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## Green industry development in different types of regions

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### ABSTRACT

At the regional level, the imperative of sustainable development often manifests itself in an emphasis on developing green industries. However, regions vary in their preconditions for achieving this. In this paper we link regional preconditions to various pathways for green industry development. This provides the foundation for identifying place-based policy implications for growing green industries in different types of regions, grounded in the emerging perspective in innovation studies on transformative innovation policy. The paper thereby helps to understand the pathways for greening the economy in different regional contexts and how such green pathways can be promoted through policy.

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## 1. Introduction

The fields of innovation studies and economic geography have for long enjoyed fruitful cross-fertilization. Geographical perspectives have increased the knowledge about the spatial embeddedness of innovation processes, and the innovation systems approach has led to improved understanding of the possibilities for regional policies to facilitate industry development. This is evident in the seminal contribution of Tödtling and Trippl (2005, p. 1203) on ‘a differentiated regional innovation policy approach’, but also in more recent work on possibilities and conditions for industrial path development in different types of regions (Grillitsch & Asheim, 2018; Trippl & Isaksen, 2016). In short, work on the functioning and challenges of innovation systems (Klein Woolthuis, Lankhuizen, & Gilsing, 2005) has been central to providing a nuanced understanding of regional policies for (new) industry development.

During the last decade, innovation policy literature has increasingly become preoccupied with understanding the opportunities for innovation policy to address societal challenges. The emerging literature on transformative innovation policy is associated with a change in the core policy objective. Innovation policy increasingly focuses on stimulating the development of innovations with clear benefits for targeting climate change, aging societies and other societal challenges. In turn, this requires attention to a new set of

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policy challenges including considerations for the direction of change, the need for experimentation and increasing emphasis on the uptake of innovation and policy coordination (Grillitsch, Hansen, Coenen, Miorner, & Moodysson, 2019; Weber & Rohrer, 2012). While the literature on transformative innovation policy had until recently lacked an operationalization of these challenges, which could guide design and implementation of policies on the ground, Grillitsch et al. (2019) provide a framework for translating conceptual work on transformative innovation policy into practice.

We argue that this most recent generation of innovation studies offers new opportunities for cross-fertilization between the fields of innovation studies and economic geography (see also Strambach, 2017; Tödtling & Trippl, 2018), in particular since the imperative of sustainable development has been taken up across multiple levels of government, including regional authorities (Cagnin, Amanatidou, & Keenan, 2012; Coenen, Hansen, & Rekers, 2015). One manifestation of this is the increasing emphasis on developing green industries, which is found in regions with highly varying characteristics. However, so far, we have limited knowledge about the prospects for the development of green industries in various types of regions and the accompanying differences in the required policies. Both from a research and from a policy perspective, this is unsatisfying. The current paper therefore contributes by attending to this lack of contextualized knowledge about opportunities for green industry development and in particular their translation into concrete policy recommendations in different regional contexts. Consequently, in the current paper we conceptually address the following two research questions:

- *How do regions differ in their opportunities for green industry development?*
- *What are the implications for policies in different types of regions?*

Our starting point is the regional typology of Tödtling and Trippl (2005) distinguishing between metropolitan, specialized and peripheral regions. We extend this by introducing a distinction between regions with existing specializations in green and dirty industries (section 2). Drawing on the path development literature, we then suggest the likely green industry development opportunities in the different types of regions (section 3). Subsequently, we consider the relevance of insights from the literature on transformative innovation policy for green industry development (section 4), before outlining policy mixes for different types of regions based on Grillitsch et al. (2019) (section 5). Finally, we conclude by emphasizing that green industry development requires contextualized policies, which give attention to both structural innovation system challenges and transformative system challenges (section 6).

## 2. Greening of different regional types

A key contribution of the regional innovation systems (RIS) approach has been to study systematically the differences between regions. According to Asheim, Grillitsch, and Trippl (2016, p. 49) this has resulted in the development of regional typologies based on '(1) key actors and governance (Asheim & Isaksen, 2002; Cooke, 1998); (2) the strengths in radical versus incremental innovations (Cooke, 2004); and (3) RIS failures (Isaksen, 2001; Tödtling & Trippl, 2005)'. The typology based on RIS failures has gained most traction in the literature and has been further developed to account for

new industrial path development (Isaksen & Trippel, 2014). This typology differentiates in three types of regions: peripheral regions, specialized regions, and metropolitan regions with specific challenges and opportunities for regional development.

These types of regions are distinct in terms of the regional support system for innovation and entrepreneurship. The exploitation of knowledge in industrial contexts is fueled by knowledge generation from for example universities and research institutes and supported by intermediaries such as technology parks, technology transfer centres, or incubators (Autio, 1998; Tödtling & Trippel, 2005). Besides factors such as human capital, networks, and knowledge intermediaries, recent literature foregrounds the importance of entrepreneurial capital, which includes competence about business models, access to risk capital and resources of successful entrepreneurs (Isenberg, 2011; Mason & Brown, 2014). Moreover, innovation and entrepreneurial activities are embedded in a social-institutional context, which shapes the outcome of these activities (Asheim & Gertler, 2005; Cooke, 1992).

