Green human capital and how it affects cleantech innovativeness

A case study of the innovativeness of the Cleantech Regio and how it can be improved using green human capital analysis

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Abstract

The green technology industry is an emerging sector worldwide and in the Netherlands. The Cleantech Regio is a Dutch region which aims to specialize in this sector, but policy makers encountered the problem that the regional level of green human capital was not sufficient to reach extensive cleantech innovation. This research aims to build a framework to analyze how an increase of green human capital leads to cleantech innovativeness and what can be done by policymakers to help this process. To build this framework, multiple methods are used. Patents, demographics and policy reports are studied and linked to relevant scientific literature to discuss the case of the Cleantech Regio in detail. The results are presented in a SWOT-analysis to provide an overview of the situation. Reoccurring themes in the strengths and opportunities are close triple helix collaborations and the creation of innovative clusters, while weaknesses and threats are for example identified in a lack of focus on the cleantech sector and insufficient green education. The SWOT-analysis and subsequent conclusion and discussion helps policy makers with improving their green innovative capacity with a green human capital approach and for future research this paper serves as a guideline for further cleantech innovativeness analyses.

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1. Introduction

Environmental crises, related to climate change, food scarcity and biodiversity loss are affecting places on a global and local scale (Leach et al., 2012), with the Netherlands not being an exception. This is why the next wave of innovation is likely to be fueled by the emergence of green technology. A big part of the Dutch environmental policy is focused on green technology, namely on energy transition (Kern & Smith, 2008). This is desirable for the environment, but may also result in the creation of up to 50.000 jobs and 1% growth in GDP (Bulavskaya & Reynès, 2018). Top-down policy changes should be able to mitigate the environmental problems, but this may not be enough and a bottom-up approach could be more helpful in environmental policy (Carolus, Hanley, Olsen & Pedersen, 2018; Leah et al., 2012; Sandhu, 2021). To support this, the TNO (n.d.), The Netherlands Organization for applied scientific research, wants to bring knowledge institutions, firms or industries and the government together on a regional scale to work towards the goal of nationwide energy-neutral households in 2050. This kind of cooperation has been dubbed a 'triple helix' model (Leydesdorff & Etzkowitz, 1998). The cooperation can happen at the national, but also on a regional level, giving it a bottom-up character as well as a top-down one. This cooperation is a good strategy according to scientific literature, as concluded by Leydesdorff & Etzkowitz (1998):

'Innovation is initially the result of a local interaction between scientific invention, economic diffusion, and political power.'

One intermediary organization powering such interactions on the regional level is 'Cleantech Regio', covering the municipalities Apeldoorn, Deventer and Zutphen, and other municipalities in between these cities (Cleantech Regio, n.d.). The institution Cleantech Regio is a knowledge- and network-organization bringing together educators, entrepreneurs and governments, acting as the engine in a regional triple helix. Since 2013, this region has ambitions in line with the national sustainability goals (Strategische Board Stedendriehoek, 2016), which is also why it is called after cleantech: the term cleantech is used to refer to various companies and technologies that aim to improve environmental sustainability (Fernando, 2020). The Cleantech Regio (n.d.) states that creating a circular and energy-neutral economy is one of the main ambitions of the region. There is however an internal problem in reaching this goal: the demand and supply of human capital is not in line in this region, as told by the thememanager human capital of the Cleantech Regio (N. Kraehe, personal communication, January 1, 2022). Human capital is defined as follows by Oxford Learner's Dictionary (n.d.): the skills, knowledge, and experience possessed by an individual or population, viewed in terms of their value or cost to an organization or country.

Human capital in the green sector, called green human capital, is necessary for the adoption of green innovation (Ali et al., 2021; Wan & Juo, 2021). So, regions across the world that are aiming for cleantech innovation need to accumulate the desired amount of green human capital to make this work. In the aforementioned region within the provinces of Gelderland and Overijssel the problem occurs that there are great ambitions with governments and companies for Cleantech innovation, but there is a lack of skills, knowledge and experience in the region to realize these ambitions in the desired tempo (N. Kraehe, personal communication, January 1, 2022). This region tries to apply the triple helix model to reach the required green human capital. In the triple helix model, the main providers of the human capital side are the education institutes, but also the other actors ensure creation of knowledge, skill

and experience on their own or as a result of the communication between helices (Leydesdorff & Etzkowitz, 1998). The helices and the communications are to be examined to provide insight to how the creation of human capital in the region can be stimulated. How actors can improve green human capital to improve a regions' cleantech innovativeness will be explored in this research.

To provide structure and a clear goal in this research, the following research question has been formed:

How can a green human capital analysis help to map opportunities and challenges for regional development towards cleantech innovation?

This question is too broad to answer at once, so the following sub questions are formed to help formulate an answer to the research question:

1. *What is human capital and in what way does it affect innovative output?*
2. *Which human capital components are relevant to cleantech and how do they affect cleantech innovation?*
3. *How can the human capital components be measured?*
4. *What are the strengths, weaknesses, opportunities and threats for the cleantech innovation in the Cleantech Regio?*

In the first question, the concept of human capital will be explored and there will be attention for its relation to innovation. Secondly, since it seems that green sectors innovate differently, the differences in skills and knowledge between green clusters and other clusters will be analyzed and the most important components in the green side of human capital will be found. Thirdly, after finding which human capital components are most important in cleantech, it will be elaborated how these can be measured. Lastly, a case study will be conducted about the Cleantech Regio. In this case study, the important human capital components will be measured regionally. With the results, a conclusion can be made regarding the extent to which the region is ready for innovation in cleantech and what aspects of green human capital creation the region should still improve.

This research has a scientific contribution in its analysis of the innovation of regional cleantech clusters. Links will be explored between human capital and innovation, after which an inventory of research about the so-called green human capital and its effects on cleantech innovation will be made. The proposed framework and corresponding data and indicators will be illustrated in an application to the green innovative capacity of the region. With the help of a SWOT-analysis, a policy advice will also be formulated. In current literature, there have been studies with SWOT-analyses regarding the cleantech sectors in certain countries (Beloborodko et al., 2015; Iglínski et al., 2016), but these are not about how to increase innovativeness in this sector. One study that did do this, by Jinqian & Chong (2015) based the innovativeness solely on a patent analysis and the research was conducted about the entirety of China. So, by using multiple data sources, including not only patent data, but also demographics and policy documents, the scope of analyzing innovativeness will be more broad. Furthermore, this research will be about a single region, making the scale of the research relatively small. This will result in a more situated analysis and more relevant policy implications for local stakeholders.

Societally, this research will be relevant for regions globally which set the goal of innovating in cleantech. This research will offer a framework for those regions to analyze whether their green human capital is large enough for their green innovation goals. When investigating their innovative capacity, the regions can follow the steps taken in this research to get an initial idea about the feasibility of innovation in cleantech. Policy makers could adjust their plans and goals with regards to the outcome of such an analysis.

2. Literature review

2.1 Human capital and innovation

As discussed in the introduction, human capital is a term for the skills, knowledge and experience an individual has (Oxford Learner's Dictionary, n.d.). The availability of human capital has proven to be important for the innovativeness of firms (Calabrò, Torchia, Jimenez & Kraus, 2021; Leitner, 2018; Simic & Slavkovic, 2019), as well as for other developments within the firms. Positive links have been found between human capital and R&D investments, strategic decision making and overall business development (Calabrò et al., 2021). Similarly, for an entire region and its firms to boost their innovativeness, human capital plays a crucial role (Simic & Slavkovic, 2019).

Human capital is part of a bigger concept: intellectual capital. The amount of intellectual capital present within a firm has a positive effect on the innovativeness (Kalkan, Bozkurt & Arman, 2014). Although this process is not heavily researched in current literature, there is consensus that the intellectual capital leads to innovation, which leads to business performance (Mention, 2012). Intellectual capital is defined as 'intellectual material - knowledge, intellectual property, experience - that can be put to use to create wealth' and consists of three components: human capital, structural capital and organizational capital (Snyder & Pierce, 2002). As stated before, human capital revolves around personal skills, knowledge and experience. Relational capital stands for the value derived from connections outside of the organization and organizational capital includes all forms of intellectual property within the routines of the company. Human capital seems to be the driver behind gaining intellectual capital, because human capital creates the knowledge, which then gets shared with relations (relational capital) and eventually institutionalized by companies (organizational capital) (Popescu, 2021). Furthermore, human capital and organizational capital both have a significant positive influence on business performance (Ahmed, Guozhu, Mubarik, Khan & Khan, 2019).

The human capital side of intellectual capital can be very extensive. To measure it, dozens of categories and sub-dimensions are known, each with their own value (Mubarik, Chandran & Devadason, 2018). The most important dimensions seem to be education, experience and training. These dimensions have multiple sub-dimensions, as seen in table 1. It is becoming clear that some sub-dimensions are more important than others, work related experience being the most important.

Goal	Dimensions	Local weights	Sub-dimensions	Local weights	Global weights
Human capital	Education	0.12	Level of education	0.270	0.033
			Quality of education	0.400	0.050
			Technical education	0.330	0.041
	Experience	0.21	Similar industry experience	0.270	0.057
			Work related experience	0.400	0.085
			Organizational tenure	0.330	0.069
	Training	0.11	On the job training	0.180	0.020
			Spending on training	0.100	0.011
			Time on training	0.110	0.012
			Technical training	0.200	0.022
			Soft skills training	0.120	0.014
			Previous training	0.290	0.033

Table 1: Dimensions and sub-dimensions of human capital (Mubarik et al., 2018)

As mentioned, human capital is important for firms and regions as they lead to innovation (Calabrò et al., 2021; Simic & Slavkovic, 2019). Innovation is defined as follows: *'introducing on the market a new or better product, as well as introducing a new process or updated process of production, with the product or process new from the perspective of the enterprise that implements it.'* (OECD, 2005). The modern way to perceive innovation is, instead of as a single event, as a complex of events that make new patterns, goods or technologies (Pater & Lewandowska, 2015). In this modern way of thinking the traditional factors of production, like natural resources, labor and capital, have been replaced by more intangible assets: information, knowledge and creativity. These assets are more closely related to human capital, proving how important human capital is in the modern concept of innovativeness. This modern innovativeness is defined by the willingness and ability to constantly seek and implement R&D, new concepts, innovations, developments and upgrades (Pater & Lewandowska, 2015). These factors are of utmost importance for business development, as innovative firms tend to generate competitive advantages, leading to better business performance (Bhaskaran, 2006).

One way to create human capital, and thus to stimulate innovation, on a regional level is to foster a close cooperation of government-, firm- and knowledge institution actors (Etzkowitz & Zhou, 2017). These actors all have their own influence on the important human capital dimensions (Mubarik et al., 2018), as elaborated in paragraph 2.3.

So, in short, intellectual capital is a very important factor for the innovativeness of businesses (Kalkan et al., 2014; Mention, 2012). Within intellectual capital, human capital seems to be the driver and most important for innovative power (Popescu, 2021). Human capital can be divided

into a few important dimensions (Mubarik et al., 2018), which, when optimized, will have a positive effect on innovation and eventually business performance (Pater & Lewandowska, 2015).

2.2. Human capital in cleantech

Rhodes & Wield (1994) coined the term 'green innovation', which they described as a form of technological innovation for the purpose of environmental protection. Innovation in green technologies holds some differences with regards to other types of innovations. Mainly, human capital required for green innovations is higher than in many other sectors (Consoli, Marin, Marzucchi & Vona, 2016; Jensen et al., 2020). Green jobs often use more intensively high-level cognitive and interpersonal skills compared to non-green jobs, which is why the higher level of human capital is required (Consoli et al., 2016). This makes it a challenging sector to innovate in, but potential benefits could be great. It is expected that for the next decades, green technology will become the main technological paradigm (Hayter, 2008), or it is at least one of the contenders to shape the next Kondratieff wave (Damsté, 2019). These waves are time periods of roughly 50 years in which a certain technological or institutional advancement shapes the economy. Currently, we are in the second half of the age of telecommunication and information, meaning that the start of the next wave is near. The possible upcoming of cleantech underlines the importance of creating skills, knowledge and experience on the subject.

Although the cleantech sector in its economic size has already surpassed the airline sector and is nearing the pharmaceuticals sector, there are still fundamental developments in the sector to be made (Marra, Antonelli & Pozzi, 2017). Firstly, the sector mainly consists of small and medium sized enterprises, which brings problems on its own. Secondly, the firms in this sector aggregate spatially in big cities, because of the local spillovers and R&D activities. Both these examples are not necessarily problems, but they do typify the youth of the sector.

