain the optimal solar photovoltaic system.

[5] http://www.polis-solar.eu/
[6] https://lisboaenova.org/en/lisboa-e-nova-3/

Figure 2. Solar potential chart for Lisbon for the downtown area around 'Terreiro do Paço'



Source: http://80.251.174.200/lisboae-nova/potencialsolar/.

Just like Lisbon, in Germany, the district of Munich developed a GIS analytic tool (tool on the Solar Initiative Munich), which provides detailed and updated information on the solar potential for each edifice. This tool not only informs the user if the roof is suitable for the use of solar energy (Figure 3) but also provides advice on planning and construction of solar system s, as well as valuable links to further information.

Figure 3. Solar potential chart for Neubiberg Municipality – Munich – Germany for the downtown area

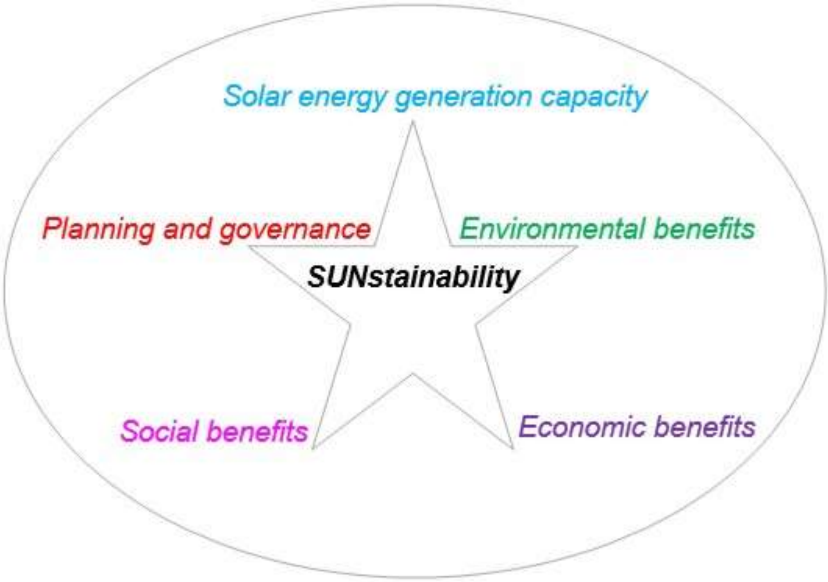
Source: https://www.solare-stadt.de/kreis-muenchen/solarpotenzialkataster2d?lat=48.074703&lon=11.671462&zoom=14.

4. Urban SUNstainability: a multi-dimensional concept

As previously stated, the concept of 'Urban SUNstainability' can be generically understood as a process of attaining sustainable development via the intense production and intense use of solar energy within urban areas.

In an ideal scenario, a fully SUNstainable urban area would not need to rely on any other energy source than solar energy. For certain areas of the globe with wide solar exposure and intensity, that is not a far cry scenario. Emanating from our previous discussion, it is also clear that the notion of SUNstainability is multi-dimensional, as it does not solely regard the assessment of the solar energy generation capacity of the analysed urban area, but also other development dimensions related to planning and governance, environment, social and economic aspects. Hence, and reflecting an integrated and interdisciplinary approach, from a methodological standpoint, the proposed Urban SUNstainability conceptual framework is supported by five analytic dimensions (Figure 4):

Figure 4. the Key Dimensions of the SUNstainability concept



Source: Own elaboration.

1. **Solar energy generation capacity**: this dimension is crucial to assess the degree of SUNstainability since this process largely depends on availability and intensity of solar radiation. Hence, one way of assessing this solar energy generation capacity is by calculating the solar radiation values in a specific urban area, for example, via the use of a Geographical Information System (GIS) software. The end result of this analysis would identify if the urban area can be fully powered by solar energy.