Metropolitan regions are endowed with a strong and comprehensive support system for innovation and entrepreneurship (Makkonen, Merisalo, & Inkinen, 2018), where major universities, research institutes, as well as training and education facilities are located. Furthermore, metropolitan regions have the scale to allow for the development of several related and unrelated industrial specializations, thus catering for a diversified industrial structure. For example, Storper, Kemeny, Makarem, and Osman (2015) argue that the metropolitan San Francisco Bay area is specialized. Yet, it is specialized in more than one industry comprising IT and software, life science and biotech, as well as environmental and cleantech. The heterogeneous industrial mix creates demand for a variety of generic knowledge-intensive business services such as ICT, legal, financial and marketing advisory services. This is a conducive environment where entrepreneurial capital can accumulate and be recycled (Isenberg, 2011).

Specialized regions differ from metropolitan regions as regards their support system for innovation and entrepreneurship. Industrial specialization refers to a set of interrelated activities within a region and their effects on learning, innovation, and production of collocated firms and organizations (Grillitsch, Asheim, & Trippel, 2018). Industrial specializations typically pivot around a lead industry (e.g. wind turbines, automotive, life science). The traded and untraded interdependencies (Storper, 1995) radiating from this dominant industry, however, cross industrial boundaries. An industrial specialization creates a strong local demand for universities and research institutes to adapt their activities to the needs of the industry, thereby strengthening the existing industrial paths. However, the region has not achieved a critical mass in other industrial specializations. This in turn entails that compared to metropolitan regions the support system is weaker as regards the more generic resources for innovation and entrepreneurship such as variety in knowledge and resources, knowledge intensive business services, or access to risk capital and smart money. Specialized regions typically experience positive or negative lock-in (Grabher, 1993; Hassink, 2010). Positive lock-in is associated with the self-reinforcing character of accumulating knowledge and resources supporting the growth of a specific industry. However, when these accumulated assets devalue due to for instance a change in technologies or demand, they can turn into a negative lock-in hindering the region to move into new fields of economic activity. Lock-in may relate to the way of thinking (cognitive lock-in), the interdependencies in the production system

(functional lock-in), or the attempts of elites to protect vested interests (political-institutional lock-in) (Grabher, 1993).

Peripheral regions have not developed a critical mass in any industrial specialization. This means that whereas peripheral regions may host single strong firms this has not led to an accumulation of high-value added, knowledge-intensive activities beyond such firms. As regards the regional support system for innovation and entrepreneurship, it may well be that some elements are present. For instance, Morgan (2016) shows that even though Wales/UK has good universities, the region has had limited success in utilizing the higher education system for developing industrial specializations and remained on a low growth trajectory. There may be innovative firms in the periphery but they rely largely on extra-regional linkages to access knowledge and resources (Grillitsch & Nilsson, 2015; Isaksen & Karlsen, 2013). Overall, therefore, the regional support system for innovation and entrepreneurship is limited and weak.

Moving on from this to the context of greening the economy and the objective of this paper to provide conceptual underpinning for developing adequate policy mixes, we argue that the typology needs to be extended as also the nature of industrial specializations matters, i.e. whether regions are specialized in green (e.g. wind energy) or dirty (e.g. coal mining) industries. Following UNEP's (2011, p. 16) definition green industries develop and sell products, solutions or technologies that 'reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services'. Conversely, dirty industries are conceived as industries where production and consumption of the industry's goods deplete the natural resources of our planet.

Whereas the traditional failure framework, differentiating in peripheral, specialized and metropolitan regions, focuses on the current characteristics of the RIS, we introduce a specific aspect of directionality (Grillitsch et al., 2019; Schot & Steinmueller, 2018; Weber & Rohracher, 2012), namely the objective of greening the economy. This aspect of directionality is concerned with what kind of knowledge, innovation, and industrial dynamics should be supported by policy in order to promote green industry development. With a given focus on greening the economy, it is then obvious that policy implications will be very different for regions with green or dirty industrial specializations as the former should be promoted and the latter transformed or replaced. Going beyond the obvious, this paper elaborates on theoretical grounds and, with empirical illustrations, how policy can support the greening of the economy in:

- (1) Peripheral regions,
- (2) Regions specialized in a green industry,
- (3) Regions specialized in a dirty industry, and
- (4) Metropolitan regions.

### 3. Green industry development in different types of regions

'Evolutionary theory deals with path dependent processes, in which previous events affect the probability of future events to occur' (Boschma & Frenken, 2006, p. 280f). From an evolutionary perspective, path-dependence does not stand for deterministic developments. '[P]ath-dependent systems also need mechanisms that generate novelty, and hence new

pathways of development' (Martin & Sunley, 2006, p. 407). This has been studied in the literature on new industrial path development and path creation (Dawley, 2014; Garud, Kumaraswamy, & Karnøe, 2010; Grillitsch & Trippl, 2016; Simmie, 2012). Industrial path development can come in many shapes (Martin & Sunley, 2006), is driven by a variety of mechanisms, and fueled by sources at the regional and extra-regional scale (Grillitsch et al., 2018). Following the evolutionary idea that previous events affect the probability of future events, the regional preconditions will also shape the likelihood with which certain types of green industrial path development will occur.