It is also important to note what factors matter for improving human capital in specifically green sectors. Green education seems especially important in the process of innovation in green technologies (Cheng & Chang, 2013). Green human capital has a similar meaning to normal human capital, but puts the emphasis on skills, knowledge and experience specifically in the environmental sense. The process of innovation in green sectors goes as follows: a sufficient amount of green human capital ensures that green intellectual capital overall increases, which helps to increase green structural- and relational capital (Agyabeng-Mensah & Tang, 2021). This holds similarities to intellectual capital overall, where human capital is also the driver (Popescu, 2021). Green human-, structural and relational capital have all been found to have a positive significant effect on green innovation adopttion (Ali et al., 2021; Wan & Juo, 2021). So, to innovate in green technologies, it is important to have a special focus on the dimensions of education, experience and training in the green category, to increase green intellectual capital as a whole, which is beneficial to green innovation.

To conclude, cleantech is a very young and upcoming sector (Marra et al., 2017). The human capital with regards to its effect on innovation in this sector seems to be very similar to human capital overall. However, the human capital requirements for innovation are higher (Consoli et al., 2016; Jensen et al., 2020). Otherwise, there are no significant differences within this sector in the process of human capital to innovation as found in the literature.

2.3 Human capital and the triple helix model

The role of universities and other knowledge institutions has changed a lot over the centuries. In the Middle Ages, universities started out with the restoration of ancient culture and were heavily influenced by the Christian church (Frondizi, Fantauzzi, Colasanti & Fiorani, 2019). At that time, they almost solely had the task of teaching, but in the nineteenth century the creation of knowledge was added to the universities' tasks. Since then, society became more and more reliant on knowledge created by these institutions, up until the 'knowledge-based society' that is present today, where government and industry get involved in the creation of knowledge.

A 'triple helix' of academic - industry - government relations has become one of the main national and regional innovation strategies during the 20th century (Etzkowitz & Leydesdorff, 1995). The government began taking on a role in offering incentives for innovation and pushing academic institutions, usually universities, to make a more direct contribution to wealth creation, while firms increasingly emerged from the created knowledge in the new knowledge economy. One requirement for a working triple helix is that the government should reform the economy to make it revolve around the capitalization of the created knowledge (Wijiharjona, 2021).

The actors within the triple helix all have their own role in improving the three main dimensions of human capital by Mubarik et al. (2018). The government has the most indirect role in improving the human capital dimensions. Governments mainly act by funding the other actors and setting innovation challenges and goals to promote innovation (Etzkowitz & Zhou, 2017). Acting like this should be sufficient, mainly because too much government-influence will hinder the innovative capacity of the industry-knowledge institution tandem. So, the government is not directly involved in improving education, experience or training.

The industry side has a more direct role in improving regional experience in a triple helix. Firms that are not bound to external investments, but are subsidized by governments tend to have more room to make mistakes, which results in more experienced firms and workers (Etzkowitz & Zhou, 2017). Firms with many experienced workers, or so-called experienced firms, are proven to achieve the best innovative results (Mubarik et al., 2018), which is why experience is so important in innovativeness. Furthermore, when firms strive for even greater innovativeness, they tend to partner up with similar organizations (Etzkowitz & Zhou, 2017). These firms and organizations increasingly provide their own schooling, in which their employees get specific training at increasingly higher levels (Etzkowitz & Zhou, 2017). This could be in cooperation with a university, with the university supplying students to firm training trajectories or projects, or this training could be organized by a firm on its own.

The knowledge side is also involved in training (Etzkowitz & Zhou, 2017), which prepares people for joining firms. Entrepreneurial training is ever more offered in knowledge institutions. Integration of firms in PhD programs or students having to write business plans for their assignment are examples of this, but also workshops or events from firms to students can be seen as a training at the knowledge institution. Furthermore, the knowledge institutions are involved in the overall education of the population (Etzkowitz & Zhou, 2017). Secondary schooling already seems to have a minor positive effect on innovativeness, while tertiary schooling has a much stronger positive effect (Chi & Qian, 2010). The cleantech sector apparently needs higher education, as it has relatively few start-up entrepreneurs without a formal educational degree (Jensen et al., 2020). Especially higher education in natural sciences and economics seem to benefit cleantech oriented businesses. However, the effects on cleantech innovation are not explored in this research.

Implementing an efficient triple helix is one of the ways to improve the creation of human capital (Etzkowitz, 2008). Knowledge institutions are the core human capital providers in this model (Etzkowitz, 2008; Farinha & Ferreira, 2013). These institutions can foster innovation and economic development, but a hybridization with the government and firms is needed to generate new institutional and social arrangements for the production of knowledge (Frondizi et al., 2019). The output from the knowledge institutions also strengthens the other sides, by resulting in higher entrepreneurial dynamics for instance (Farinha & Ferreira, 2013). One requirement for a working triple helix is that the economy should revolve around the capitalization of the created knowledge (Wijiharjona, 2021).

There is some criticism about this system. To start, von Humboldt, founder of the Berlin University, already stated in the nineteenth century that governments should not interfere in knowledge creation: '*...when [universities] fulfill their specific objective, they also fulfill the State's needs, and indeed they do so in a broader way*' (Frondizi et al., 2019). Criticism that is heard more recently is that research has shown that the local and regional effects of the triple helix co-operations may be exaggerated (Truffer & Coenen, 2012) and the implementation of the triple helix model only leads to 'small victories' (Coenen, Moodysson & Martin, 2015).

However, the majority of academics conclude that a triple helix does foster human capital creation and innovation. For instance, it has been found that the more actors cooperate, the more business innovation takes place (Hernández-Trasobares & Murillo-Luna, 2020). This cooperation makes sure that knowledge and skills flow smoothly from knowledge institutions to firms (Etzkowitz & Zhou, 2017). For example, the actors can coordinate to specialize in certain niches, which would fail without the proper communication. So, the synergic effects between the triple helix agents do lead to innovation when knowledge is being capitalized, as stated before by Wijiharjona (2021).

So, the universities' role in human capital creation has always been present, but governments and firms have become more and more important, up until today where triple helix collaborations are broadly studied. All actors have their own goals and their own tasks in creating human capital. In short it can be stated that knowledge institutions and firms create the human capital, while the government helps by funding and setting challenges.

2.4 The triple helix collaborations

All actors in a triple helix have their own interests in innovation. Knowledge institutions are involved in the generation and transfer of knowledge while the firms and government contribute with policy innovation (Lerman, Gerstlberger, Lima & Frank, 2021). In this system, the 'entrepreneurial university', which is a university with commercialized research, is the driving force (Etzkowitz & Zhou, 2017).

The collaboration between knowledge institutions and firms is influenced by many factors, for instance by relational and institutional factors (Rybnicek & Königsgruber, 2019). To reach a strong collaboration, flexibility, honesty and clarity are advised. This advice is also underlined in the 'seven keys to collaboration success' by Greitzer, Pertuze, Calder & Lucas (2010), which describes in seven points more or less how flexibility, honesty and clarity are important for success. A close, open collaboration between the two actors like this contributes to the birth of innovative achievements (Bektaş & Tayauova, 2014). This openness will also help create a two-way flow of influence, as the distance between institutional spheres is

reduced, which will help in achieving the three goals in this relationship (Etzkowitz & Zhou, 2017):

1. Firms funding basic research interests of the knowledge institutions;
2. Firms relying on academic input in their projects;
3. Formulating joint research programs with conjoint goals and multiple funding sources.

The government-knowledge institution relations have more to do with policy and funding. The government promotes innovation by the provision of basic research funding to establish a linear model of innovation (Etzkowitz & Zhou, 2017). This means that governments traditionally get involved in innovation by funding R&D projects, helping the knowledge institutions succeed with their model of innovation. This relationship is compared to the agency theory, in which the agent, in this case the university, performs tasks on behalf of the principal, the government (Kivistö, 2008). Most important in this relationship are three elements:

1. Government delegates tasks to a university;
2. Government allocates resources for accomplishing those tasks;
3. Government governs the accomplishment of those tasks.

The relationship between firms and government is once again mainly a funding one (Etzkowitz & Zhou, 2017). The Dutch government for example, provides funding via tax breaks, innovation credit and subsidies (Rijksoverheid, n.d.). Start-ups especially profit from this relation, as traditional investors can be hesitant to invest in these firms, while the government is more willing to do so out of a job creation- and research advance point of view (Etzkowitz & Zhou, 2017). Firms that are more open to government investments tend to be or become more innovative (Laursen & Salter, 2006). Only when a start-up proves successful, then traditional investors will take over the funding role (Etzkowitz & Zhou, 2017). The success of government investments is underlined by Shen, Li, Wang & Liao (2020), exploring the positive effect between environmental regulations or subsidies put in place by the government and the green innovativeness of firms. A strong government influence, under the name of 'command-and-control', has a positive effect on end-of-pipe treatment technology, or simply put: to assure innovation regarding clean waste management. Furthermore, environmental policy regulations assure cleantech innovation overall by stabilizing the green innovation system (Yang, Chen, Du, Lin & Lu, 2021). There is no single answer to how this policy instrument should take shape, as 'there is no single magic instrument to promote [sustainable] innovation' (Kemp, 2000). There are many different roles a policy maker could take on for many different situations, examples of the roles being sponsor, planner or regulator.

The government benefits from their funding role by steering firms into certain research, which eventually should lead to science-based economic development (Etzkowitz & Zhou, 2017). This government tool relates to the aforementioned statement, claiming that capitalization of knowledge is needed for a successful triple helix collaboration (Wijiharjona, 2021). Also, to reach desirable innovation, the government will serve as a mediating actor between knowledge institutions and firms, making sure that produced knowledge in universities and schools is on the same page as what they want firms to continue researching.

To summarize, the government mainly funds firms and knowledge institutions and in exchange they get to set innovation goals, of which the progress they govern. This process is especially important for green innovation. Firms and knowledge institutions have more of a two way relationship, by starting joint research projects for example.

2.5 Triple helix collaborations in green clusters

Cleantech is a unique sector in the sense that it needs relatively high skills compared to other sectors to innovate (Consoli et al., 2016; Jensen et al., 2020). Because of this, to innovate in cleantech, strong local networks are exceptionally beneficial (Chapple, Kroll, Lester & Montero, 2011). Close ties in regional networks will result in a strong regional evolution within the cleantech sector (Cooke, 2010). A main example of such a network is a triple helix collaboration, which especially helps green technologies advance (Kiryushin, Mulloth & Iakovleva, 2013).

The government is more of a key player in the 'green triple helix' collaboration compared to other sectors, because the need for innovation in green technologies is a big societal issue (Brem & Radziwon, 2017). The government, in collaboration with the industry, formulates the regional innovation policy, which for instance expresses itself by altering municipal locational factors (Lerman et al., 2021). But, although the policy is dictated by the government and firms and they seem more important, the knowledge institutions are still important. Tertiary education is especially important in green innovation systems (Hsu, Quang-Thanh, Chien, Li & Mohsin, 2021), which is no surprise, since cleantech needs relatively high skills (Consoli et al., 2016; Jensen et al., 2020).

In renewable energy systems, which are an example of green clusters, the input of the triple helix actors on the policy has been analyzed, as seen in figure 1 (Lerman et al., 2021). In a green triple helix cooperation, the only added value of universities on policy seems to be knowledge creation. There is no evidence of them having input in the policy about creating cooperative systems or developing locational factors. The government and private sector also influence the policy on knowledge creation, which is beneficial to the innovation system. Furthermore, they create policies for cooperative systems to strengthen the helix and they help form favorable locational factors, both of which eventually support local innovation.

	RES Policy		
TH actors	**Cooperation**	**Knowledge**	**Location**
Government	Yes	Yes	Yes
Private sector	Yes	Yes	Yes
University	Not supported	Yes	Not supported

Figure 1: Triple helix actors and their impact in renewable energy systems (Lerman et al., 2021)

The main collaborations within the green triple helix consists of two strategies, both between industry and university (Yang et al., 2021): the collaborative innovation strategy and the betrayal alliance strategy.

Most important in the collaborative innovation strategy is that there is a strong reliance on external factors, because innovation is seen mostly as a result of interaction between actors (Hartley, Sørensen & Torfing, 2013). The interaction increases innovation especially in green clusters, because in this sector the skills needed are high and there are more financial burdens

(Consoli et al., 2016; Jensen et al., 2020). In this strategy, the government can help with the financial burdens (Yang et al., 2021). Industry and knowledge institutions can choose to accept the financial help, but in return the government gets a say in what innovation should take place.

