

# Challenge to Sustainability; the Territorial Agglomeration of Renewable Energies Projects in Central-South Chile

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## ABSTRACT

The imperative of energy transition towards alternative forms to fossil fuels has meant the approval and construction of countless renewable energy projects in non-urban areas of Chile. This productive pressure has meant the accelerated creation of energy geographies that untie production and consumption in a model that, in some perspectives, deepens into traditional extractive forms. Based on an official cadastre of hydroelectric production in the country, we seek to reveal a process of territorial agglomeration in energy production. This productive agglomeration is far from the traditional advantages recognized for industrial clusters and, on the contrary, stresses socio-environmental relations in the context of energy transition.

**Keywords:** *sustainability of development, renewable energy sources, territorial agglomerations.*

## 1. INTRODUCTION

The literature on economic geography has tended to describe the processes of productive agglomeration as virtuous phenomena (Carlino & Kerr, 2015). Based on case studies, various investigations have highlighted: i) improvements in resource allocation, ii) cost reduction, iii) linkage of processes and even iv) productive use of industrial waste (Ehrenfeld & Gertler, 1997; D'Amico et al 2007; Chertow et al., 2008). Although, for industrialized economies there is evidence to support these claims, they may be uninformative if what one seeks to address is the situation in other regions of the world, as well as studying a greater variety of production processes. This is the case of the territorial agglomerations generated by weakly regulated forms of industrial production and which has led to what is known as "sacrifice zones" (Lerner, 2012; Scott & Smith, 2017; López de Souza, 2021), especially in developing countries (Bolados & Sánchez, 2017). The same occurs with agglomeration linked to mono-production in extractive industries such as mining (Romero-Toledo, 2019) or neo-extractive industries such as agriculture

(Budds, 2012), forestry (Reyes & Nelson, 2014) or aquaculture (Mascareño et al., 2020).

The previously mentioned situations provide evidence to support the existence of harmful effects of productive agglomerations, which raises a research space that has not been systematically developed by the international literature. In other words, it is possible to point out that the productive agglomeration is not an advantage just because there is territorial proximity between industries. On the contrary, the productive agglomeration, when it comes from a single economic activity, has a greater probability of building territorial tensions associated with processes of environmental degradation and pollution. This, despite the extensive bibliography that highlights the economic value of regional specialization (Malmberg & Maskell, 1997; Traistaru et al., 2002; Dzemydaité, 2021) and currently proposes a shift towards Industrial Symbiosis.

Despite this critical view of the studies on productive agglomerations, there has been little research that explored this situation regarding the production of renewable energies (Kennedy, 2018). Above all, considering that they depend completely on their

territorial location, unlike what happens with energy production using fossil fuels. Advancing in this line of research would allow answering the question about the real socio-environmental consequences of the energy transition in different national contexts. Thus, our argument maintains that the social desirability associated with the construction of a carbon neutral matrix has prevented a real evaluation of the way in which the production of renewable energies has been deployed on the territories. A situation that has resulted in two parallel movements: on one hand, an intensive public-private promotion of renewable energy projects in territories with high productive potential in Chile. On the other hand, an increase in socio-environmental tensions due to mega-projects or else, due to the concentration of smaller-scale energy production projects, especially in the south-central zone of the country (Campos-Medina et al., 2021).

In this research we question ourselves about the logic of territorialization of hydroelectric projects understood as renewable energies in Chile. Thus, our objective is to provide evidence to support the existence of a process of territorial agglomeration as the main logic of territorialization, in the production of renewable energy in Chile, specifically hydroelectric. In this way, we seek to open the discussion on the possible -socio-territorial-tensions of a public policy that seeks sustainability. After this introduction, the second section briefly positions the problem of productive agglomeration in literature. In the third section we describe the methodology and analyse the case of hydroelectric production in south central Chile from the perspective of agglomeration. Then, we discuss the consequences of crowding in the fourth section and, finally, develop some general conclusions.