Several proposals have been advanced how to frame the different types of path development (e.g. Isaksen and Trippl, 2014; Martin & Sunley, 2006). We focus on four major forms, following closely Grillitsch & Asheim (2018): First, path development may simply represent growing existing green industries. Second, path upgrading consists of a major qualitative change of existing industries, which can rest on several mechanisms such as the introduction of new technologies, organizational innovations, or business models. As regards greening, the introduction of green technologies to a dirty industry would stand for green path upgrading. Third, path diversification implies a development from existing into new industries by applying existing knowledge in new industries (Frenken & Boschma, 2007) or combining existing with unrelated knowledge (Grillitsch et al., 2018). Forth, the emergence of new green industries, which are unrelated to existing regional industries, is another form of green industry development. Emergence can either refer to the raise of a completely new industry often based on a technological breakthrough or the importation of already existing industries by drawing heavily on extra-regional knowledge and resources.

### 3.1. *Peripheral regions*

We argue here that the likelihood of certain types of green industrial path development is contingent on regional characteristics. In peripheral regions without critical mass in any specialization, we can exclude diversification as a relevant form of new path development because diversification rests on exploiting accumulated knowledge and resources from one industrial specialization in another industry. This leaves upgrading and path emergence as possible options. The empirical examples from the literature often refer to the creation of new sustainable paths in renewable energy (Dawley, 2014; Essletzbichler, 2012; Simmie, Sternberg, & Carpenter, 2014). It is hardly technological breakthroughs that drive the rise of renewable energy in such contexts. The rise of such new paths is, however, to a high degree place-specific due to regional actor constellations, natural resources that can be exploited for renewable energy, and existing infrastructure. Therefore, the main challenge often does not lie in importing the technology but in shaping the conditions for their implementation, which requires the coordination and mobilization of distributed actors (Späth & Rohrer, 2010). These processes are, however, not exclusively local, but embedded in multi-scalar institutional contexts and networks through which knowledge and resources can be mobilized (Binz, Truffer, & Coenen, 2016; Chlebna & Simmie, 2018; Grillitsch, 2015; Trippl, Grillitsch, & Isaksen, 2018).

Path upgrading is the other likely form of path development in peripheral regions. The idea of path upgrading acknowledges that although peripheral regions lack a critical mass in any industry, some firms or entrepreneurs may have a high level of capabilities. Indeed,

there are innovative firms in the periphery, which tend to compensate for a lack of local knowledge spillovers with national or international networks (Grillitsch & Nilsson, 2015). Pivoting around such core agents, the region may attempt to establish a strong position in a green niche, or enhance their position in global value chains. Furthermore, it is thinkable that regions have developed a certain scale in a green industry (e.g. production of solar cells), but focus on low-skill manufacturing while the high-value and knowledge intensive activities are located elsewhere. For such regions, path upgrading in the sense of increasing knowledge-intensity in the industry and attracting higher-value added activities to the region (such as research and development) could potentially play an important role.

### **3.2. Regions specialized in a green industry**

Regions with a green specialization have achieved a critical mass of high-value, knowledge intensive activities in a green industry. Considering that there is still a long way to achieve a global 'green' economy, the possible future market is large. Following a pure economic logic, early concentration has a big impact in the long term as industries scale up due to increasing returns (Krugman, 1991). Firms that achieve scale economies early will be hard to catch-up later. The growth of a strong regional specialization, however, is not only a process of individual firm growth but concerns also the creation of interdependencies between regional actors in terms of knowledge flows embedded in a shared socio-institutional context, which underpins learning and innovation activities (Gertler, 1995; Storper, 1995). As a regional specialization gains momentum, self-reinforcing mechanisms promote growth even further. This relates among others to the attraction of new firms and skilled labour, the formation of new firms through university or corporate spin-offs, the development of a specialized supplier base, as well as dynamic competition between firms.

Another important source of path development in regions with green specializations is to diversify into other industries based on the existing competencies. In this regard, we refer to the path branching argument advanced in evolutionary economic geography, which stipulates that 'firms typically diversify into products that are technologically related to its current products' (Frenken & Boschma, 2007, p. 637). It is further argued that firm diversification leads to regional diversification and in consequence to firm and regional growth. This will further contribute to the self-reinforcing mechanisms mentioned above. An example would be the reuse of competences from the manufacturing of wind turbines for the manufacturing of hydropower turbines. Finally, it may be added that we do not see regional emergence of a new green industry unrelated to existing industries in the region as a very likely form of new path development. The reason is that most actors will have vested interests in the existing specialization and occupy knowledge and resources, which would have to be redirected to new paths. Hence, it is more likely that these actors can be mobilized to further grow an existing specialization or to diversify based on the existing competencies, than develop new paths where the accumulated knowledge and resources are of little value.

### **3.3. Regions specialized in a dirty industry**

Regions with a specialization in a dirty industry are similar to regions with a green specialization as regards the nature of their industrial and economic dynamics, but have



completely different challenges in terms of greening the economy. Regions with a dirty specialization are similar as they face strong lock-ins due to the existing specialization. This implies that it will be difficult to mobilize actors for strategies that devalue past investments and thus are against vested interests. Hence, it may be the most promising pathway to green the dirty industry by introducing new technologies, often sourced from outside the region, that reduce the environmental impact. One typical example is the introduction of electric or hydrogen powered cars, which would make the automotive industry cleaner bearing in mind that other aspects such as the environmental impact of producing electricity or hydrogen has to be considered. Another possibility is the use of existing competencies for new green purposes. The mechanism behind is diversification, for instance of the oil and gas industry in Norway to offshore wind that reuses competences from the maritime environment (Asheim, Grillitsch, & Tripl, 2017b; Steen, 2016).