The interference of the government however could mean that there are stricter rules to be held in account, like environmental regulations (Yang et al., 2021). Firms and knowledge institutions could choose to 'betray' the government and to draw their own plan. The financial cost could be very high in this case, because of the absence of subsidies and possible penalties, but some alliances choose this strategy to exclude as much government interference as possible.

So, the triple helix in specifically the cleantech sector does not seem to have significant differences as compared to other triple helix systems. However, the cleantech sector does distinguish itself in its need for strong networks, especially since firms and knowledge institutions specializing in this sector are relatively dependent on governmental funding compared to other sectors.

2.6 How actors enhance green innovation

So far, the importance of (green) human capital on (green) innovation has been stressed and the role of the triple helix in this human capital creation and innovation is also covered. Which tools and methods the actors themselves can use to positively affect the green innovative capacity of the region are yet to be explored.

As stated before, regional innovative capacity benefits from strong government regulations (Shen et al., 2020; Yi, Wang, Yan, Fu & Zhang, 2020), with the regulations stabilizing the green innovation system (Yang et al., 2021). Public investments are less likely to be short-term compared to private investments, which would disrupt green innovation processes when the investments are retracted in the process of innovation (Owen, Brennan & Lyon, 2018). Public investments are less likely to be retracted in the initial stages of business innovation, mainly because these investments are usually also done out of a job-creation point of view (Etzkowitz & Zhou, 2017). One policy choice a public institution like a government could take is to provide financial grants for businesses to complete certain steps in an innovative process, like designing a prototype or the marketing of the new green product (Owen, et al., 2018). A disadvantage in this funding strategy is that following the early stages of the process, external funding is almost essential, which is hard to get for businesses when they previously were fully dependent on public support, causing many inventions to be abandoned somewhere in the middle of the process. Innovative projects and enterprises could also be funded by bank loans or crowd funding, but these bring the disadvantages of early-stage entrepreneurs and small-scale firms barely being funded. So, especially the early stages of innovation benefit from a close government cooperation and funding, after which they should find external funding, but this could be hard to find after the reliance on public investment. The government should implement a policy in which they bring together firms and funding after the initial innovation phase, while closely following the process and implementing regulations. This is backed by Yi et al. (2020), stating that external financiers are more likely to invest when prior R&D has already been funded by governments. Direct financial contribution to R&D leads to an increase of green innovation activities.

The firms receive funding, but have the task to translate these means to innovations. Firstly, firms that are open to government investments and have a higher openness towards

external sources are proven to be more innovative (Laursen & Salter, 2006). These external sources get more important after the early innovation stages (Owen, Brennan & Lyon, 2018). The strong government relations, which positively affect the regional innovativeness (Shen et al., 2020), are to be replaced with other funding. Wang & Li (2022) explored the effect of Green Credit Guideline in China and concluded that following this guideline resulted in an increase of 21.1% in green patent applications, compared to firms not participating in this programme. The 30-point guideline describes how banks should strongly regulate firms on the receiving end of their investments (Sustainable Banking Network, n.d.). The guideline provides support for innovation in green businesses by, among other things, contributing to the transformation of economic growth patterns. The transformation takes shape in close monitoring of the innovation strategy and strict rules set by the financer. With constant evaluations of environmental and social risks of the business, the business model is being stabilized. With public funding and later private funding, firms should operate in a certain way to gain innovativeness. The most important keywords in this are cooperation, openness and training (Galia, Ingham & Pekovic, 2015). All of these improve human capital within the firm in such a way that benefits environmental innovation especially. The cooperation is about innovation arrangements with other actors, openness is about how many sources the business interacts and shares resources with and training is about finances invested into the training of employees. The cooperation is also needed spatially, as concluded by Díez-Vial, Belso-Martínez & Gregorio (2022), who state that green innovativeness is enhanced by geographical closeness, or clustering, due to knowledge spillovers. Cooperation, openness and training all have a positive effect on environmental innovation and thus should be important in the green innovative business model.

Knowledge institutions' most important task is providing the education dimension of human capital (Etzkowitz & Zhou, 2017). This is best done by a hybridization with firms and government (Frondizi et al., 2019). This way, knowledge is produced in subjects that are societally or economically relevant. Knowledge institutions should be open to allow the other actors to govern the knowledge production. With existing PhD programmes, events and workshops for example the firms are involved in the knowledge creation which benefits innovation and governments stay involved to steer the innovation to a societally important direction (Etzkowitz & Zhou, 2017), the direction being ever more towards cleantech the past years. The cleantech sector itself especially benefits from universities, as they play a strong role in creation and support of cleantech innovations (Ott, Wadsack, Ihly & Cozart, 2021). Moreover, universities are also a birthplace of innovative companies: 49% of the companies that are formed at a university use the valuable 'university-developed intellectual property', compared to only 26% of firms that were not formed in a university setting (Ott et al., 2021). For knowledge institutions, to enhance regional green innovation, they need to implement a policy of openness, because it seems that the more universities collaborate with firms and governments, the more cleantech innovation takes place (Frondizi et al., 2019).

In short, firms involved in green innovation profit from strong collaborations with public actors in the early stage of innovative activities, after which it is most effective for private funding to take over. This strategy seems relatively effective for innovation in the green sector. Close governing seems to improve the innovativeness of especially those firms in the cleantech industry. The government should govern firms and knowledge institutions closely, as they also benefit from governmental regulations and close governing. So, to enhance green innovation, there is not much the actors could individually do, with the main methods being collaborating with other actors, as also described by Etzkowitz & Zhou (2017). This collaboration in a triple

helix is effective in many sectors, but in the cleantech sector it seems more of a necessity to reach an increase in innovation.

3. Methods

The first two sub questions of the research are of a theoretical nature and the answers to these are already found in existing literature. Furthermore, how human capital components can be measured will be expanded upon in this chapter. For the fourth sub question, '*what are the strengths, weaknesses, opportunities and threats for cleantech innovation in the Cleantech Regio?'*, the methods as described in this chapter are to be used. Answering this question will demonstrate that this report is able to act as a guideline in measuring a regions' green human capital, which is the scope of the overall research question.

More exactly, by applying all of the methods described in this chapter, it will be concluded how the three actors influence the three key dimensions, which leads to a conclusion of which actors and dimensions are important in the creation of green human capital and which lack behind to reach the green innovation ambitions. A detailed analysis will be provided on these actors and dimensions.

3.1 Actors

This research focuses on three groups of actors. This chapter provides a conceptualization of these actors and points out who these are in the Cleantech Regio.

The government side could consist of municipalities, provinces or even national governments. When researching the innovative capacity of an entire country, the main focus should be on national policies, but in research on local innovativeness, the focus should be more on lower levels of governments, such as provinces and municipalities. In this research, the municipalities chosen are shown in table 2 in paragraph 3.2.3. Also, intermediary organizations, which often have close ties with governments, are taken into account. Furthermore there are intermediary organizations active in the region which are not exactly governments, but are heavily influenced by government policy. The first is the Cleantech Regio, which brings together all triple helix actors in the region: municipalities in the form of different aldermen, firms in the form of different managers and education in the form of college board members (Cleantech Regio, n.d.). Circles is another intermediary organization which technically is a branch of the Cleantech Regio, but is also a relatively big network, bringing together 22 partners with a circular focus (Circles, n.d.).

The knowledge institution side also includes multiple layers. Although much research focuses solely on universities, tertiary education overall seems to have a positive impact on green innovation (Hsu et al., 2021). So, it is clear that the focus should be on tertiary schooling overall. The tertiary knowledge institutions will be collected, which mainly consist of MBO's and HBO's. The advantage of using these institutions is that, unlike universities, they focus more on occupation-oriented research and thus will create green human capital which would be useful for firms.

The firms that are to be analyzed are also prone to the scale of the research. When researching the innovative capacity of a single city, it could be possible to take a broad selection of big firms into account. But, when research becomes regional or even national, individual firms will become relatively more irrelevant and focus should shift more to entrepreneurs' associations to get a broader view of firm initiatives overall. Also, when firms have great innovative goals, they tend to partner up in organizations (Etzkowitz & Zhou, 2017).

In this research, the focus will be on the bigger associations and their overarching initiatives. The VNO-NCW is the biggest entrepreneurial organization in the region and has a separate branch for the Cleantech Regio. From this organization, workshops and other training events are organized, which are chosen to be highlighted to characterize the training in the region. Unfortunately, smaller initiatives, like events organized by single firms, are not feasible to examine due to the constraints of the research.

In scientific literature the roles of the actors in improving human capital have been explored. The government mainly has a governing role and does not provide direct input in improving the dimensions of education, experience or training (Etzkowitz & Zhou, 2017). Knowledge institutions contribute by improving the dimensions of education and training (Etzkowitz & Zhou, 2017), and firms contribute by improving experience and training (Etzkowitz & Zhou, 2017).

3.2 Data collection and operationalization

This section will explain how data will be collected in this research and how this data will help to answer the research questions. Multiple sources were consulted to retrieve the data for this research.

3.2.1. Firms

Operationalization firms

In scientific research, patents have been analyzed to measure the amount of innovation in a region (Lee, Florida & Gates, 2010), but also to regionally measure the level of human capital (Ge, Huang & Png, 2016). Using green patent registrations to analyze green technology and green innovation overall is ever more being used in order to help move the economy to green production modes (Jinqian & Chong, 2015). It is a quantitative way to measure the level of innovativeness in the green sector. These patent registrations, or innovation output, can be seen as experience and so patent registrations will be the measure of experience output of firms in the region. Absolute and relative numbers of green- and non-green innovations are being used to get an idea of the state of the green innovative sector in the cleantech regio. The cleantech regio consists of the NUTS-3 regions Veluwe (NL221), Achterhoek (NL225) or Zuid West Overijssel (NL212) and whether or not an innovation is green is defined by their patent class: IPC-class Y02 encapsulates green innovations. This class is called Climate Change Mitigation Technologies.

In the literature review, certain training, regulations or subsidies have proven to be effective in raising the green innovativeness of firms. Current years' agendas of VNO-NCW Midden and Circles will fully be gone through and discussed. When items are recognized as stimulating for green innovativeness, according to the literature review, these items will be highlighted and a link is made to the scientific literature. Some of those highlights are presented as quotes in the results section. Expected effects of the agenda items on green innovativeness, according to scientific literature, will be the conclusion of the exploration.

Data collection firms

To measure the regions' firm side input in regional experience, I collected data on registered patents. Registered patents can be found in databases, categorized by the region in which the inventors reside. The OECD REGPAT Database (2021), which includes these patent registrations, has been downloaded. This database contains many variables. For this research

the following variables are used: the NUTS-3 region of residence of the inventors, the years of registration and the IPC classes of the invention. In this research, I have selected patents from 2010 onwards. This choice is made because the ambitions for cleantech innovations in the region started in 2013 (Strategische Board Stedendriehoek, 2016). With data from 2010, the trend prior to these ambitions can also be taken into account. Because of the delay in the registration of patent applications, 2018 is the most recent year that has a complete overview of the registered patents, while 2010 also seems to consist of incomplete data. Furthermore, this research focuses on the regional and national, which is why only patent registrations with at least one inventor from the Netherlands is taken into account.

The patent registrations paint a picture of the regional experience, but firms also provide training. To collect data on this, agendas of two entrepreneurs' organizations are consulted. VNO-NCW Midden is the regional entrepreneurs' organization of Utrecht, Flevoland, Overijssel, and Gelderland, who organize training events like workshops for local entrepreneurs. Branched off from this organization is Circles, an organization on a lower scale, only eastern Netherlands, which focuses on circular entrepreneurship. Both the organizations publish agendas of their activities, which will be consulted to explore their training activities.

Constraints patent data

There are some constraints in using the patent data in this research. First, as mentioned, NUTS-3 regions are used in the registration, which transcend the cleantech regio. The geographical boundaries of this research transcends NUTS-3 regions and the cleantech regio consists of parts of NUTS-3 regions. Data about the municipality or town of residence of the inventor would yield more precise results about experience in the cleantech regio itself. Furthermore, a limitation of this research is that there is no indication of the importance of the specific patents: it could very well be that one year has little patent registrations, but the inventions are very important in further innovations. To include this, a network analysis would have to be conducted, but due to constraints this will not be done in this research. Lastly, not all innovations are patented. In some sectors firms patent more than others, varying between 8.1% in textiles and 79.2% in pharmaceuticals (Arundel & Kabla, 1998). To get a full scope of a regions' innovations, data on every firm has to be collected. This is unfeasible for this research, making patent analysis the best method to inventorize regional innovations.

