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Energy sprawl, land taking and distributed generation: towards a multi-layered density

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HIGHLIGHTS

- Energy sprawl is not a necessary consequence of the transition to renewable sources.
- A polycentric, distributed renewable energy system reduces land consumption.
- This polycentric model is founded on *building-related renewable energy production* and *micro-grids.*
- Enabling rules, simplified compliance, and tax cuts can foster this result.
- The concept of *multi-layered density* is proposed as a new framework for interpreting this scenario.

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ABSTRACT

The transition from fossil fuels to renewable resources is highly desirable to reduce air pollution, and improve energy efficiency and security. Many observers are concerned, however, that the diffusion of systems based on renewable resources may give rise to *energy sprawl*, i.e. an increasing occupation of available land to build new energy facilities of this kind. These critics foresee a transition from the traditional fossil-fuel systems, towards a renewable resource system likewise based on large power stations and extensive energy grids. A different approach can be taken to reduce the risk of energy sprawl, and this will happen if the focus is as much on renewable sources as on the introduction of *distributed renewable energy systems* based on micro plants (photovoltaic panels on the roofs of buildings, micro wind turbines, etc.) and on multiple *micro-grids*. Policy makers could foster local energy enterprises by: introducing new enabling rules; making more room for *contractual communities*; simplifying the compliance process; proposing monetary incentives and tax cuts. We conclude that the diffusion of innovation in this field will lead not to an energy sprawl but to a new energy system characterized by a *multi-layered density*: a combination of technology, organization, and physical development.

"Any serious effort to develop a decentralized energy system will inevitably require a different set of institutional arrangements to that which supports centralized energy production" (Johnson and Hall, 2014).

"Despite the benefits of distributed generation, renewable energy policies tend to promote development of large renewable energy generation systems located far from urban centers of power consumption" (Powers, 2013).

"By far the biggest barrier to the creation of micro-grids is contradictory, unclear, or hostile law" (Bronin, 2010).

1. Introduction

The transition from power systems burning fossil fuels to renewable energy sources can produce much-needed benefits, ranging from less air pollution to more energy security, or broader access to energy, up to the establishment of a new economic paradigm, the so-called "low-carbon economy". This energy transition is at the top of many political agendas nowadays. In Europe, short-and medium-term targets are defined in the *20-20-20 Package* and the *Framework 2030* (da Graça Carvalho, 2012). But

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the most ambitious vision is outlined in the *EU Roadmap 2050*, which suggests a development path designed to cut European emissions to 80% lower than they were in 1990 (by 2050). For this challenge to be feasible and affordable, all sectors need to be involved in developing cost-effective solutions. In particular, the growth of renewables in the electricity sector plays a crucial part in the decarbonization and diversification process. As clearly stated in the *EU Roadmap 2050*, despite the expectation that electricity consumption will continue to increase, the corresponding greenhouse gas emissions would be reduced by between 93% and 99%. Such an impressive goal demands a massive penetration of renewables in the power sector in order to benefit from their near-zero emissions factor. Judging from the results obtained by Turconi, Boldrin and Astrup (2013: 560) using the *life cycle assessment method*, only 13–190 kg CO_2-eq are produced for every 1 MW h generated by photovoltaic systems, and 3–41 kg CO_2-eq using wind power, as opposed to 660–1050 kg CO_2-eq if we burn hard coal, or 380–1000 kg CO_2-eq using natural gas. As the U.S. Department of Energy (2008: 127) put it, we can reduce CO_2 emissions by up to 99% by using wind instead of coal, while using wind instead of gas means a CO_2 saving close to 98%.

The global share of renewable power generation was 22% in 2013, and is expected to rise to more than 26% by 2020 (OECD/IEA, 2015). The contribution of renewables for electricity generation to the achievement of the global targets specified in international agreements is noticeable and feasible, bearing in mind that "all countries in the world have at least one abundant renewable resource and many countries have a portfolio of resources" (IEA, 2016).

While they see the benefits, many observers are concerned that the diffusion of renewable resources may be responsible for a so-called "energy sprawl", i.e. an increasing use of available land to build new energy facilities (based on renewables) (Muller, 2012).[1] The present article discusses whether this is a real threat. Land occupation is an important metric to consider when assessing different energy production systems, though it may not necessarily be the primary, overriding concern (Moroni, 2013, 2016). While we are not "in a world of mounting land scarcity" (Hernandez et al., 2015: 13581),[2] we should nonetheless seriously consider land taking *too* (Howard et al., 2009).