### 3.4. Metropolitan regions

As metropolitan regions typically host a mix of green and dirty industries in different stages of development, all forms of green industry development discussed for the other three types of regions are in principle relevant. In addition, however, metropolitan regions provide strong preconditions for the introduction of new technologies, and the emergence and growth of new green industries. Advanced research milieus are a major source for the development of new technologies for green industries. An example would be the use of material- and nano-technology to increase energy efficiency. Introducing new technologies in existing industries is, however, difficult as the complexity for knowledge transfer and learning increases with cognitive distance (Nooteboom, 2000). Such cognitive distance is overcome more easily if actors are embedded in a similar socio-institutional context or located in close geographic proximity (Boschma, 2005; Hansen, 2015). In fact, Agrawal, Cockburn, and McHale (2006) show that co-location is especially important for co-patenting involving different technological fields. As regards growing new green industries, the availability of resources, in particular human capital, and of knowledge-intensive business services such as legal, financial and marketing advisory services play an important role. Also, the closeness to decision makers as regards shaping regulations and markets has been mentioned as an important factor for the emergence and growth of green industries (Coenen, Moodysson, & Martin, 2015). Furthermore, as metropolitan regions are typically home to several specializations, an additional opportunity may be what Grillitsch et al. (2018) called a shift between industries. This occurs if certain competencies and resources currently occupied in dirty industries are reused in green industries. For instance, an engineer may have relevant competencies for both dirty and green industries. A growing green industry could then absorb relevant labour from shrinking dirty industries, thereby facilitating a transition towards a greener regional economy without negative consequences such as structural unemployment (Table 1).

## 4. Policy rationales for green industry development

A natural starting point for considering possible policy implications for green industrial path development in different types of regions is the literature on structural innovation system failures (Klein Woolthuis et al., 2005; Laranja, Uyarra, & Flanagan, 2008). Building on the innovation systems literature, this perspective highlights how policy intervention is



**Table 1.** Regional typology for green industry development.

	Peripheral region	Specialized region		Metropolitan region
Support system for innovation and entrepreneurship	Weak and limited	Strong in supporting sector-specific innovation, but weak in provision of generic resources		Strong and comprehensive
Regional industrial specialization	No specialization	Specialization in a green industry	Specialization in a dirty industry	Mix of industrial specializations
Forms of green path development	<ul style="list-style-type: none"> <li>Regional emergence of a green industrial specialization</li> <li>Upgrading of existing embryonic green industries</li> </ul>	<ul style="list-style-type: none"> <li>Growing existing green industrial specializations</li> <li>Diversification into other green industries based on accumulated knowledge and resources</li> </ul>	<ul style="list-style-type: none"> <li>Introduce new technologies to green the dirty industry</li> <li>Diversification into green industries based on existing competencies</li> </ul>	<ul style="list-style-type: none"> <li>Developing new technologies for green industries</li> <li>Forms of path development for green and dirty industries apply also in this context</li> <li>Shift resources from dirty to green industries</li> </ul>

justified in order to make innovation systems function effectively. In a regional setting, this implies understanding the regional innovation system and addressing eventual deficiencies regarding the *capabilities* of regional actors, *network* failures in the form of too weak or too myopic network relations internally or externally in the region, and *institutional* shortcomings such as inadequate formal (e.g. rules, regulation and laws) and informal (e.g. norms and values) institutions that hamper regional innovativeness.

However, as the focus of the current paper is not on increasing innovativeness and development of new industrial paths *in general*, but specifically for *green* industries, important complementing insights can be gained from the literature on transformative innovation policy. From this perspective, the aim of innovation policy is to contribute to addressing societal challenges, which require specific attention to directionality, experimentation, demand articulation, and policy learning and coordination (Grillitsch et al., 2019; Weber & Rohracher, 2012). Given the specificities associated with *green* industrial path development aspects from the transformational challenge framework are of importance in this context as well. Below, we briefly elaborate on the four challenges and consider (1) their specific relevance for green industry development and (2) if we would expect variation in the importance of addressing the challenges for different types of regions.

#### 4.1. Directionality challenge

*Directionality* ‘points to the necessity not just to generate innovations as effectively and efficiently as possible, but also to contribute to a particular direction of transformative change’ (Weber & Rohracher, 2012, p. 1042). In this case, orientation for industry development is needed. Firstly, this requires establishing a shared vision for regional industry development. In addition to a prioritization of green over dirty industries, it may also include specification of a focus on particular green industries. Secondly, policies concretizing the vision need to provide designated support for green industry development. Furthermore, directionality is particularly important for green industries as policies should also create room for green industries by destabilizing competing dirty industries, e.g. by initiating control policies or withdrawing support (Kivimaa & Kern, 2016). Arguably, the challenge of achieving directionality towards green industry development will be

less important in green regions, where this focus may follow almost inevitably from the character of the existing industry structure.