3.2.2. Knowledge institutions

Operationalization knowledge institutions

The relative number of graduates from tertiary schooling institutions will have a positive effect on the innovativeness of a region, while secondary schooling helps as well (Chi & Qiang, 2010). But, to reach innovation specifically in the green sector, especially green human capital seems important (Cheng & Chang, 2013). For this reason, first the numbers of the tertiary schooled population will be looked at. CBS publishes these numbers in categories per municipality: low-, middle- and highly educated. In this research, the middle- and highly educated population is important, as these categories include the population with a degree from: a university, a HBO, MBO levels 2, 3 and 4 and the middle school levels HAVO and VWO. These include the highest levels of secondary schooling and all but the lowest levels of tertiary schooling. Absolute and relative data on this population will be explored per municipality. After this overview of the middle- and highly schooled population of the cleantech regio, the research will focus on the tertiary educational programs themselves. With the collection of 'green educational programs', as described before, an overview will be made per

knowledge institution about to what extent they offer green educational programs. The knowledge institutions can be compared on their share of available green educational programs. The descriptions of the green educational programs will be expanded upon, by exploring the courses and goals and linking this to what the literature review concludes as favorable actions towards green innovation.

Data collection knowledge institutions

To analyze the overall education levels, CBS data is used. This data contains, per municipality, the total population from 15-75 years old and divides them into three categories: low, middle and highly educated. Data is collected for the timespan of 2010 - 2019, which includes the years before the creation and up until the complete data.

Furthermore, to make an inventorisation of all available tertiary educational programs in the region, the websites of the relevant schools are consulted. The tertiary knowledge institutions in the region can be found in paragraph 4.2.2. of the results section, table 4. These educational programs have been explored and a selection is made of those relevant to green innovation. On the websites of these schools, all educational programs that they offer can be found, including their descriptions. Educational programs that are considered 'green human capital creating' at least consist of following keywords, or anything closely related: 'green innovation', 'cleantech', 'green energy' or 'climate change'. These educational programs will be subject to further exploration, for example by looking at the offered courses. Educational programs or classes that take 1 year or less will not be considered in this analysis, as this would have relatively minor effects on the green human capital creation compared to full educational programs and the time constraints for this research.

3.2.3. Governments

Operationalization governments

The goal of analyzing the documents is to find out how organizations and governments aim to improve the green innovativeness or green human capital in the region. To reach this goal, the documents will be read thoroughly. With the scientific research from the literature review in mind, parts of documents that indicate measures promoting green human capital enhancement will be highlighted. The findings will be shown in the results section as a summary of the key elements. The results section will briefly conclude the favorable or unfavorable policies regarding green human capital creation or green innovativeness. A more detailed analysis will be conducted in the discussion chapter.

Certain concepts came forward in the literature review which are deemed important for green human capital creation or green innovation. First of all, the most important elements of human capital are education, training and experience (Mubarik et al., 2018). The sub-dimensions of table 1 describe what elements are looked for when studying the documents. Secondly, the implementation of a triple helix is important for creating human capital (Etzkowitz & Zhou) and even more important for green human capital (Kiryushin, 2013), in which governments should take on a strong role (Brem & Radziwon, 2017). Policies indicating that the government is trying to bring together the triple helix in favor of the green sector are also highlighted. Thirdly, in paragraph 2.4 all the traditional links between triple helix actors have been described. When these tasks are spotted in policies, they will be highlighted as well. Fourthly, geographical closeness of firms is also beneficial for green innovativeness (Díez-Vial et al., 2022), so

clustering is also deemed an important element. Lastly, external sources also have positive influence on the green innovation of an area (Laursen & Salter, 2006; Owen et al., 2018), which is why external influences like investments are also looked for.

Data collection governments

The governments' influence on the triple helix is mainly a funding and governing one (Etzkowitz & Zhou, 2017). Training is provided by firms and education, but the government and entrepreneurial organizations have a strong role in setting goals and providing financial means like subsidies to reach set goals (Etzkowitz & Zhou, 2017; Lerman et al., 2021). Such close cooperation with governments is desired in green technology (Chapple et al., 2011). It needs to be explored how they fund and govern by collecting documents describing this process. Many policy documents have data on the cleantech goals and economic goals overall and in their plans steer towards training of human capital. Budget reports of governments can reveal how much money is spent on increasing human capital in cleantech. Before these documents are collected, the selection of governments that are going to be explored is key. This is because the region consists of differently sized municipalities with varying financial contributions to the Cleantech Regio. Some municipalities pay relatively little contribution, making their influence on the policy also limited. For the choice of municipalities, table 2 is consulted.

Municipality	**Contribution**
Apeldoorn	475.474
Deventer	292.642
Zutphen	139.052
Lochem	98.130
Epe	95.971
Voorst	71.687
Brummen	60.354
Heerde	54.275
Total	**1.287.583**

Table 2: *Financial contribution to Cleantech Regio in euros in 2022 (Cleantech Regio, 2021a)*

With this table it becomes evident that there are big differences in contributions from municipalities towards the organization Cleantech Regio and their goals. I will explore only the three largest municipalities, Apeldoorn, Deventer and Zutphen, because of their share of financial contribution and research constraints. Also, I will analyze an outdated document from the collective of municipalities, to shine a light on prior goals and ambitions. Furthermore, the agendas, documents and other sources of intermediary organization Cleantech Regio are also included in the data. The documents are collected by consulting the websites of the actors, after which the documents are deemed interesting when they have to do with budgets, economic choices or future goals. With these parameters, most if not all documents which have to do with enhancing green innovativeness or green human capital are expected to be

collected. Certain economic policy choices described in other documents will be missed. However, the chosen documents will be most relevant for the research and it is more efficient to focus on these. The yearly overviews of VNO-NCW Midden and Circles are included in table 3, as these are also documents that are going to be collected.

Municipality or organization	**Document**
VNO-NCW Midden	Jaaroverzicht 2021 (VNO-NCW Midden, 2022)
	Project website (VNO-NCW Midden, n.d.)
Circles	Support website (Circles, 2022)
Cleantech Regio	Begroting 2022 (Cleantech Regio, 2021a)
	Jaarstukken 2020 (Cleantech Regio, 2021b)
Apeldoorn	Meerjarenprogrammabegroting (Gemeente Apeldoorn, 2022a)
	Woest Aantrekkelijk Apeldoorn (Gemeente Apeldoorn, 2022b)
	Visie Citymarketing Apeldoorn 2025 (Apeldoorn Marketing, 2020)
	Ambitiedocument Apeldoorn 2040 (Gemeente Apeldoorn, 2020)
Deventer	Begroting 2022-2025 (Gemeente Deventer, 2021)
	Duurzame Mobiliteit Deventer, Uitvoeringsplan (Keypoint Consultancy, 2018)
	Energieplan Deventer (Gemeente Deventer, 2020)
	Voortgangsrapportage DEVisie2020 (De Kopgroep Economie en Arbeidsmarkt, 2016)
	Uitvoeringsagenda economie en internationaal beleid 2019-2022 (Gemeente Deventer, 2019)
Zutphen	Programmabegroting 2022 - 2025 (Gemeente Zutphen, 2021a)
	Economische visie en ambitie gemeente Zutphen (Gemeente Zutphen, 2021b)
Apeldoorn, Brummen, Deventer, Lochem, Voorst, Zutphen	Regionale Structuurvisie Stedendriehoek 2030 (Gemeente Apeldoorn, Brummen, Deventer, Lochem, Voorst, Zutphen, 2007)

Table 3: *Documents regarding cleantech ambitions*

3.2.4. Operationalization table

So far, theory is discussed in which certain important dimensions came forward regarding green innovation. How to measure these has been discussed in the current chapter, including which actors influence the dimensions. Below, an operationalization table is included to serve as an overview of how and why these dimensions are measured. It should be noted that governments have a governing and funding role in each dimension, but are not included in the actor column, as they improve the dimensions indirectly with policy, executed by firms and knowledge institutions.

Dimension	**Actor**	**Operationalization**	**Data, coverage, data type**	**Indicator**
Experience	Firms	Patents can be used to measure the level of innovation and human capital creation in an area. This prior knowledge output can be seen as experience.	OECD REGPAT Database (2021). Years: 2010 - 2018 Quantitative	Compare relative and absolute amount of cleantech patents in the cleantech regio with national levels.
Education	Knowledge institutions	Tertiary education is very important in enhancing innovative power.	CBS education levels per municipality (2020). Years: 2010 - 2019 Quantitative	Visualize the relative numbers of middle- and highly educated people per municipality.
		Green human capital especially leads to green innovation, so green educational programs are desired.	All educational programs provided by local tertiary knowledge institutions as published on their websites. Year: 2022 Qualitative	Tally educational programs with cleantech components and examine these.
Training	Firms Knowledge institutions	Governments and organizations incentivize training executed by the firm and knowledge side, by subsidizing and influencing policy.	Official policy documents, budget reports and other, as described in table 3. Years: 2007 - 2022 Qualitative	Examine the goals and resolutions stated in the documents which have to do with green human capital creation according to the theory, as described in paragraph 3.2.3.

Table 4: Operationalization table

3.3 SWOT-analysis

With all of the above, a quantitative assessment is given of the green human capital and cleantech innovativeness of the cleantech regio. Because of the extensiveness of the results, a SWOT-analysis will be made to conclude the results. In such figures, strengths, weaknesses, opportunities and threats of the regions' green human capital creation and green innovative capacity are exhibited. A SWOT-analysis is a framework to evaluate a competitive position (Kenton, 2022), which is why it is a good way to use in this research regarding the competitiveness of a regions' innovativeness. Measuring competitiveness is most ideally done in comparison to other regions. However, because only the cleantech regio is explored in this research, the analysis focuses on the strengths, weaknesses, opportunities and threats of only this region. In the model, the strengths are what the region currently excels at, while the weaknesses are what is stopping the region from performing at optimum level (Kenton, 2022). Opportunities and threats are respectively the potential favorable factors a region could acquire or the potential factors that could harm the region. The SWOT table will act as a summary of the complete results section.

4. Results

In this chapter, the methods from the previous chapter are carried out and the outcomes are presented. These results form the foundation for answering the last two sub questions and eventually the research question. The structure of the results section follows the operationalization in table 4, meaning that the chapter first discusses the regional patent registrations, then the tertiary schooling and the green educational programs are explored and lastly the important data from the documents in table 3 is highlighted and linked to scientific literature.

4.1 Experience

To measure the experience in the region, regional patents in the IPC class Y02 from 2010 onwards have been gathered. Figure 2 provides a visual representation of the absolute trend in cleantech patents in the Cleantech Regio.

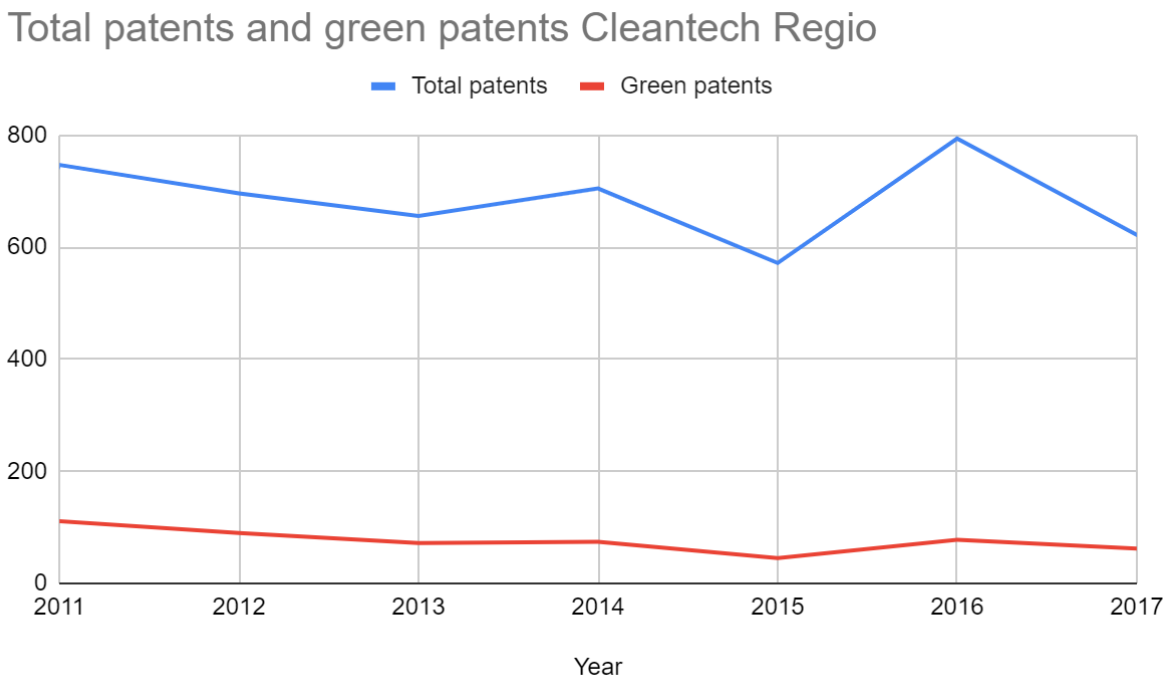

Figure 2: Absolute number of patents and green patents in the Cleantech Regio per year (OECD, 2021)

Firsty, it is to be noted that in the data, the years 2010, and 2018 are incomplete. Because of this, statements about absolute numbers in these years can not be made, while statements about relative numbers are also less reliable, if not unreliable. Because of this, focus will be on the numbers for 2011 - 2017 in the patent section of the research. Furthermore, in the graph it becomes visible that the total number of patents stays somewhat the same: between 2011 and 2017 the number fluctuates between nearly 600 and nearly 800. The years with the highest number of patents are 2016 and 2011 with 794 and 747 applications respectively. So, there is no clear trend in the amount of patents and green patents in the cleantech over the years.