2. **Urban planning and governance processes**: the sound implementation of 'Urban SUNstainability' processes require appropriate urban planning and governance instruments, which can regulate and stimulate the use of solar energy by all interested stakeholders. In this light, the assessment of Urban SUNstainability should take into account in what measure the incorporation of regulations into urban plans are stimulating the use of solar energy use and production in the city. Likewise, it is fundamental to analyse if and how dedicated institutional capacity to coordinate stakeholders in implementing Urban SUNstainability governance processes is taking place.

3. **Environmental benefits**: in the end, Urban SUNstainability should be a key driver for achieving environmental sustainability processes within urban areas. As such, the analysis of this process requires the assessment of its direct and indirect impacts in improving environmental conditions (reduction of air and water pollution, and CO2 emissions, etc.).

4. **Economic benefits**: Urban SUNstainability processes should entail positive impacts in stimulating a greener economy, both via the creation of indirect and direct green jobs and business activities, and also by stimulating the reduction of the use of carbon-related energy sources in transport and economic activities across the urban area.

5. **Social benefits**: the analysis of Urban SUNstainability processes requires the analysis of the direct and indirect social benefits from the production and dissemination of solar energy related practices. In the end, these practices should contribute to improving the quality of life of urban dwellers, for instance in their health and income status.

As seen, the proposed methodological approach is innovative in a sense that is goes beyond the purely technical perspective on the use of solar equipment in cities (see Pitt et al., 2018; Chow et al., 2016; Ko et al., 2017) and the regulatory settings to promote their use (see Steffen et al., 2019) (Table 1). Instead, the Urban SUNstainability conceptual framework is intended not only to unveil the detailed solar energy capacity of each case-study, but also to shed light on existent or non-existent municipal planning/governance processes (regulatory and financial instruments) which aim to support Urban SUNstainability processes. Moreover, the proposed framework is completed by collecting information on the potential economic, social and environmental benefits of such strategies in urban areas.

Table 1. Dimensions, components and variables to assess solar energy potential in the available literature

Variables to assess the solar energy: source (Pitt et al., 2018)	
1. Avoided energy costs	- This variable accounts for the cost that a utility would otherwise incur to purchase or generate an equivalent amount of electricity
2. Generation capacity	- Proponents argue that distributed solar energy should be credited for helping to avoid the cost of future power plants that would otherwise be built to meet rising electricity demand
3. Transmission and distribution grid impacts	- In theory, distributed solar can avoid the need for new transmission infrastructure by concentrating generation closer to its point of use
4. Natural gas market impacts	- Certain VOS studies argue that distributed solar provides utilities with a hedge against the volatility of natural gas prices, thus saving money that would otherwise be spent on risk mitigation investments
5. Environmental benefits	- Studies credit solar energy for its positive environmental impacts
6. Economic development	- Solar proponents generally argue that increased solar energy use creates jobs
Factors influencing the production of PV solar energy in buildings. Source: (Chow et al., 2016)	
1. Roof type	- There are two major types of roof types, flat and pitched. This is important because it determines the potential tilt of the PV systems to be installed.
2. Structural adequacy	- This takes into account the structural soundness of the rooftop, since PV systems add loads to rooftops. Building code requirements (wind loading, snow loading) and the structural adequacy of the roofs therefore need to be analysed. It should be noted that this is not an issue in most cases
3. Material compatibility	- This refers to the material suitability and aesthetic appeal for PV installation. This issue is however, almost never considered
4. Shading	- This factor takes into account the reduced solar radiation that may be caused on the rooftops by trees, HVACs, other equipment, vents, chimneys and other roof structures
5. Orientation	- The direction in which the roof surface is oriented. It is not an issue for flat rooftops; however, it has a significant impact upon pitched roofs
6. Module coverage	- This factor accounts for the space needed between PV modules, inverters, wiring, access to modules and other maintenance requirements. This value was applied as a "packing factor" to modify and lower the power density of the PV system