#### **4.2. Experimentation challenge**

*Experimentation* refers to the importance of activities aimed at, firstly, testing new technologies and social practices and, secondly, learning about the structures inhibiting their diffusion and how to overcome these structures (Sengers, Wieczorek, & Raven, 2019). Consequently, experimentation is particularly important to green industry development as green industries are based on technologies that challenge existing structures (Geels, 2002). The challenge of achieving a sufficient level of experimentation is predominantly important to address in metropolitan regions and regions with specialization in a dirty industry, where structures around incumbent industries are more strongly established than in peripheral regions or regions with specialization in a green industry.

#### **4.3. Demand articulation challenge**

*Demand articulation* highlights the need of considering market uptake of products and services. In the context of green industries, market uptake is particularly challenging, as green technologies often do not result in specific user-benefits, but rather produce benefits for non-payers in the application phase (Rennings, 2000). Further, insufficient knowledge about user practices and needs are evident in the case of many green technologies (see e.g. Nyborg & Røpke, 2013) and may further inhibit the diffusion of green technologies. These challenges are particularly important to target for green industries producing products with a high degree of technological complexity, since localized demand is central to these types of industries. Conversely, demand articulation is likely to be less important for green industries producing low-complexity products for mass markets (Binz, Gosens, Hansen, & Hansen, 2017; Hansen, Klitkou, Borup, Scordato, & Wessberg, 2017; Huenteler, Schmidt, Ossenbrink, & Hoffmann, 2016). Consequently, challenges related to demand articulation may be particularly important to tackle in metropolitan regions, which have favourable preconditions for achieving specialization in green industries with high technological complexity.

#### **4.4. Policy learning and coordination challenge**

*Policy learning and coordination* direct attention to the need for coherence and consistency between policy levels and fields, while at the same time allowing for modification and transformation of policy approaches based on learning and previous experiences (Grillitsch et al., 2019; Rogge & Reichardt, 2016; Weber & Rohracher, 2012). Addressing the policy learning and coordination challenge is central for complex, uncertain and long-term processes. As development processes for new green industries are not *per se* more complex, uncertain and lengthier than development process for new industries in general, we would not expect that addressing this challenge is of greater importance for development of green industries compared to dirty industries. Still, addressing this challenge is arguably always a priority for industry development, even if the specific focus may differ between the regions. As new green industry development processes are likely to be

particularly lengthy and uncertain in peripheral regions, which are characterized by a lack of existing specializations to build on and a weak support system for innovation, policy learning is of key importance here. Conversely, policy coordination may be of greater significance in the other types of region: in regions with specialization in a green industry, which are likely characterized by the existence of multiple 'green policies' in need of coordination; in regions with specialization in a dirty industry where policies should transition from supporting one type of industry to another; and not least in metropolitan regions where policies supporting a variety of green and dirty industries will coexist.

## 5. Green industry development policies in different types of regions

The current section brings together the likely types of green industry development for the different types of regions (section 3) with the key challenges emphasized in transformative innovation policy (section 4) in order to emphasize the geographical variation in key policy priorities. Consequently, we outline policy mixes for green industry development for our four ideal type regions, drawing on previous work on policy initiatives for addressing structural innovation system failures (Grillitsch & Asheim, 2018; Hassink, 2010; Isaksen & Trippl, 2017; Tödting & Trippl, 2005) and transformative innovation policy challenges (Grillitsch et al., 2019) as well as empirical illustrations from the literature. Table 2 summarizes the overall policy objectives and the specific focus of policy instruments at the level of actors, networks and institutions.

### 5.1. Peripheral regions

With the lack of specializations in peripheral regions, green industry development policies should stimulate path upgrading and path emergence. Path upgrading requires attention to improving the capabilities of niche actors in a green industry through specialized training programmes and support for attracting highly skilled labour in clearly defined competence fields. It also involves connecting niche actors to industry leaders and universities outside of the region. Regional policymakers may facilitate this by supporting the creation of formalized partnerships to extra-regional actors in the form of e.g. innovation projects. Policymakers may also encourage an international outlook among regional firms in a green industry niche by creating awareness of developments in technologies and markets through e.g. organizing seminars and workshops with invited international experts.

Path emergence in the case of peripheral regions involves deployment of green technologies developed elsewhere. Policymakers may facilitate this by establishing connections to extra-regional technology providers and project developers, and by supporting competence development in relation to servicing of the infrastructures. However, as illustrated in Murphy and Smith's (2013) analysis of wind energy development in the Scottish periphery, of perhaps even greater importance is to coordinate between the multiple local actors with a stake in the deployment, and facilitate a visioning process that encourages an embedded and contextualized implementation of the technologies in the region. In this case, the degree of stakeholder involvement in the development process and anchoring in the community are key explanatory factors behind the varying success of wind development projects (Murphy & Smith, 2013).