## **2. PRODUCTIVE AGGLOMERATION: THE TWO SIDES OF A COIN**

Research on innovation in the cultural industry uses territorial agglomeration as an explanatory variable of its success in the city context (Cooke & Lazzarretti, 2008; Coll Martínez et al., 2016) the same happens with the study of innovation in the creative, digital and computational industries (Asheim & Isaksen, 1997; Chang & Oxley, 2009). These investigations shed light on the construction and consolidation of regional innovation systems at the subnational level. In all these explanations, the agglomeration of activities allows accelerating the circulation of ideas, solutions and products between professionals and companies. Thus, the closeness of many people linked to creative processes replaces the image of the brilliant and lonely inventor in his laboratory as a socio-spatial form of innovation.

At the economic level, examples of territorial agglomeration can be traced in the idea of regional specialization. This points out the value that the economy gives to a region focusing on a productive process and

intensifying its development, renouncing other activities. Thus, regional specialization is calculated as a relationship between jobs or income produced by a productive activity regarding the total. In this context, the focus is not on accelerating innovation as it is the case in creative industries. On the contrary, the benefit is found in the reduction of costs that means for an industry that the surrounding environment offers inputs, services and the qualifications of workers. However, this comparative advantage ignores the territorial vulnerability that a single productive orientation means, as recognized by the popular saying “don't put all your eggs in one basket”.

In another line of research, we find the literature on “industrial ecology and symbiosis” steadily gaining relevance. As Gregson et al. (2011) indicates, a paradigmatic case of “industrial symbiosis” is found in Kalundborg, Denmark. Four plants converge in this industrial complex: a coal-fired power station, an oil refinery, a pharmaceutical plant and a plasterboard manufacturing plant, which carry out a series of exchanges, ranging from energy, heat, water and even wastes, the last two mentioned are transformed to be used in other production processes (Deschenes & Chertow, 2004). Returning to the analysis of Gregson et al. (2011), little is said in the Kalundborg case regarding the development of the complex over the last 25 years as a way of minimizing the costs of complying with environmental regulations. Which, without a doubt, questions the biological metaphor of symbiosis and highlights the regulatory-institutional content behind the upwelling of a socio-territorial form. In any case, industrial symbiosis, every time it uses successful examples in the use of resources and reincorporation of waste, contributes to maintaining the widely extended belief regarding the benefits of territorial agglomeration.

The not thematized face of territorial agglomeration in production is the intensification of forms of contamination, as occurs in the case of the so-called “sacrifice zones”. In these places, the territorial proximity of polluting industries has a negative impact on the dynamics of land value, so that it is more economical to concentrate new unwanted productive activities in their surroundings -e.g. polluting and / or perturbing industries. Thus, agglomeration is made possible by weak environmental regulations regarding the limits to production-contamination. In other words, we can affirm that both the positive and negative side of the agglomeration have among its most important causes the institutionality and environmental regulation. In the case of symbiosis, it distances itself from being a spontaneous result of collaboration between industries, each time we observe it as a corporate strategy to deal with environmental regulation. In the same way, the sacrifice zone is less a territorial necessity of production than a corporate way to obtain advantages thanks to the regulatory weaknesses that allow concentrating unwanted activities.