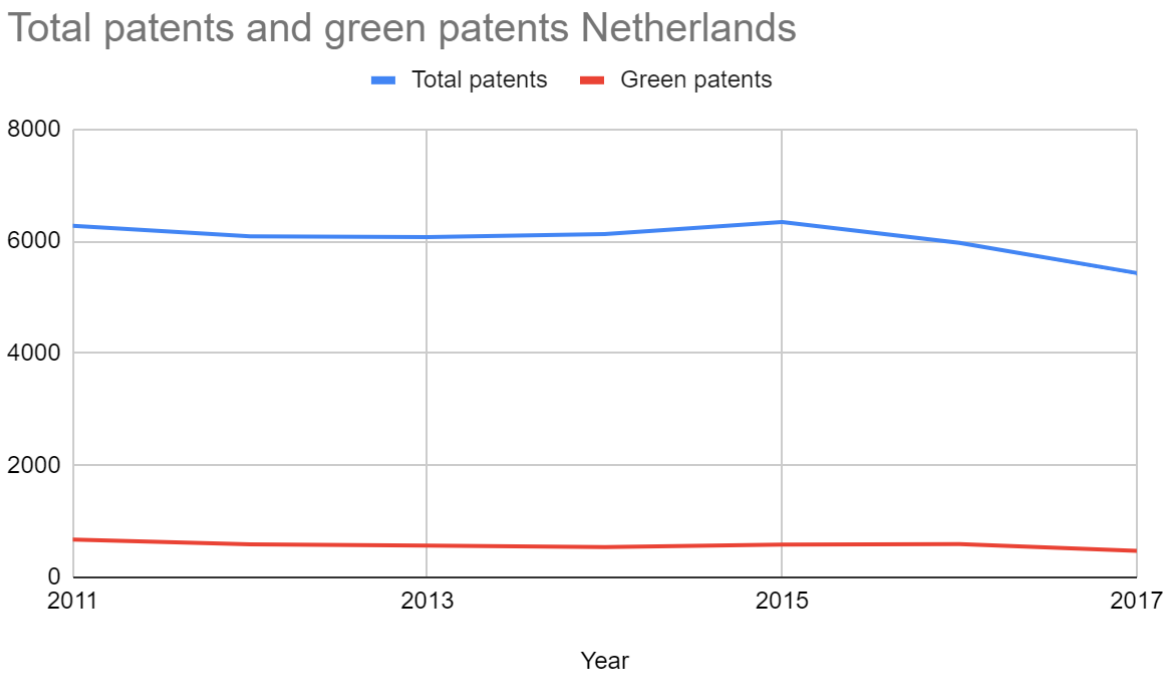

Figure 3: Absolute number of patents and green patents of the Netherlands per year (OECD, 2021)

Just like the regional absolute patent numbers, the national number of registered patents overall and in the green sector are relatively stable over the years. However, the number of registered patents does seem to dip in 2016 and 2017. The relative amount of green patents should be consulted to make a statement about green experience in the region and the country.

The total patents in the region tell a story about the experience overall, but the relative amount of patents in cleantech is more useful to find the relative experience in green technology. Figure 3 visualizes the relative number of patents in IPC class Y02 compared to the total number of patents in the Netherlands as a whole and in the NUTS-3 regions of the Cleantech Regio.

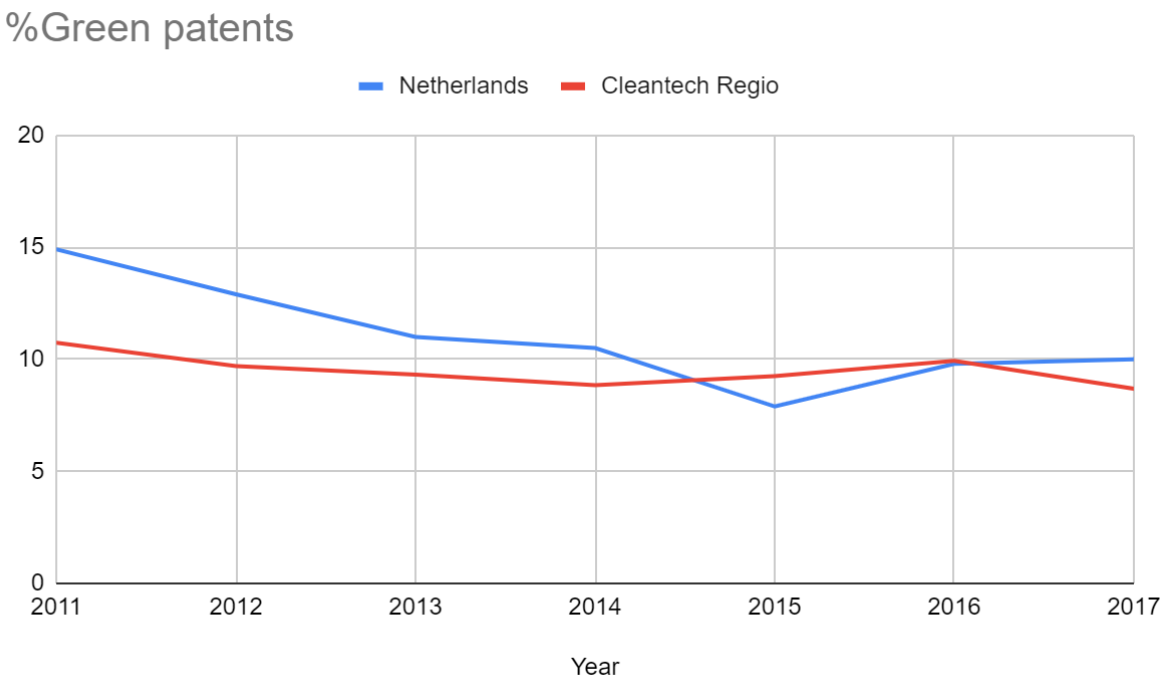

Figure 4: Relative amount of green patents in the Netherlands and Cleantech Regio per year (OECD, 2021)

Looking at figure 4, it is visualized that the Cleantech Regio is an underperformer in their share of green patents in the first few years. But, the share of green patents on the national scale reduced quicker than in the Cleantech Regio, causing the Cleantech Regio to overtake the national score in 2015. After this, in 2016 and 2017, the relative amount of national green patent registrations increased again, once again surpassing the Cleantech Regio, which has had a quite stable share of green patents through the years. So, to conclude, the Netherlands overall had years in which they had a high share of green patenting, after which the numbers plummeted and these numbers seemed to restore in 2016 and 2017. The Cleantech Regio overall has a stable share of green patent registrations over the years, rarely outperforming the nationwide share.

Conclusion

A growth of the share of green patents would mean that the economy moves towards green production modes, paired with an increase in green innovation (Jinqian & Chong, 2015). The lack of growth in the share of green patents indicates that this move to green production modes in the regional economy is not being made, thus indicating that green innovativeness also has a small chance of being viable in the near future.

4.2 Education

To measure education, the highest attained education and the local education programs in tertiary schooling institutions have been examined.

4.2.1. Overall education

First off, to get a deeper understanding of the overall education level, and indirectly the innovative capacity of the region, the relative amount of middle- and highly educated

inhabitants per NUTS-3 region and municipality are visualized in figures 5 and 6, with the data to be found in appendices 1 and 2.

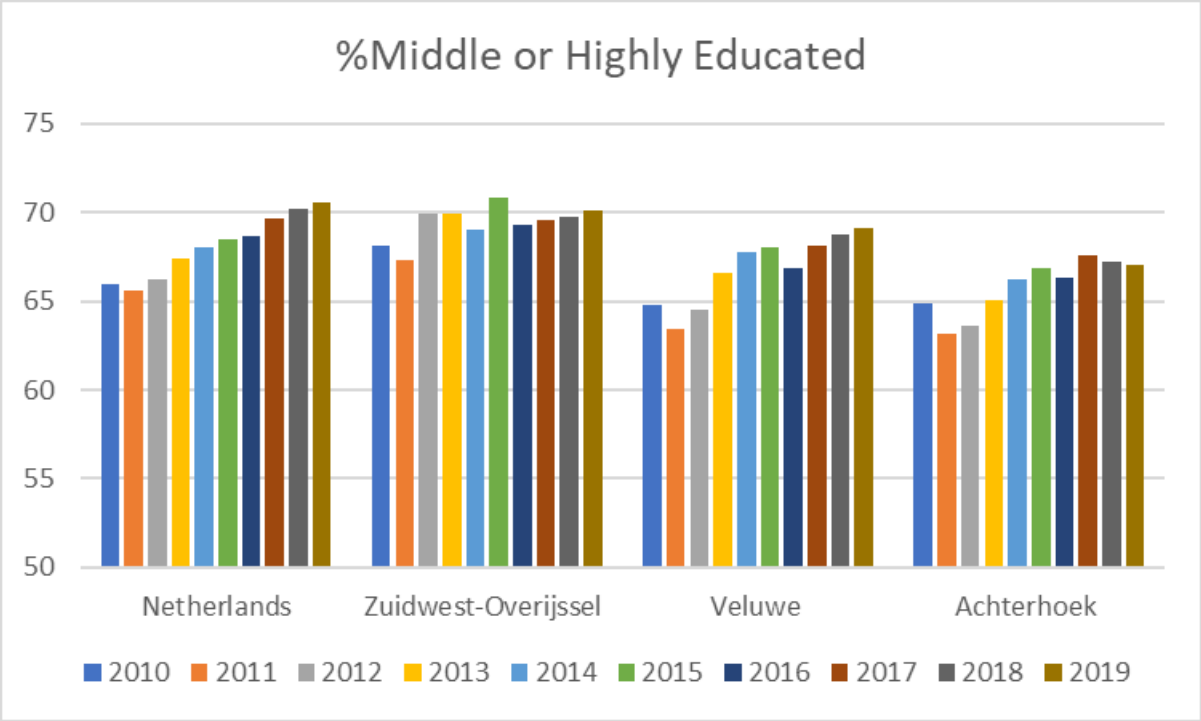

Figure 5: Percentage of middle- or highly educated 15-75 year olds per NUTS-3 region per year (CBS, 2020)

The data in figure 5 starts with a visualization of the percentage of middle- or highly educated population of the 15-75 year olds of the Netherlands. In all of the Netherlands, a steady increase can be found in the percentage of middle- or highly educated people: from 66% in 2010 to 70,6% in 2019.

Zuid-West Overijssel shows an increase in their share of the middle- or highly educated population, although this increase is below average. The NUTS-3 region had a well above average share of this population in the first years of the graph, but now seems to be around the national average.

The trend of Veluwe is comparable with the national trend. With a steady increase of the middle- or highly educated population, Veluwe is getting smarter by the year. However, Veluwe has always been slightly below the Dutch average in this statistic.

Achterhoek has also seen an increase in this statistic. However, the most recent years, the share of middle- or highly educated people in Achterhoek is not rising anymore, solidifying what has been the case for at least since 2010: that Achterhoek is below the Dutch average in this particular statistic.