Variables for solar PV production. Source: (Ko et al., 2017)	
1. Population density	- Number of inhabitants per km2
2. Rooftop areas per capita (PC)	- Total rooftop areas/number of inhabitants
3. Rooftop solar PV potential *PC*	- Total rooftop solar radiation/number of inhabitants in each area
4. Vehicle Kilometres Travelled (VKT) per capita	- Total distance travelled by vehicle trips/number of inhabitants in each area
5. Vehicle energy use per capita	- VKT per capita/vehicle energy efficiency
Key roles of city government in catalysing utility-scale solar PV projects. Source: Steffen et al., (2019)	
1. Target setting and planning processes	- Set solar energy production targets and align policy spheres and stakeholders; establish integrated urban planning process to promote the use of solar energy; foster dedicated institutional capacity to coordinate stakeholders
2. Norms and regulations	- Promote the use of solar energy via land use, building codes, solar ordinances, and grid connection regulations; adapt local taxation rules, enable households and business to purchase solar energy through obligations on energy suppliers
3. Direct purchase and investment	- Develop and invest in city-owned solar PV projects and portfolios; directly purchase solar power from households and business; prescribe a share of renewable energy to supply facilities and services owned and operated by cities
4. Financing and investment promotion	- Facilitate long-term loans for solar energy project developers; issue municipal green bonds and create funds to support municipal solar PV investments; proactively advertise solar PV investment opportunities to engage and attract investors

Source: own elaboration based on Pitt et al (2018); Chow et al (2016); Ko et al (2017); Steffen et al (2019).

Although all the five proposed dimensions for assessing Urban SUNstainability are important, for efficacy's sake, cities should be aware that the use of photovoltaic energy systems in a dwelling with a poor solar light radiation or a plant of the wrong size, could not allow for the return of their investment (Tamburini et al., 2015). In this context, it is crucial to firstly determine the solar energy potential of each city, before implementing an Urban SUNstainability plan. From an environmental and technological point of view, solar energy should allow for an optimal supply of the electricity network while emitting little or no pollution (Hatti, 2019). Besides solar exposure, other factors can contribute to enhance the capacity of cities to use solar energy: (i) high density in the urbanized areas that enhances new energetic strategies; (ii) new and advanced building technologies that can save energy demand and consumption; and (iii) urban morphology and compactness […] (Maltese et al., 2016).

From an urban governance perspective, the implementation of an effective Urban SUNstainability plan presumes an iterative process linked to the policy cycle, where vertical (across stakeholders) rather than horizontal (within a specific category of stakeholders, e.g. government, private sector) coordination prevails (Vidican, 2015). Based on existing evidence, it is also possible to conclude that the implementation of subsidies and attractive financial schemes and attitude changing activities are essential for cities to promote small-scale solar energy. To attract city dwellers and energy utility companies to install solar panels and thermal collectors, city councils, central governments, and energy authorities should establish several measures which include attractive economic and policy plans (Dahal et al., 2017). In large measure, planning for future energy-efficient and energy-producing buildings requires specific knowledge during the design process. Indeed, future buildings need to comply with strict rules concerning their supply and demand energy balance. In this regard, not only do they need to reduce their energy demand, they should also produce a considerable part of their own energy locally with renewables (Kanters and Wall, 2014).

Alongside, and following the concept of 'brightfields', cities can promote the regeneration and redevelopment of underused, abandoned and derelict sites and properties (so called brownfields) by implementing solar energy projects (Spiess & De Sousa, 2016). Furthermore, as the recent report of IRENA concludes, there are three priority areas where cities can take action: (i) renewable energy in buildings (for heating, cooling, cooking, and appliances); (ii) sustainable options for transport (electric mobility and biofuels); and (iii) creating integrated urban energy systems. As concerns specifically solar energy, there are other technological solutions (besides PV panels on roofs) which can be implemented in urban areas, such as central solar heating plants (CSHP) with seasonal heat storages, solar thermal (ST) power plants, solar ventilation preheat (SVP), solar water heating (SWH), solar cooling systems, etc. (IRA, 2016).