The debate on distributed energy production – and electricity generation in particular – is prevalently focused today on technological issues, with some economic reflections thrown in, at most. But it seems fundamental to cast the net wider and include other issues, and primarily the *institutional* and *organizational* aspects involved (which have been largely ignored so far[3]). Energy-related transitions are always inherently socio-material transitions because they inevitably also involve institutions and users' organizations and behavior, not only natural resources and physical infrastructure (Calvert, 2015: 11). In this regard, adopting a new idea of (*multilayered*) *density* may enable the debate to be developed from a fresh overall perspective because it brings together the three main elements of the problem discussed here: *technology*, *organization* and *spatial development*.

The article is organized as follows: Section 2 considers a desirable (polycentric) energy generation *scenario*; in Section 3 we discuss the *advantages* of this scenario (in terms of reducing land taking and other benefits); Section 4 concerns the *policies* that could facilitate the transition process; and Section 5 is devoted to the conclusions.

2. A polycentric scenario: two main elements

A desirable distributed and polycentric scenario is based on *building-related renewable energy* production (Section 2.1), and new forms of *local contractual community* (Section 2.2).

2.1. Building-related renewable energy production (and micro-grids)

Those who are concerned about energy sprawl generally assume that the transition underway is from the traditional fossil-fuel burning systems with their large power plants and long transmission lines[4] towards a system that exploits renewable resources but is likewise based on large power stations (e.g. large-scale multiple photovoltaic plants or large wind farms) and extensive energy grids.[5] Hernandez et al. (2015: 13579) write that, "If up to 500 GQ of USE [utility-scale solar energy] may be required to meet the United States-wide reduction of 80% of 1990 greenhouse gas emissions by 2050, 71,428 km^2 of land may be required (roughly the land area of the state of South Carolina) assuming a capacity factor of 0.20".

On the other hand, a different organizational approach that involves distributed energy systems based on *building-related renewable energy production* (Bronin, 2012) and *micro-grids* can effectively reduce the risk of energy sprawl and excessive land occupation. Unlike the existing transmission and distribution networks (designed to deliver unidirectional power flows to consumers), smart micro-grids involve users interactively within local grids. Current advances in energy storage technology (Chen et al., 2009; Toledo et al., 2010) are also crucial to the full enablement of "prosumers" (producers *cum* consumers) in such micro-grids.

It is important to emphasize that, in a distributed energy systems scenario, on-site power production would cover not only lighting, heating, and cooling, but could also be used to sustain clean mobility solutions. Though challenging, the integration of electrically-powered vehicles in smart distributed energy systems has great potential, also because batteries and chargers for electric vehicles (i.e. bicycles, cars, segways and the like) may be suitable for storing energy and covering mismatches between production and load peaks (Barkenbus, 2009; Waraich et al., 2010; Delucchi and Jacobson, 2011; Zakariazadeh et al., 2014). The distributed energy framework thus brings together two of the main sources of energy consumption, traditionally approached and considered

[1] In very general terms, energy sprawl is "the phenomenon of ever-increasing consumption of land, particularly in rural areas, required to site energy generation facilities" (Bronin, 2010: 547); that is, the increasing amount of land altered for energy production (Jones and Pejchar, 2013). The central question here is how much energy is produced in a given amount of space (McDonald et al., 2009). On the concept of "energy sprawl" see also Rule (2010), Outka (2011 and 2012), Pocewicz et al. (2011), and Jones et al. (2015).

[2] As regards the United States, for instance, the percentages of the principal categories of land use reported for the year 2007 were: (a) urban: 3% of the total; (b) forestry: 30%; (c) grassland, pasture, and range: 27%; (d) cropland: 18%; (e) special uses (mainly parks and wildlife areas, also including rural transportation and national defense areas): 14%; (f) miscellaneous (such as tundra or swamps): 9% (Nickerson et al., 2007).

[3] As underscored by Hoffman and High-Pippert (2005), Alanne and Saari (2006), Ribeiro et al. (2012). More specifically regarding the issue discussed here, Friedrichsen et al. (2014: 264) made the point, for instance, that the institutional set-up of the smart distributed energy system "is still uncertain"; Johnson and Hall, (2014 also said that "the systemic institutional transformation necessary to support the widespread adoption of community/decentralized energy schemes … [has] … received limited attention to date".

[4] Today, electricity is mainly produced by large power plants located far from developed areas, and distributed to end-users via long, complex networks of power lines. The United States electric grid comprises more than 482,000 km of power transmission lines (U.S. Department of Energy, 2013). Italy's national power grid currently has more than 72,000 km of cables (Terna, 2016).

[5] For a discussion on the environmental impacts of large-scale solar power plants, including land taking, see Turney and Fthenakis (2011), and Hernandez et al. (2014 and, 2015); for macro-wind turbines, see Diffendorfer and Compton (2014).