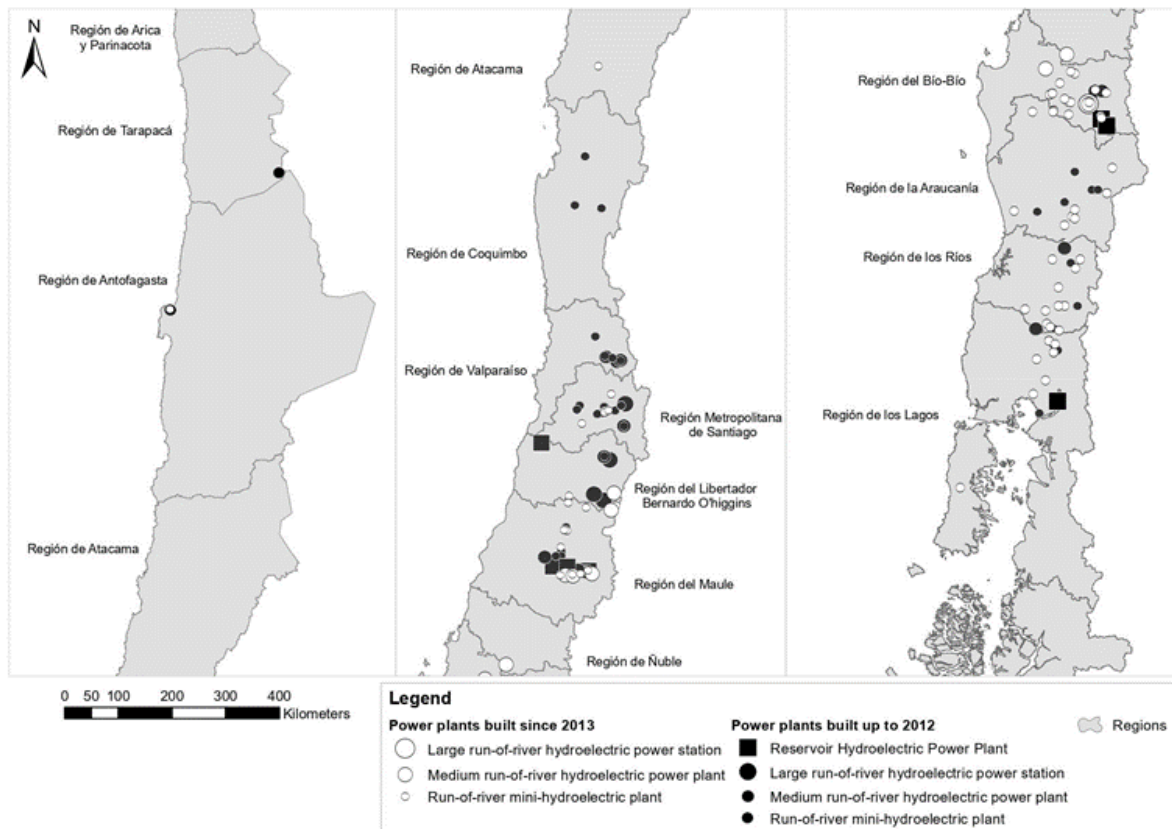
In this context, we cannot ignore the fact that regional productive specialization and associated forms of territorial agglomeration have been a desired objective of public action. This means that there are many actors who have coordinated their actions assuming that a region presents better possibilities of socio-economic development if it produces a product, and it produces it well. Although this statement is consistent with common sense, it doesn't consider that true development requires coordinating a different series of socio-economic functions with an impact on the territory. In this way, a territory oriented towards mono-production or the concentration of polluting or disruptive productive activities can offer a poor quality of life to its inhabitants. This is what we will investigate regarding the territorial agglomeration of hydroelectric production in the territories. Our intention is to show how the production of renewable energies develops with an agglomerated production pattern, which undoubtedly increases its socio-environmental impacts. Thus, we collaborate to a critical vision of the energy transition and of the productive agglomerations. Two concepts where its social desirability outweighs the negative results of its implementation.

### 3. HYDROELECTRIC PRODUCTION IN SOUTH CENTRAL CHILE FROM THE PERSPECTIVE OF AGGLOMERATION

#### 3.1. Materials and Methods

In this section we expose the methodology used for the research, describing the origin of the information, the database management mode and the techniques used to prepare the cartographies. From a quantitative approach, we rebuilt a database from the information on installed energy capacity of the Ministry of Energy of Chile (2015). Filtering the total number of hydroelectric production cases at the national level, we generate a database with 185 cases, which are analyzed in detail and supplemented, especially regarding the missing information for geolocation. We make the database available to readers in excel format, ensuring the reproducibility of the study and / or carrying out another type of analysis with the information [29].