5. Conclusion

In our day and age, the continuous presence of growth vs development policy agendas is illustrative of how little the world has evolved in absorbing the sustainable development concept, formally launched by the Brundtland Report, in 1987. Indeed, despite the efforts of the UN and many other international and national entities in presenting compelling arguments on the advantages of implementing sustainable development policy agendas, rather than narrow-vision neoliberal growth agendas, several economic crises, coupled with fossil-energy lobbying forces have, in some cases, been able to halt the necessary progress for implementing sustainable territorial development agendas, in many territories. These include some of the most developed areas of the world, like the USA.

Against this backdrop, the UN continues its meritorious efforts to alert the world to the need to implement a sustainable development agenda, as an indispensable requirement to achieving socioeconomic progress and positive sustainable territorial development trends, whilst contributing to mitigate and invert current global challenges, such as global warming, deforestation, ocean acidification, and poverty. Crucially, urban areas can be regarded as fundamental playgrounds to implement these sustainable territorial development policies, since they are largely responsible for contributing to many of those global problems.

In this article, a case is presented on how urban areas, in particular those located in territories with abundant solar radiation, can significantly contribute to promoting sustainable territorial development policy agendas, by exploring their untapped solar energy potential, towards a carbon-free economy. Based on a wealth of literature, it is possible to conclude that, as we speak, these potential Urban SUNstainability policy agendas, supported by the idea that an urban area can be gradually self-sufficient in covering all its energy needs via solar energy, with indirect and direct social, economic and environmental beneficial impacts, is very much realistic. Firstly, the production of solar energy is by now far more economically competitive than it was a few years ago, and soon can be more economically viable to explore than fossil-fuel related sources of energy. Secondly, there is an increasing global awareness that there are several indirect costs associated with the use of fossil-fuel energy sources, in particular for human health and the world environment. Thirdly, and despite the absence of concrete goals and measures to implement Urban SUNstainability policies, both in UN and EU mainstream development agendas, there are already a few eloquent examples being implemented in some European cities, including some in northern and less sunny territories. This is, as we expect, just the beginning, of an Urban SUNstainability catch-on process, not only in Europe, but in many other parts of the world.

In order to assess the current Urban SUNstainability process, and also to assess its potential, this article presents a conceptual framework based on five analytic dimensions. First and foremost, the solar energy generation capacity needs to be assessed, since this process largely depends on the availability and intensity of solar radiation. In future research, there is a need to assess existing urban planning and governance procedures which can stimulate and consolidate the implementation of Urban SUNstainability policy strategies. Lastly, the analysis of the potential effectiveness of this process needs to find causalities of its implementation to provoke positive social, economic and environment development trends, and in particular to the implementation of a greener and circular economy, higher standards of living, and a cleaner environment.

As regards the case of Lisbon, one could expect that a path towards an increasing use and production of solar energy, towards a smarter and more sustainable city, would require policy measures, at the urban level, which could attract the urban population to become both producers and consumers of solar energy. Likewise, this intended sustainability path requires experimenting with novel multi-level governance models, which can embrace a whole-of-society approach in view of increasing the administrative capacity of urban government structures, as well as the awareness of the positive transformative nature that the use and production of solar energy can provide to all urban dwellers.

In conclusion, as presented in this paper, Urban SUNstainability conveys an understanding of a greener, prosperous and sustainable world for the years to come. Rooted in the image of an emergent need for an age of sustainable development, all the potential territorial development benefits associated with the implementation of Urban SUNstainability policy strategies are yet to be fully assessed. This paper intends to provide an academic contribution to better assess their potential implementation both in an ex-ante and ex-post phases across the world, by means of a multi-dimensional policy evaluation framework. This framework is, obviously, open for further improvements, following its implementation in several case-studies, which will be the next step of this academic endeavour. In the end, this analysis also intends to disseminate the notion of Urban SUNstainability across the academic and policy meanders, as a way to contribute to the institutionalisation of palpable and potent political forms supporting Urban SUNstainability agendas across the world.

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