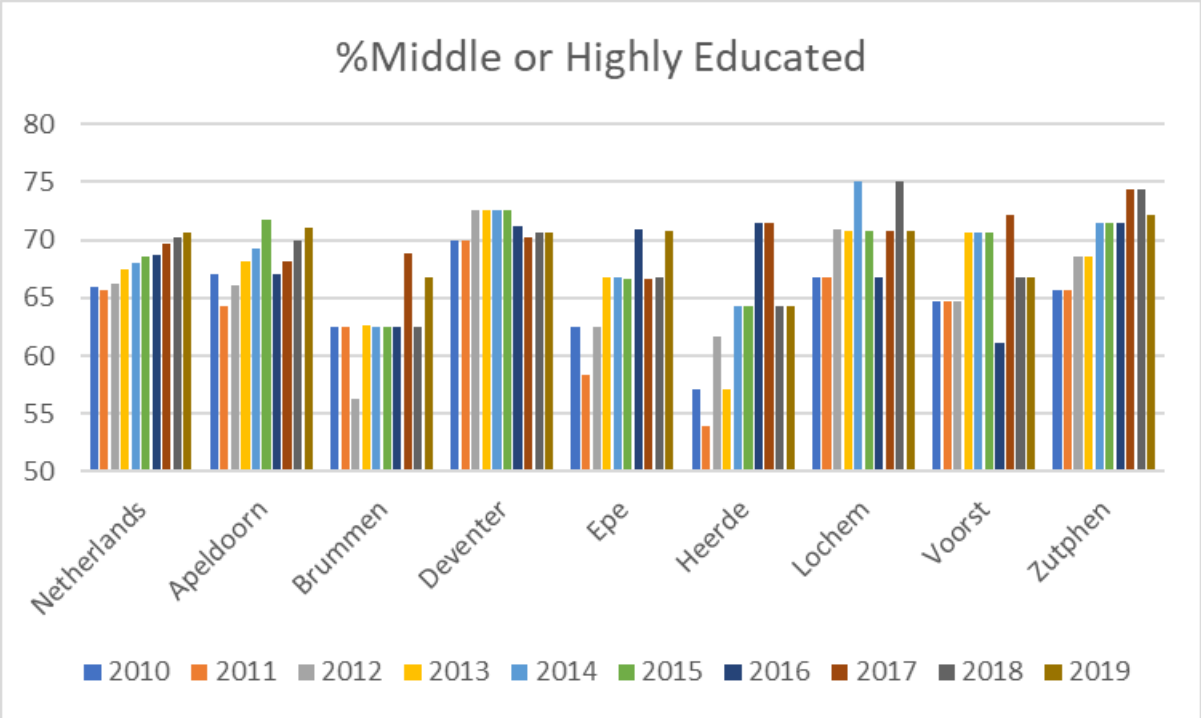

Figure 6: Percentage of middle- or highly educated 15-75 year olds per municipality per year (CBS, 2020)

The individual municipalities in the region do not all follow the same trends.

Apeldoorns' numbers show an increasing trend over the years. Some years have relatively more middle- or highly educated people than other years, but overall it seems like Apeldoorn slowly gains some middle- or highly educated people over the years, with percentages comparable to the national average.

Brummen has quite steady numbers in their middle- or highly educated population. For years, the percentages stayed about the same, apart from one outlier, and in most recent years the percentages seem to rise, but they still fall behind on a national level.

Deventer is, just like Brummen, also quite consistent. The difference between the two is that Deventer has a higher percentage of middle- or highly educated population overall. Deventer was for years above the national level in this category, but seems to have stagnated while the national average caught up.

Epe is one of the municipalities that showed an increase in their relative number of middle - or highly educated population. The first years of this graph, the municipality scored well below the national average, but after a few years they caught up and in the most recent years they touched upon the national average.

Heerde shows peculiar numbers. This municipality scored the lowest of all in the first years, after which they recovered strongly and in most recent years their numbers of middle- or highly educated population fell down again. So, although at one point they were above average on a national level, they are well below this average in recent years.

Lochem shows volatile percentages over the years. They went from below the national average to above multiple times, ending up around the average in 2019.

Voorst also has quite volatile numbers. The municipality scores just below the national average in about half of the years, but also goes above in multiple years. There is no clear trend to be found in this.

Zutphen does have a visible trend. They seem to follow the national upwards trend, ending up just above the Dutch average.

To summarize, of the greater NUTS-3 regions, Zuid West Overijssel is the only region with an above average share of middle- or highly educated people, while the other two regions score below average. There are also a few municipalities that catch the eye. Zutphen is overall the strongest municipality, with a positive trend and the highest percentage of middle- and highly educated people. The other big cities of the region, Apeldoorn and Deventer, can also at least compete with the national average. The other municipalities do have slightly positive trends, but score below the national average, except for Lochem. Lochem also has relatively many middle- or highly educated inhabitants.

Conclusion

According to the literature, having a population with tertiary education is very important in innovating (Chi & Qian, 2010), and even positively influences green innovative capacity (Hsu et al., 2021). The NUTS-3 region Zuid West Overijssel and the big cities are about the national average or even slightly above that in tertiary education numbers, which makes them promising places for future green innovations according to prior scientific literature. The other regions and cities will be less likely to innovate in this sector, because of their lower share of tertiary schooled population (Chi & Qian, 2010; Hsu et al., 2021).

4.2.2. Tertiary education

To create an understanding about the tertiary educational programs in the region, table 5 presents the number of educational programs offered in the region.

School	**Total educational programs (full- and part-time)**	**Total climate-oriented educational programs**	**% climate-oriented**
Saxion Deventer	58	1	1,7
Saxion Apeldoorn	4	0	0
Hogeschool Wittenborg	24	1	4,2
Theologische Universiteit Apeldoorn	3	0	0
Aventus Apeldoorn *Laan van de Mensenrechten*	126	0	0
Aventus Apeldoorn *Musschenbroekstraat*	12	0	0
Aventus Apeldoorn *Edison College*	3	0	0
Aventus Apeldoorn *Sleutelbloemstraat*	7	0	0
Aventus Apeldoorn *Boogschutterstraat*	2	0	0

Aventus Apeldoorn *Newtech Park*	2	0	0
Hoornbeeck College	67	0	0
Aventus Deventer *Schonenvaardersstraat*	39	0	0
Aventus Deventer *Snipperlingsdijk*	29	0	0
Aventus Deventer *Middelweg*	20	0	0
Aventus Deventer *Handelskade*	3	0	0
Zone.college Deventer	3	0	0
Aventus Zutphen *Stationsplein*	10	0	0
Aventus Zutphen *Dreef*	9	0	0
Aventus Zutphen *Industrieweg*	6	0	0
Total	**427**	**2**	**0,5**

Table 5: Tertiary knowledge institutions in the Cleantech Regio

From the table it can be concluded that, although the absolute amount of available educational programs in the region is quite substantial, the relative amount of educational programs focused on cleantech is very limited. Only 2 of the 427 educational programs , or about 0,5%, have a focus on green energy. These are *Klimaat en Management* (climate and management) at Saxion Deventer and a master of business administration (MBA) with a specialization in clean technology management at Hogeschool Wittenborg.

Conclusion

According to prior research, to innovate in the green sector, education in this sector is very important (Cheng & Chang, 2013; Hsu et al., 2021). Tertiary education in this sector boosts the innovative system and will cause an increase in green patent registrations and more focus on environmental policy (Hsu et al., 2021). So, the relative amount of green patents below average in the Cleantech Regio over the past decade. Furthermore, it does not seem likely for the share of green patent registrations within this region to significantly increase over the next few years, judging solely on their supply of tertiary education.

4.2.3. Local cleantech educational programs

As mentioned previously, there are two tertiary educational programs focused on cleantech in the region. These educational programs will be expanded upon.

Klimaat en Management is a four year period during full-time study, including an internship and minor in the third year and a so-called ‘mastertrial’ in the fourth year (Hogeschool Saxion,

n.d.). The first two years are fixed with courses, projects and training. Some of the courses are ‘sustainable society’, ‘thinking about and working towards climate solutions’, ‘energy transition’, ‘climate adaptation’ and ‘circular economy’. Projects that are carried out are for example 'climateproof city’ and ‘futureproof city 2050’. Skills that are being trained have more to do with the management side of the study, with courses about communication, problem analysis and intercultural awareness. This base knowledge is put to the test with a minor, internship and the master trial as end assignment, which can be filled in more freely and do not necessarily have to do with cleantech knowledge, but can also be more managerial. Fitting professions after this study can be *climate director* at government instances, informant for sustainable energy or developer at energy companies.

The MBA with a specialization in clean technology management at Hogeschool Wittenborg is an eighteen month full-time study which comes forth from an international initiative (Hogeschool Wittenborg, n.d.). The United Kingdom, Ireland, Belgium and the Netherlands work together in a project that *‘sought to encourage SMEs and collectives of SMEs to develop and apply sustainable technological solutions related to Renewable Energy, Smart Grid and Distributive Generation.’* So, governments encourage firms to strive for sustainable development, while including Hogeschool Wittenborg as a knowledge institution in the project. Hogeschool Wittenborg offers training to local enterprises, which completes the triple helix. The aim of this project was ‘*to collect and supply information regarding economic and institutional aspects of decentralized energy networks and smart grids, and it also provided an assessment of the institutional and regulatory landscape.’* This project, because of its embeddedness in society, will make entrepreneurs and businesses move towards running a sustainable, socially-responsible, and energy efficient business.

The first semester of the study is filled with six management courses about among other things human resources and marketing. The second semester focuses more on the cleantech part, with the courses ‘smart grids’, ‘renewable energy: solar, wind and hydro’ and ‘Zero-Energy Buildings and Energy Transition’. In the third semester, the knowledge will be applied in a final project. After the study, there are no specific possible workfields mentioned by Hogeschool Wittenborg, just that career prospects overall increase.

<u>Conclusion</u>

So, especially the Hogeschool Wittenborg education implements the triple helix cooperation, while Saxion’s education also implements the firm side with a mandatory internship. Collaborating with the firms in this manner leads to the birth of innovative achievements (Bektaş & Tayauova, 2014) and also the government interference leads to a linear model of innovation (Etzkowitz & Zhou, 2017). Furthermore, the fact that the courses are very much green oriented enhances green innovation (Cheng & Chang, 2013). With this knowledge, green structural- and intellectual capital (Agyabeng-Mensah & Tang, 2021) will be increased in the region, also positively affecting green innovation (Ali et al., 2021; Wan & Juo, 2021). According to scientific literature, the way these courses are set up should have a positive effect on future green innovation, but once again: the region only offers two of those courses.

4.3 Training

The knowledge institutions provide training (Etzkowitz & Zhou, 2017). Furthermore, the firms take part in training the population and the government also plays a role.

4.3.1. VNO-NCW Midden

To explore ongoing projects in the entrepreneurial organization VNO-NCW Midden, the yearly overview in the form of an infographic and the project website are important to analyze.

Firstly, the project website names 5 ongoing projects (VNO-NCW Midden, n.d.): perspective on work, Circles, on to 100.000 jobs, technical days and energy saving. On to 100.000 jobs is deemed irrelevant for green human capital creation, because it focuses on integrating handicapped people into the labor market, which could have an effect, but is not focused on the cleantech sector per se. Also, although Circles is a VNO-NCW Midden initiative, it is a quite sizable organization, which is why it will be explored later on. Furthermore, technical days is an initiative carried out outside of the Cleantech Regio, which is why it is also irrelevant for human capital creation in this region.

Perspective on work is an initiative derived from the idea that a lot of people want to work, but can't find their way to the labor market (VNO-NCW Midden, n.d.). Two financial injections of a million euros each have been done in 2019 and 2020 with the goal of reducing the distance between the unemployed and the labor market. This money has gone towards 'retraining of workers, regional action plans, the sharing of learning experiences and broadening the applicability of successful methods.' All in all, the financial resources reportedly led to a closer interaction between governments, entrepreneurial organizations and knowledge institutions, working together to reach the societal goal of reducing unemployment rates.

Energy saving is a project with the intent to help entrepreneurs make their business more sustainable (VNO-NCW Midden, n.d.). Entrepreneurs can get up to 25.000 euros subsidy for sustainability purposes. This stimulates the energy transition in the region and possibly indirectly has an effect on the innovativeness in this sector by the rising demand for sustainability, but in a direct manner there seems to be no human capital creation from this project.

<u>Conclusion</u>

The VNO-NCW is an organization closely collaborating with firms, providing resources like funding where it is deemed needed. These actions reportedly strengthen the triple helix and provide training.

4.3.2. Circles

Circles, a branch of VNO-NCW with special focus on circularity, offers nine support events for local entrepreneurs (Circles, n.d.). Below they are explored one by one.

First off, Circles organizes three-day workshops for entrepreneurs in which they are taught to design a circular business plan. The first day, the entrepreneurs explore their own business chain and its chances for circularity. On the second day, the most promising proposition will be worked out, the entrepreneurs design their businesses' road maps on the third day to move towards a circular business climate. So, there is a lot of focus on the

individual entrepreneur, who is being taught the basics of circularity and sustainable business operations.