**Table 2.** Place-based green industry development policies.

	Peripheral region	Specialization in a green industry	Specialization in a dirty industry	Metropolitan region
Policy objective	Develop specialization in a green industry through path upgrading and path emergence	Grow existing specializations and develop new ones through path diversification	Transform dirty into green through path upgrading and path diversification	Develop and grow green industries and transform dirty into green through path emergence, diversification and upgrading
Targeting actors	<ul style="list-style-type: none"> <li>• <i>Attract external actors in a green industry</i></li> <li>• <i>Strengthen capabilities of existing actors in a green niche</i></li> <li>• <u>Develop governance learning capabilities</u></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Build a critical mass, accumulate experience and resources, and develop economies of scales</i></li> <li>• <i>Build competencies in developing business models and growing businesses</i></li> <li>• <u>Stimulate intrapreneurship in green incumbents</u></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Build competencies in technologies/solutions needed for greening the industry addressing both firms, but also higher educational institutes and government</i></li> <li>• <i>Attract actors from outside the region with such competencies</i></li> <li>• <u>Stimulate green intrapreneurship in dirty incumbents</u></li> <li>• <u>Promote green institutional entrepreneurs</u></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Build a critical mass, accumulate experience and resources, and develop economies of scales</i></li> <li>• <i>Build competencies in developing business models and growing businesses</i></li> <li>• <u>Stimulate green entrepreneurship</u></li> <li>• <u>Support identification of lead users for new green technologies</u></li> <li>• <u>Develop capabilities on green public procurement for innovation</u></li> <li>• <u>Promote capabilities for experimentation among non-firm actors</u></li> </ul>
Targeting networks	<ul style="list-style-type: none"> <li>• <i>Strengthen extra-regional networks to key players related to the niche</i></li> <li>• <i>Strengthen extra-regional networks to universities</i></li> <li>• <u>Coordinate between actors involved in technology diffusion</u></li> <li>• <u>Establish networks to learn from extra-regional policymakers</u></li> <li>• <u>Connect to and build on green directionality exercised by global level actors</u></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Strengthen networks to providers of entrepreneurial resources</i></li> <li>• <i>Strengthen networks to unrelated industries</i></li> <li>• <i>Foster coalition between the private and public sector around the green path</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Strengthen networks to unrelated knowledge sources that may contribute to greening</i></li> <li>• <u>Break-up alliances that hinder green restructuring</u></li> <li>• <u>Encourage collaboration between incumbents, start-ups and civil society</u></li> <li>• <u>Challenge established regional hierarchies in policymaking</u></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Strengthen networks between dirty and green industries regionally</i></li> <li>• <i>Strengthen university industry links</i></li> <li>• <u>Stimulate interaction between producers and lead user</u></li> <li>• <u>Encourage collaboration between heterogeneous actors</u></li> </ul>

(Continued)

Table 2. Continued.

	Peripheral region	Specialization in a green industry	Specialization in a dirty industry	Metropolitan region
Targeting institutions	<ul style="list-style-type: none"> <li>• <i>Provide institutionalized access to resources available in core regions</i></li> <li>• <i>Promote open, outward looking mindedness</i></li> <li>• <i>Develop a shared green vision among multiple actor groups</i></li> <li>• <i>Establish and promote green policy rationales</i></li> <li>• <i>Set green objectives that provide direction in an actionable way</i></li> <li>• <i>Promote green industry development across policy domains</i></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Promote a global market perspective</i></li> <li>• <u>Coordinate green diversification policies across multiple policy fields</u></li> <li>• <u>Establish systematic evaluation and learning mechanisms for diversification policies</u></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Provide incentives for adopting green and disincentives for dirty technologies</i></li> <li>• <u>Provide incentives for diversification experiments</u></li> <li>• <u>Provide assistance in accessing funding devoted to greening</u></li> <li>• <u>Develop a 'becoming green' vision and align policies accordingly</u></li> <li>• <u>Support green test and demonstration projects</u></li> <li>• <u>Promote risk-taking behaviour and acceptance of failure</u></li> </ul>	<ul style="list-style-type: none"> <li>• <i>Decrease institutional boundaries between industries</i></li> <li>• <i>Increase incentives for mobility between industries as well as sectors</i></li> <li>• <u>Support the development of new green paths by creating local demand</u></li> <li>• <u>Promote social acceptance for green emerging technologies</u></li> <li>• <u>Gradually increase exposure of experiments to selection pressures</u></li> <li>• <u>Align policies targeting multiple industries</u></li> </ul>

*Italics: initiatives addressing structural innovation system failures; underlined: initiatives addressing transformative innovation policy challenges.*

The absence of existing specializations also implies that peripheral regions are characterized by, firstly, a need for setting a direction for development of a green industry, and, secondly, particularly lengthy and uncertain green industry development processes, hence, emphasizing the need for focusing on policy learning. The case of Murau, Austria nicely illustrates the importance of these policy priorities for economic development in peripheral regions, in this case centred on bioenergy. Most importantly, a very broad coalition of actors established a green energy vision, which led to private sector alignment with the vision and facilitated private investments in the bioenergy field. The establishment of this vision also resulted from drawing on and linking up to agents exercising directionality at the national and international scale, including a federal ministry and the international network of energy agencies, which promoted transitions in energy systems (Späth & Rohracher, 2010, 2012). Drawing on Grillitsch et al. (2019), we would argue that policies in peripheral regions should also focus on strengthening so-called governance learning capacities (Borrás, 2011) understood as the abilities to reflexively consider the wider implications of policies, in order to learn about (un)successful policy instruments and practices in a given context. Such abilities follow not only from policy evaluations and benchmarks, but also from efforts targeting building wider organizational capacity and intelligence among public and non-public policymakers.