In the results section we present two cartographies that were constructed with the Arcgis software. In the first map, hydroelectric production is characterized according to the sizes of the plants and their opening date. For this, we use the gross power variable, categorizing



Source: Own elaboration based on information from the Ministry of Energy of Chile (2017).

Figure 1 Locations of Hydroelectric Power Plants in South-Central Chile.

the plants into small (less than 20 MW), medium (between 20 and 100 MW) and large (greater than 100 MW). Temporarily, we group the plants into two moments: i) prior to 2013 (that is, implemented until the end of 2012) and in or after 2013. We chose the year 2012 as the transition time because it coincides with the failure of large reservoir projects in the emblematic case of HydroAysén (Reyes & Rodríguez, 2015).

In the second cartography we delve into the territorial analysis identifying the concentration of power plants in specific areas of the country. For this, we use Kernel Density Analysis (Węglarczyk, 2018); calculating the number of plants and the distance between them in a circular area of 100 kilometers. From this analysis, we identify zones according to the densities of hydroelectric plants and, consequently, areas of greater agglomeration.

### 3.2. Results

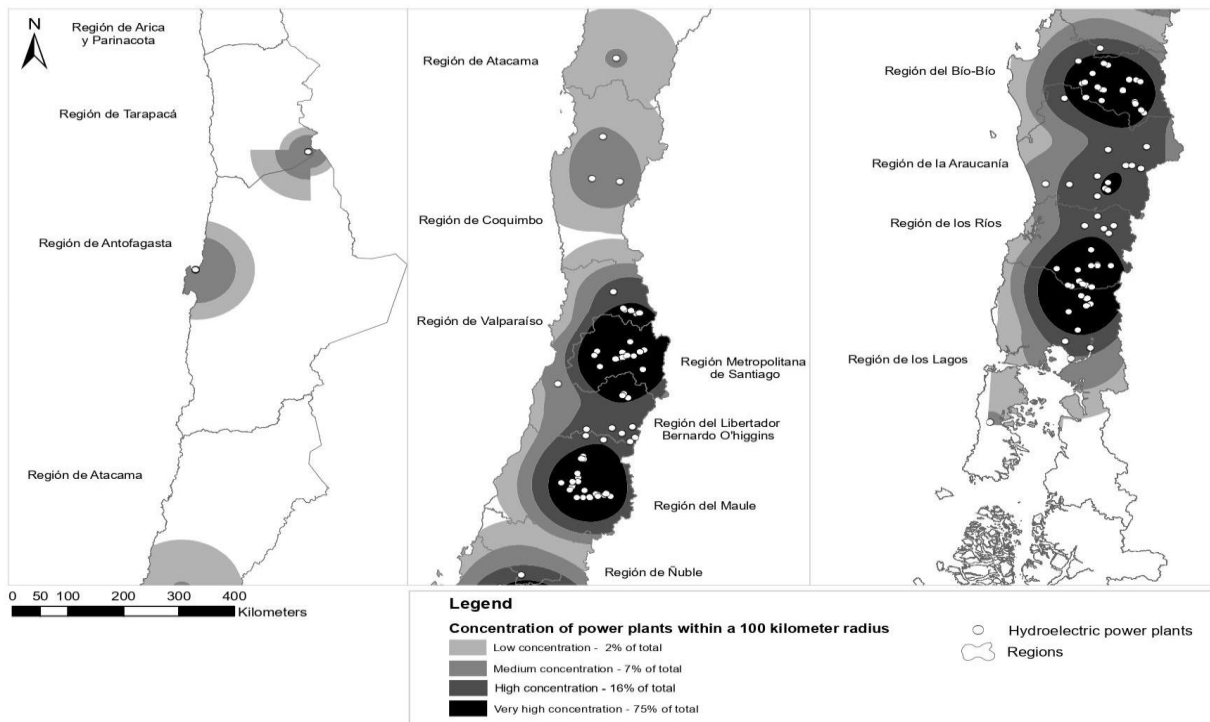
In this section we approach the results through what we have called a space-time analysis. At first, we approached the change in the hydroelectric production model in south-central Chile as of 2013 and we describe its territorial orientations. Subsequently, we observe the density in the location of hydroelectric projects to account for trends towards territorial agglomeration. These two results are descriptive in nature and their consequences at the level of industrial dynamics, relevance for public policies and impact regarding socio-