Circles also offers workshops called ‘purchasing circularly’. In this one day workshop, local entrepreneurs are introduced to a new method for purchasing their goods. This way, the focus will be less on price, but more on their sustainable ambitions. The idea is that the contractor and client will find each other based on ambitions. So, in short, this workshop reduces the difficulty for local entrepreneurs to work sustainably.

‘Challenges and solutions’ is the next offered event. Students from the HAN Hogeschool, Saxion Hogeschool and Wageningen University support entrepreneurs in their sustainability challenges by for instance advising about social innovation, design for disassembly and re- and upscaling. This takes form, for the students, as a project, internship or graduation assignment, linking the scholars to real world problems. This way, both parties profit.

The next support Circles offers is more of a service called ‘service and partnerships’. Circles offers their network of entrepreneurs and experts. Local entrepreneurs who struggle with for instance CO2 reduction or using sustainable resources can get support through this service. Also, an online platform for these entrepreneurs has been set up by Circles.

‘Closing chains’ is the next support offered, which revolves around a programme called AcCElerator. This programme, intended for production companies and business parks, will work towards a structural solution regarding closing the resource chains. By offering companies and business parks the tools, they can work towards a sustainable future by themselves.

Circles also supports ‘circular revenue models’, helping businesses move from a traditional business model to a circular one. With the help of creative sessions, bottleneck analysis, stakeholder consultations and more, businesses learn how to close their resource cycle and how to set up a new, circular business model.

Furthermore, CIrcles also makes a budget available for supporting businesses initiating circular business models. Three types of financing are available from Circles: a participation, in which Circles buys a share of the business, loans, and public finance. Each business model is evaluated individually to determine the right type of financing for that business.

An ‘organization scan’ is the next thing Circles offers. This online tool helps in the first steps towards circularity: identifying problems and bottlenecks. Middle- and small businesses can benefit from this 30-question survey by weighing not only their financial and sustainability values, but also natural, social and intellectual values among others.

Lastly, Circles organizes workshops called ‘exchanging resources, energy and ideas with other sectors’, where businesses from different sectors get together for an intensive four hours of idea sharing. It is claimed by Circles that surprising collaborations come forth from these sessions.

<u>Conclusion</u>

Circles takes on a strong leading role in organizing workshops that act as education or training. All actors of the triple helix are named and Circles tries to bring these actors together, all the while promoting circularity. Creativeness and innovativeness are other key elements in the programme.

4.3.3. Cleantech Regio

The intermediate organization Cleantech Regio has two relevant available documents to explore how they try to increase green innovation. With their overall yearly report (Cleantech Regio, 2021b) and budget report (Cleantech Regio, 2021a) from 2020, a conclusion can be made about the extent to which the organization facilitates a green innovation climate. Before this, the 'Structuurvisie' of the region from 2007 is explored briefly.

Structuurvisie 2007

The 'Structuurvisie Stedendriehoek' from 2007 described the region's vision for the future (Gemeente Apeldoorn, Brummen, Deventer, Lochem, Voorst, Zutphen, 2007). This document puts the emphasis on the agricultural sector of the region, with the countryside being a widely discussed subject. Innovation is pursued, albeit mostly in the agricultural sector and not per se in circularity, as the region strives to reach nowadays. But, agricultural innovation would not only be aimed at increasing efficiency, sustainability is also subject in this innovation, laying the foundation for what would become a bigger theme in later years. In 2007 the region already acknowledged that sustainable development would be the futureproof way to go in this sector, making technological innovation a priority. Aside from this, there is no mention of innovation to make the region more green technology-wise.

Yearly report 2020

First of the Cleantech Regio documents, the overall yearly report of 2020 is explored (Cleantech Regio, 2021b). Alderman Economy of the municipality Apeldoorn starts off by claiming 2020 was an exceptional year for the regional cleantech sector. The biggest accomplishment was the *Regio Deal*, which was a deal that took the regional collaboration between government, firms and knowledge institutions a step further. Furthermore, the housing agenda, sustainable working locations, regional energy strategy and the enhancement of regional mobility are pointed out as successful projects. The implementation of a regional energy strategy is especially influential for the future of the regional green human capital. The deal, consisting of 26 sustainability, economical projects, has received an investment impulse of 100 million euros, of which just over 5 million euros comes from the municipalities.

"The Strategic Board pulled off the Regio Deal in February 2020. A fantastic success which allows municipalities, entrepreneurs and education to work together on innovative projects and developments." (Cleantech Regio, 2021b)

The two action lines that are to be followed in the Regio Deal are 'cleantech works' and 'green growth' (Rijksoverheid, 2020).

First, cleantech works consists of three programs (Rijksoverheid, 2020). The programme 'matching and mobility' puts a central focus on matchmaking, career switches, education and coaching. This should lead to an increased influx of workers in technical- and ICT sectors, a decrease of people on welfare aid and an increased labor mobility. The programme 'place for technique' aims to create creative technical hubs, which will lead to knowledge- and innovation hotspots. More influx of workers in the technical sector and more innovation in business and education is the desired result. Lastly, the programme 'rich learning region' focuses on creating new learning styles in the region. Learning places should focus

more on developing new skills. Easier inflow into studies and better training are desired results.

"The Cleantech Regio as a triple helix collaboration provides a steady base. It leads for example to cooperative work of education and entrepreneurs on R&D and innovation" (Rijksoverheid, 2020)

Secondly, green growth is also an action line with three programmes (Rijksoverheid, 2020). The first one, 'innovative energy systems', helps businesses convert to new, more sustainable energy systems, with more used energy from hydrogen, restwarmth and biogas as a desired outcome. 'Futureproof business parks' is the next programme, which makes sure that the big business parks of the Cleantech Regio are ready to house businesses in the long term. Results from this programme should be strengthening the organizations within the business parks, setting up a roadmap for sustainable electricity and creating circularity. Thirdly, the programme 'circular businesses' follows the idea that circularity will lead to economical and ecological profit. By stimulating circular innovations, a whole new economic branch will be created in the region, with available knowledge production. On the one hand because entrepreneurs are urged to share their newly found knowledge and experience with the region, on the other hand because as a direct effect of this programme Saxion will teach a minor in circular industry.

"[The programme circular businesses] leads to the following results: eight to ten businesses are supported in their circular innovations … As a return of investment the entrepreneurs have to share their new knowledge and experience with regional SME's. (Rijksoverheid, 2020)

Conclusion

As a traditional agricultural region, the Cleantech Regio changed its course to innovation in the green sector. The Regio Deal is the biggest accomplishment thus far, focusing greatly on the regional triple helix. The allocation of resources in the form of funding is discussed and governments govern firms with their programmes. Innovative spots are created for human capital creation by these firms and quotas are set for reaching a higher sustainable energy production. Knowledge creation is implemented in the business side of the plans and even middle school youth are being involved in the process.

Budget report 2020

The budget report of the Cleantech Regio is also divided into programmes (Cleantech Regio, 2021a). The budget report consists of five programmes, of which three are already round up. The subsidies, mobility and performance agreements are no longer in use, leaving only the programme 'board and bureau Stedendriehoek' and 'agenda Cleantech Regio' to be explored. They get respectively €944.111 and €343.472, or 73,3% and 26,7% of the total budget.

The programme 'Board and bureau Stedendriehoek' states a few goals. Working on a multiannual perspective translates to mutual trust between the Cleantech Regio and internal or external partners. One of the internal partners is the Strategic Board Cleantech Regio, which works on the main themes 'human capital', 'circular economy' and 'energy transition'. Externally the provinces of Gelderland and Overijssel are main networking- and lobbying partners. Concrete actions that are taken to reach the trust and collaboration are first off to make yearly reports, as explored before. Facilitating communications between municipalities

and other official instances, like workgroups, are also a high priority. Furthermore, lobby plans are made concrete and capacity is supplied to the aforementioned themes. Of the €944.111, €72.176 is used for public relations, while the rest of the budget goes towards the more content-related goals, like lobbying and subsidizing the programmes within the themes.

"There is joint input within the region about the themes energy transition, circular economy and human capital" (Cleantech Regio, 2021a)

With 'agenda Cleantech Regio' the organization tries to reach progress on five regional themes. The theme 'housing' aims to drastically increase the amount of houses, by lobbying and making deals. The theme 'coordination area development' aims to keep the region clean and to reach this, biannual meetings are organized with local aldermen. These two themes have little to do with cleantech innovation, unlike the other three themes. The theme 'economy' corresponds with the programme 'futureproof business parks' from the yearly report, aiming for agricultural energy transition and making business parks circular. To reach this, a housing protocol for large scale logistics companies is to be made, the Regio Deal will be monitored more closely and communications with local policy makers in regards to circularity will be strengthened. The theme 'accessibility' aims for a better reachability, but also more sustainable and smarter mobility. For this, a measures programme has been set up, next to intensive lobbying. Lastly, the theme 'regional energy strategy' has also been described broadly in the yearly report, announcing large scale sustainable energy generation for the transition to a circular region.

"The regional energy strategy 1.0 investigates possibilities for large scale renewable energy generation on land via wind and sun, the availability of heat sources and required infrastructure" (Cleantech Regio, 2021a)

In table 6, the budgets per theme line are visualized.

Theme	**Budget 2022 in euros**
Contribution board (for coordination area development)	70.373
Housing	85.933
Economy	85.933
Accessibility	85.933
Regional energy strategy	*External financing*

Table 6: *Budget available by Cleantech Regio per theme of agenda Cleantech Regio in 2022* (Cleantech Regio, 2021a)

When looking at table 6, the fact that the budgets per theme are the same or a little lower, stands out. Housing, a non-cleantech theme, gets the same amount of budget as cleantech subjects. The other non-cleantech theme, coordination area development, gets a little less budget, but taking into account that this budget is only for two meetings, the budget still seems quite substantial.

Conclusion

The majority of the budget is invested in the programme board and bureau Stedendriehoek, which aims to strengthen bonds with internal and external partners. Also, the Cleantech Regio announces to take on a strong governing role regarding the projects where subsidies are being provided. These programmes of the Cleantech Regio all focus on the green sector.

4.3.4. Apeldoorn

Apeldoorn is the biggest municipality in the region population-wise. This municipality has multiple policy documents about ambitions for the economy or society as a whole, in which they also elaborate on green innovation.

Meerjarenprogrammebegroting

In the *meerjarenprogrammabegroting*, or multi year programme budget, four strategic goals are stated: 'comfortable family city', 'tourist top landscape', 'sustainable Apeldoorn' and 'entrepreneurial city' (Gemeente Apeldoorn, 2022a). The latter two are relevant to the green human capital creation and innovative capacity of the municipality.

'Sustainable Apeldoorn' has the goal of setting the energy transition in motion by aiming for the municipality to save energy, generate more sustainable energy and by getting rid of gas. This way, Apeldoorn makes a contribution to the regional energy strategy and eventually the municipality will be climate neutral by 2050. There are multiple goals or achievements coming forth from the 'sustainable Apeldoorn' programme which enhance green human capital. There are some broad, big plans. One of those is a collaboration with European projects, effectively sharing and bringing in knowledge about circularity to further develop in local research. Other plans are for instance reworking the energy programme, so that local actors are more involved with making the region sustainable, and subsidizing research regarding sustainable warmth, to facilitate the energy transition. More specific projects are for instance making airport Teuge more sustainable in collaboration with the Cleantech Regio or deciding on a Greenplan to protect the local milieu with innovations.

"With other European cities, knowledge institutions, entrepreneurs and residents, we are conducting research and participating in project development … By actively participating in these projects, we are expanding our knowledge in circular energy and are looking for (co-)financing." (Gemeente Apeldoorn, 2022a)

The goal 'entrepreneurial city' has less to do with circularity and creating relevant human capital than the plan 'sustainable Apeldoorn', but still there are some parts that hint towards stimulating the creation of green human capital. The goal for the entrepreneurial plan is among others to make use of the economic potential with the focus on safety, circularity and innovation. This economic potential is to be reached by strengthening the bridge between regional education and the labor market, in which the municipality wants to play a strong role. By using a triple helix approach, the economy, and thus the businesses, in the Cleantech Regio will profit. Apeldoorn subsequently drives the businesses to move towards aforementioned goals: safety, circularity and innovation.