### **5.2. Regions specialized in a green industry**

The strong presence of a green industry implies that policies should focus on growing existing specializations and stimulate path diversification based on existing knowledge and resources. In terms of growing existing specializations, one of the most well-described empirical cases (e.g. Simmie, 2012) is the development of the Danish wind turbine industry, centred in Jutland. This case highlights several key policy priorities, in particular the importance of continuous enrolment by policymakers of multiple types of actors in shaping the further-development of the path. Policy also played a key role in supporting internationalization of the industry and in facilitating the accumulation of knowledge and experience by establishing organizations such as the Danish Wind Turbine Test Station (Buen, 2006; Garud & Karnøe, 2003; Meyer, 2004).

To our knowledge, there is little empirical work on regional path diversification from one green specialization to another (cf. Cooke, 2010). However, arguably, policy priorities are to stimulate intrapreneurship in green champions and strengthen networks to unrelated industries (Grillitsch et al., 2018). Reflecting this, previous research highlights how partnerships between cleantech firms specialized in green technologies, and producers of traditional, non-environmentally conscious products are important for firm-level diversification into new cleantech products (Hansen, 2014).

Considering the region's existing specialization in a green industry, it is likely that the regional policies already have a focus on the green economy but may be in need of coordination. We expect this to be particularly important in terms of supporting diversification into new green industries. Work on policy mixes for green industry development highlights the importance of alignment between policies targeting diverse aspects, from knowledge development to market access and availability of finance (Binz et al., 2017; Rogge & Reichardt, 2016), but also the role of coordination in terms of the policy strategy, which may vary significantly (see Imbert, Ladu, Morone, & Quitzow, 2017).



### 5.3. Regions specialized in a dirty industry

Greening the economy in industries specialized in a dirty industry revolves around introducing green technologies in the existing industry, thereby reducing its environmental impact, and the stimulation of industrial diversification towards green industries. For instance, González-Eguino, Galarraga, and Ansuategi (2011) underline the need for regionally-based, industrial policies that give polluting industries in old industrial regions incentives to adopt new green technologies. Focusing specifically on the Ruhr Valley, Hospers (2010) describes the role played by public policies in the form of designated technology transfer offices, strict environmental rules incentivizing firms to minimize environmental impacts, and support for demonstration projects. In the Ruhr Valley, this process eventually led to path diversification into the environmental technology industry, which today employs 100,000 people in the region. Other contributions focusing specifically on path diversification into green industries include Steen (2016) and Steen and Hansen (2014), which analyze diversification of oil and gas regions into offshore wind turbines. They show that start-ups by entrepreneurs with a background in oil and gas are of some importance, but this process is in particular driven by diversification of oil and gas firms into the new market, thus, emphasizing the need for policies supporting intrapreneurship and diversification experiments. The latter entails support for establishing relations to firms with complementary assets and market knowledge (see also Hansen & Coenen, 2017). Finally, Dawley's (2014) analysis of offshore wind in the UK also highlights the importance of policy efforts supporting diversification of the oil and gas industry, in this case in the form of individual consultations where policymakers raised awareness among oil and gas suppliers of market opportunities in the emerging industry.

The strong presence of incumbents in specialized regions implies that it is central to address challenges related to directionality and experimentation. In this respect, Steen (2016) underlines the importance of agency for green industry diversification and how this agency is informed by expectations about future developments in technologies, markets and value chains. This highlights the role of policy in supporting institutional entrepreneurs that may influence the formal and informal institutions that shape the future orientations of actors. Furthermore, Hospers (2010) points to the significance of challenging established hierarchies, including the importance of 'a modernization of institutions and procedures of regional policy' (p. 50) in order to provide fertile ground for the experimentation needed for green industry development in the region. To this, we would add the importance of introducing policies that promote risk-taking behaviour and acceptance of failure (Grillitsch et al., 2019). Finally, Hospers (2010) also shows how a multifaceted and aligned policy approach was instrumental in developing the environmental technology industry in the Ruhr Valley, thus, highlighting the role of policy coordination in diversifying into green industries.

### 5.4. Metropolitan regions

Green industry development in metropolitan regions may happen through path emergence, diversification and upgrading. Even though metropolitan regions are characterized by a mix of green and dirty industries, the recommended set of policies is not simply the additive combinations of policies for regions with specialization in either a green or a dirty industry. This is because the variety of capabilities and resources in metropolitan regions

offers additional opportunities, which justifies different policy priorities. This is exemplified by Gibbs and O'Neill's (2014) account of green economy policies in Boston, which stresses the importance of facilitating university-industry relations for the development of new green industries, and establishing test environments for experimenting with prototypes for new green technologies. Furthermore, the Boston case also points to the role played by designated organizations gathering actors from multiple industries and sectors in order to promote green industrial path development by focusing on entrepreneurship, developing business models, and workforce mobility.