territorial conflicts will be treated in the discussion section.

When observing image 1, our analysis shows two territorial elements. First, a productive intensification in existing production areas. The clusters present prior to 2012 in the regions: Metropolitana, Libertador Bernardo O'Higgins, Maule, Bio-Bio and Los Lagos (power plants represented in black on the map) are intensified as of 2013 (power plants in white). Second, the opening of the south-central part of the country to the construction of run-of-the-river hydroelectric plants, which means a shift from mega reservoir plants to small run-of-the-river plants. For example, in the region of La Araucanía and Los Ríos.

The previous description allows us to affirm the existence of two ways in which the territorial expansion of the energy industry occurs. On one hand, the intensification of existing production sites. This occurs especially in the Metropolitan, O'Higgins, Maule, Bio-Bio regions. On the other hand, the opening of new productive spaces, which is observed in the regions of Los Lagos, Los Ríos and La Araucanía. Thus, it is important to observe these two movements every time we address the socio-territorial dynamics of the extractive and neo-extractive industries.

From Image 2, it is possible to identify 4 high-density areas in the location of hydroelectric power plants. The first is found in the Metropolitan Region, where the



Source: Own elaboration based on information from the Ministry of Energy of Chile (2017).

Figure 2 Density and Agglomeration of Hydroelectric Power Plants in the Center-South of Chile

country's capital is located. This area joins - given its smaller territorial extension - with the neighboring regions, to the north, the Valparaíso region in its mountain range and the same, to the south, in the O'Higgins region. The second productive zone is in the Maule region, the third in the Bío-Bío region and the fourth -the newest as we saw previously-, is located on the border between the Los Ríos and Los Lagos regions. Among all these areas, 75% or more of the hydroelectric plants are located.

At a second level of analysis, we observe that the four zones are linked in pairs. Thus, in the center of the country we find the macro-zone generated by the Metropolitan Region and the Maule Region, where the O'Higgins region, with a lower density, functions as a space for linking. The same is observed in the south, where the productive zone created in the Bío-Bío region connects with the new existing zone on the border between the Los Ríos Region and Los Lagos. Thus, the macro zone contains the La Araucanía region, which has less project developments.

When observing the 4 productive zones and their organization in two macro-zones, we can point out that they occupy the mountain areas and the central valleys, this means that they do not involve the coastal space. On the other hand, its current lack of connection -in a single macro-productive zone- is found in the non-existence of projects in the Ñuble region. Situation that could change in the coming years.

#### **4. DISCUSSION**

A central element that is revealed in this research is the adaptive speed of the energy industry in Chile. After the failure of the mega reservoir projects, with the emblematic case of HidroAysén, in less than 5 years, the national energy matrix made a drastic shift towards small and medium-sized plants. We want to understand this adaptive capacity as a socio-territorial way of operating with state regulations as well as a way of dealing with social restrictions. It is important to note that this adaptation has effects on the territory, as it creates new productive geographies by opening up and intensifying production in the center-south of the country, specifically, in the mountain areas, which are places that had not previously received a similar productive pressure and, therefore, show lower capacities to manage or limit the income of projects.

Following the previous line of argument, the adaptive speed of the energy industry has the effect of building new productive geographies (Campos-Medina & Noguer s.f.). With the previous sentence we want to show that both phenomena are structurally related and are not simple coincidences. Thus, an important space for questioning the public energy policy and territorial planning is opened, as both cannot continue to operate

under the paradigm of the individual and isolated project, because energy production is not organized territorially in that way. This means that "hot-spots", "productive clusters" and "industrial agglomerations" are socio-territorial forms of production that must be evaluated and regulated as such. In other words, energy policy for the transition to a carbon neutral economy, like environmental impact assessments, needs to incorporate agglomeration as the way extractive and neo-extractive activities unfold.

Thus, the new geographies of energy production intersect with territories that have consolidated other uses and meanings. This is the case, for example, of nature tourism or adventure tourism that collides with energy projects, as both activities are often not compatible. Even more dramatic is the case of the indigenous people, in the case of the Mapuche ethnic group, rivers are spaces through which the souls of the deceased ascend, making it impossible for them to allow the construction of energy projects in their sacred places (Aigo et al., 2020). Thus, the spatial intersection of different territorial projects supposes a growing tension between different actors, which, if not managed, can turn into socio-environmental conflicts. Here, again, it is necessary to question the public energy policy and territorial planning to observe their capacity to contain the productive advance over the territories that have traditionally been oriented towards other forms of link between society and nature.

#### **5. CONCLUSION**

In the Chilean case, social criticism towards hydroelectric reservoir megaprojects meant an almost total shift towards small and medium-sized passing plants. This happened in less than a decade and is clearly charted in our results section. In this context, the major socio-environmental conflicts linked to the construction of dams in territories with a high symbolic value -as were the cases of Hidroaysén projected in Chilean Patagonia and previously, the Ralco plant built in Alto Bío-Bío- have given way to a multiplicity of tensions on a smaller scale in the south-central mountain range of Chile.

In our analysis, the logic of territorial agglomeration of energy production has only considered hydroelectric production. If other renewable energies are added to this, such as wind energy, we would probably be in the presence of a process of productive agglomerations, which, being inter-companies, achieves greater scale and intensity. In this sense, it is important to warn about this phenomenon of productive agglomeration in renewable energies, as it can mean greater socio-territorial conflict as territories are saturated by mono-productive trends.

At another interpretive level, the empirical evidence presented in this article allows us to reflect on the need for a critical reading of renewable energies and the energy transition. With this we do not seek to rule out the

relevance of moving towards a carbon-neutral economy, rather we try to promote research regarding the specific ways in which energy production is territorialized and discuss its socio-environmental consequences, especially because of agglomeration. Although renewable energies show an advance on the horizon of sustainability, in the case of being built in a highly agglomerated way, an increase in the impacts on territories, communities and ecosystems is indisputable.

In this way, it is essential to stress the idea of agglomeration as a desirable productive situation, considering that this can easily translate into socio-territorial conflicts. At the same time, in this context, we allow ourselves to problematize the role of the State and public policies in the containment and regulation of emerging energy geographies. From our perspective, national regulatory instruments seem to be non-sensitive at the time of doing a diagnosis and addressing territorial agglomerations, so it becomes essential to rethink how permeable public policies are achieved regarding the complex contemporary territorial dynamics and the consequences for citizens.

Finally, from a critical reading, we question the idea that territorial agglomeration refers to a spontaneous symbiotic condition, in a kind of biological metaphor. On the contrary, we propose to understand the productive agglomeration, both in its positive and negative condition, as the socio-territorial result of an institutional arrangement. In other words, the symbiosis produced by territorial proximity between companies is based on the existence of regulations that facilitate or hinder proximity. Thus, for example, no matter how much symbiosis is desired to articulate creative processes, it exists in a normative space that sharply differentiates intellectual property. What we want to illustrate with the previous sentence is that the institutional and regulatory environment is essential for productive agglomerations to enter virtuous dynamics such as industrial symbiosis. Similarly, the institutional component is central to the problematic consolidation of the so-called “sacrifice zones”, where regulatory weakness allows unwanted agglomerations.

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