Considering the favourable preconditions for achieving specialization in technologically complex green industries, challenges related to demand articulation are important to tackle in metropolitan regions. Analyzing fuel cell technology, Tanner (2014) highlights how some metropolitan regions develop specialization in the industry based on the existence of sophisticated users with core competences in integrating the fuel cells into new applications. This draws attention to the need for demand-side policies aimed at identifying lead users for new green technologies and stimulating interaction between producers and lead users. In line with this, Gibbs and O'Neill (2014) note the importance of incorporating instruments aimed at creating local demand in green industry development policies in Boston, and Carvalho, Mingardo, and Van Haaren (2012) point to role played by public procurement policies for greening of the heavy vehicle industries in cities such as Hamburg and Gothenburg. In addition, we would emphasize the relevance of policies promoting social acceptance for green emerging technologies as an additional aspect of a demand-sensitive policy portfolio in metropolitan regions (Grillitsch et al., 2019). Finally, Carvalho et al. (2012) also showcase the importance of coordination between policies targeting multiple industries, from transportation and vehicle manufacturing, to fuel cells and biogas.

## 6. Conclusions

The paper contributes with a regional typology and policy framework aimed at facilitating the identification of policy challenges and opportunities for green industry development as well as appropriate policy interventions. We start from the regional typology of Tödting and Trippel (2005) distinguishing between metropolitan, specialized and peripheral regions. Whereas this typology emphasizes the current characteristics of the regional innovation system, we introduce an aspect of directionality, i.e. the goal of green industry development. In this context, it matters whether regions are specialized in green or dirty industries as the former should be promoted and the latter transformed or replaced. Hence, the nature of industrial specialization will determine which knowledge, innovation, and industrial dynamics should be supported by policy.

The proposed framework brings together two literatures related to new industrial path development in regions and transformative innovation policy. The former has provided insights about new industrial path development in different regional contexts, but is in principle agnostic about the greenness of the developed industries. The latter has increased our understanding about the challenges for switching from unsustainable to sustainable patterns of consumption and production, but is not concerned with industrial path development in particular regional contexts. We consider it to be a relevant and timely conceptual contribution to synthesize these insights and elaborate on the implications for green

industry development in specific regional contexts. In this we also bring insights from transformative innovation policy to the regional level, by extending previous work on the operationalization of transformative innovation policy (Grillitsch et al., 2019) to arrive at a set of concrete interventions that policymakers can draw on when promoting green regional industry development.

We would argue that this also is an important contribution for policy in practice. After all, policymakers have the most direct influence, power and responsibility for their constituencies. However, policymakers have previously been found to emphasize policies aimed at building innovation systems and correcting structural innovation systems failures, while policies addressing transformative innovation challenges are few and far between (Kivimaa & Kern, 2016). Thus, the outlined policy mixes (Table 2) are a starting point for regional policymakers to consider policy initiatives that not only provide direct support for new green industries, but also aim at destabilizing competing dirty industries. Moreover, if policies are conducive not only for the environment, but also for the creation of jobs and income, then it will be comparably easy to mobilize the required support.

However, we do acknowledge several limitations. This paper focuses on green production and gives less attention to the role of green consumption patterns. Also, the paper does not focus on national/global institutional constraints for the development of green industries (which have previously been studied in greater detail, see Capasso, Hansen, Heiberg, Klitkou, & Steen, 2019), but concentrates on the opportunities for green industry development in specific regional contexts. Thereby, it zooms in on what regional policy makers can feasibly and realistically achieve to contribute to a green economy. That being said, the paper does explicitly consider the role of extra-regional linkages for green industrial path development and how the importance of such linkages vary according to the type of regions. To exemplify, policies focusing on establishing extra-regional linkages are of significant importance in peripheral regions in order to provide access to capabilities and technologies as well as to build on directionality exercised by actors operating at the national or global scale.

The primary value of the proposed regional typology and policy framework lies in their application. This calls for empirical research to validate the conceptual arguments as well as to further our theoretical understanding of green industry development in different types of regions. We have provided empirical illustrations based on existing research for the four regional types. However, we would suggest a dedicated research design, which theoretically selects cases to investigate the differences and similarities as regards innovation system and transformative innovation policy challenges, opportunities, and interventions by regional type.

Besides the empirical application and validation of the framework, we would also like to point out several blind spots in the literature. It is necessary to reflect on what can be done at the regional level: What is outside the power of regional governments? Do regional governments e.g. have the power to address the challenges identified in the policy framework and stimulate green industry development accordingly? How do different power relations affect the opportunities and challenges for green industry development in regions (e.g. Hansen & Mattes, 2018; Sotarauta, 2015)? Furthermore, we do not dig into qualitative differences in industrial specializations. For instance, the knowledge base approach suggests that knowledge, learning, and innovation differs between industries and regions (Asheim et al., 2017a). However, we do not address such differences in our

framework. Therefore, we would consider it valuable to intersect our typology with other dimensions that zoom in on systematic differences between regions, for instance as regards power of regional actors, or type of knowledge bases developed in regions. Finally, our framework does not consider the role of external shocks in the form of e.g. political conflicts, changes in oil prices, or the introduction of new breakthrough technologies. Future research should address how such shocks open or close windows of opportunity for policy action (cf. Normann, 2015), to better understand their influence on the development of green industrial paths in different types of regions.

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