"[the goal is to] solidify Apeldoorns entrepreneurial power with focus on safety, circularity and innovation, together with European partners." (Gemeente Apeldoorn, 2022a)

The 'omgevingsvisie' is a document which describes and announces the core values of a municipality (Ministerie van Onderwijs, Cultuur en Wetenschap, n.d.). The values of Apeldoorn are explored point by point in six themes in their omgevingsvisie 'Woest Aantrekkelijk Apeldoorn' (Gemeente Apeldoorn, 2022b). The themes are familiar: 'housing', 'mobility', 'economy', 'recreation', 'circularity' and 'energy' are all terms that have been mentioned in aforementioned documents. Every theme mentions sustainability, but only few go deeper into how to achieve sustainability. In the theme 'economy', the municipality announces that farmers will be stimulated to make their operations more sustainable regarding nitrogen emissions and circular agriculture among others, but concrete plans or promises are not made. 'Circularity' is a very limited theme for a municipality within the Cleantech Region, with only 90 words dedicated to garbage reduction. 'Energy' is the main theme regarding moving towards a green future, mentioning the move to sustainable energy and CO2 reductions. This is also the only theme mentioning proactive steps to reach a greener future. Research projects are announced, as well as building wind turbines and solar panels. These mentions however are not related to the creation of human capital or innovation. The municipality does speak out on the intent to invest in innovative power and human capital in order to become energy neutral. One of the ways to do this, is pointing out three areas as innovative milieus: 'cleantech hotspot Zwitsal', 'station location' and 'Hertzberger Park', which all contain a hogeschool. The Zwitsal location for instance will be a '*place for development with room for experimenting and discovering'*. These places will need to pay attention to the newest innovations to stay competitive, according to the document. Apeldoorn has the potential to follow the innovations and translate this into economic prosperity. Further specifications on the eyed innovations are limited, except for that the emphasis will be on the green sector. However, detailed plans are not usually found in such documents anyway.

Also the city's external branding is focused on the innovative economy (Apeldoorn Marketing, 2020). With the branding, the municipality tries to strengthen the small- and medium sized firms in the region with an external influx of finances or knowledgeable firms for example. To excel in the sustainability goals, this external influx may help.

"[For the brand], the link with sustainability and innovation is important, so that the strategic line of the innovative economy comes to its own" (Apeldoorn Marketing, 2020)

In the ambition document for 2040 a picture is painted which is quite recognizable (Gemeente Apeldoorn, 2020). One of the showpieces of Apeldoorn in 2040 will be that it is a fully circular and climate neutral city. Furthermore, once again there is mention of innovative entrepreneurship. What does differ from previous documents is that what is mentioned in the Regio Deal: the aim to work on futureproof business parks (Rijksoverheid, 2020). Apeldoorn claims the opposite, that Apeldoorns' resilient economy has already proven to be ready for the future (Gemeente Apeldoorn, 2020). Despite this claim however, the document continues about future plans of densifying business parks and a new business park. Furthermore, the document mentions the future of education. The focus of the education shall be on cybersecurity and other IT-related fields, which is not consistent with the great ambitions of the Cleantech Regio for innovation in green technology.

"Apeldoorns innovative entrepreneurship guarantees broad sustainable employment for Apeldoorns residents and the region" (Gemeente Apeldoorn, 2020)

In short, Apeldoorn has made multiple relevant documents in which the same themes come back constantly. Creating a circular, climate neutral city by 2040 seems to be a top priority. To reach this goal, Apeldoorn is facilitating external links for the region, by branding the city for small- and medium sized firms and engaging into European collaborations. The local firms get a lot of attention from the municipality: their innovative capacity and the sectors in which they operate are clearly being monitored and the municipality wants to help them with their operations by providing a good, futureproof business climate which is about to get even better by providing business parks. This creates clustering and should improve green innovativeness. Lastly, important sectors for the municipality are IT and cleantech, with contradicting statements about this in different documents. It remains unknown which of the sectors takes priority in the local future economy.

4.3.5. Deventer

After Apeldoorn, Deventer is the biggest municipality in the Cleantech Regio population wise, but also in contribution to the organization Cleantech Regio (Cleantech Regio, 2021a). Just like Apeldoorn, it has budget reports and programmes to paint a picture of the future plans.

The budget report for the period of 2022 - 2025 consists, just like Apeldoorns', of strategic goals (Gemeente Deventer, 2021). Six goals are mentioned, of which one is 'financially healthy', containing just the aim to stay financially stable. The other, more in depth strategic goals are 'Deventer works', 'sustainable Deventer', 'eye for each other', 'lively Deventer' and 'work together and live together'. Of these, only 'sustainable Deventer' focuses on sustainability in a cleantech sense. Most important for the green human capital creation in this goal are two things: the programme 'sustainable mobility', which goes into innovation and technology, and the 'energyplan Deventer', which is another document exploring how to reach an energy neutral city.

Commissioned by the municipality of Deventer, Keypoint Consultancy (2018) developed an action plan to move towards sustainable mobility. Many main sustainability goals are as expected: more bike paths, more electric cars and more charging stations for those cars. But, it is also acknowledged that this alone is not enough and investment in innovation techniques is necessary. A targeted approach to reach this innovation is barely described: the ambitions of the Cleantech Regio and the municipality itself are explored, but little actions are advised to live up to those ambitions. The most important intent mentioned is that Deventer will invest in changing the mobility system to reach sustainable and smart mobility.

"[The region] knows a high concentration of innovative firms, who develop technologies, processes and products improving the entrepreneurial milieu … The focus on cleantech provides an improved business climate and a boost for the economy." (Keypoint Consultancy, 2018)

The energyplan Deventer has been made as a direct result of the national climate agreements (Gemeente Deventer, 2020). This plan translates goals to measures that are to be executed. These have to do with two main challenges, namely sustainable energy and sustainable warmth. Furthermore, societal challenges regarding the energy transition are explored.

First off, the sustainable energy challenge sets the goal of energy neutrality by 2030 (Gemeente Deventer, 2020). Apart from saving energy and switching to sustainable energy sources, there are some more intentions. The current electricity network will need to be upgraded, so research regarding innovating this network is encouraged in the plan, just like initiatives regarding a broader usage of energy from hydrogen. This begs electrolyse research. So, research and innovation in the electricity network and hydrogen sector is needed to move towards an energy neutral future.

Another challenge is warmth, or more precisely: how to keep buildings warm without the use of natural gas (Gemeente Deventer, 2020). The municipality Deventer wants to have 10.000 of their almost 50.000 houses gas free by 2030. The biggest challenge lies in that replacing natural gas with electricity from sustainable energy sources often leads to a higher CO2 output. To reach a sustainable and clean energy output, Deventer experiments with riothermia and aquathermia in the neighborhood Zandweerd. This experiment has proven to be very costly. The municipality barely funds this experiment or research regarding these sustainable techniques, but brings together the water board, housing corporations and the local grid manager to help with funding. The municipality takes on a coordinating role in the funding of the experiment. Despite being expensive, there is confidence in the success of the experiment in Zandweerd, with three more neighborhoods waiting to follow a similar experiment. In the future, geothermia seems also a viable option to use, which is yet to be experimented with.

"With the project 'Slim Warmtenet Zandweerd', we are the national leader in taking on the energy transition on neighborhood level" (Gemeente Deventer, 2020)

Furthermore, there are energy challenges in the society, like the businesses who account for 36% of the total energy consumption in the municipality and also profit from the relatively low fossil energy price rates for industrial use (Gemeente Deventer, 2020). To make businesses use more sustainable energy, the municipality announces a number of initiatives, like transforming business parks and constructing a warmth net, but innovating the energy generation or energy use is not named. However, innovation is named in the next societal energy problem, which has to do with mobility. Like Keypoint Consultancy (2018) worked out, the municipality wants to move towards sustainable mobility with the likes of improving infrastructure, but also by improving technology surrounding mobility, like implementing smarter technology in the road network or developing smarter traffic lights for cyclists (Gemeente Deventer, 2020). Once again, in the sustainable mobility challenge, the suggested solution is barely innovative and more so using existing knowledge and techniques.

The goal 'sustainable Deventer' has been explored, but aside from this goal, the budget report also states an economic and international policy programme (Gemeente Deventer, 2021). This programme promises development in business parks 'de Poort van Deventer' and 'A1 Bedrijvenpark' to make them high quality innovative locations for sustainable industry and smart logistics. The municipality's intention is to improve relations between the business parks and city campus 'De Kien', home of Saxion and Aventus schools. The municipality takes on a coordinating role and supplies the means for businesses and knowledge institutions to find each other and to use their joint skills to enhance innovation.

The municipality coordinating a collaboration between knowledge institutions and businesses is not new, as they were already working on it years ago (De Kopgroep Economie en Arbeidsmarkt, 2016). To enhance technical knowledge within the region, the municipality worked together with local firms and Aventus to create the 'Technicampus', which provides

students with applied education to thereafter give a direct contribution to the labor market. A comparable collaboration exists with Saxion, called ‘stadsLAB’. These existing collaborations already provide innovative capacity, which can be utilized with the announced future proof, innovative business parks (Gemeente Deventer, 2021).

The aforementioned economic and international policy was also on the agenda in the period 2019 - 2022 (Gemeente Deventer, 2019). Noticeable differences are that in the older policy, there was mention of four business parks ready for upgrading, instead of two. The economic stimulation of these business parks has gotten increasingly more funding in recent years, from 50.000 euros in 2020 to 100.000 and 175.000 euros in 2021 and 2022. Furthermore, the development of city campus de Kien was a main example for the intended network- and innovation enhancement. Networking was highly valued in the view of Deventer, which still seems to be the case when looking at the updated programme (Gemeente Deventer, 2021).

“In our vision, ‘De Kien’ is the main office- and education location of Deventer, where the knowledge- and open information city thrives. We pursue a lively milieu, which stimulates interaction and innovation” (Gemeente Deventer, 2019).

So, to conclude, Deventer has stated a lot of goals and ambitions, of which a few also have to do with cleantech innovation. The most important green innovation challenges for the municipality seem to be the implementation of new sustainable energy sources and to make businesses and business parks more sustainable, by for example experimenting with the energy transition in neighborhoods like Zandweerd. These innovative ambitions are quite clear and how they are going to be reached is explained, for example by offering finances, taking on a coordinating role. A further important element is that the collaboration of the government with firms and knowledge institutions has been a recurring theme for the past years, giving off the idea that the triple helix collaboration is a strong and important one in this municipality specifically. How to reach the goals in other sustainability challenges, like mobility, is less clear. What seems to be missing is direct financial support from the municipality itself regarding the projects.

4.3.5. Zutphen

Zutphen is the third biggest and also the last municipality in the region of which the policy documents will be explored individually. Just like Apeldoorn and Deventer, the budget report will be discussed first, after which multiple different reports which can have an effect on the creation of green innovative capacity are explored.

The budget report for 2022 - 2025 consists, just like the previously explored budget reports, of programmes (Gemeente Zutphen, 2021a). These are ‘board’, ‘safe city’, ‘sustainable living environment’, ‘vital society’ and ‘appealing city, with a strong economy’. Of these programmes, ‘boards’, ‘sustainable living environment’ and ‘appealing city, with a strong economy’ are the programmes which mention ambitions and goals that mention innovation or creation of human capital in the cleantech sector.

The programme ‘board’ discusses actions with regional partners. The collaboration with the Cleantech Regio is deemed especially important, with the Regional Energy Strategy and future-proofing of business parks as examples of this collaboration. Further details are

not provided, Zutphen refers to the plans of the Cleantech Regio.The budget for this over the years is almost the same every year: about 2,8 million euros.

The programme ‘sustainable living environment’ states important sustainable goals: a 49% CO2 emission reduction and more sustainable public transport and mobility overall. To reach sustainable living, working and moving, knowledge, perseverance and execution power is needed. In order to enhance knowledge, perseverance and execution power, Zutphen set up goals and how to act upon those goals. For sustainable mobility, the focus is on reducing total mobility CO2 output, which is to be reached by non-innovative measures like prioritizing cycling. Furthermore, the programme goes on about a climate adaptive approach, which will be executed with the help of local residents, organizations and businesses. For example, the municipality facilitates and stimulates organizations and businesses to experiment with building circularly, focusing on creating as little waste as possible, which already happens at business park ‘De Mars’. The first steps in making this park circular are promising enough that the experiment is being continued and expanded to other business parks. Likewise, Zutphen tries hard to participate in the regional energy transition by stimulating businesses: providers of sustainable energy are being inspired to innovate their energy output. Of all the above mentioned goals and measures, the waste management gets the highest budget yearly, between 5,7 and 5,9 million euros. Other themes, like energy transition and environment, receive significantly less money, 176.000 and 1,1 million respectively. This can be explained by the fact that the plan in these themes relies mainly on businesses to invest as well.

“We stimulate and facilitate experiments regarding circular construction” (Gemeente Zutphen, 2021a)

“Gained knowledge and experiences are utilized and conveyed” (Gemeente Zutphen, 2021a)

‘Appealing city, with a strong economy’ is the final programme which hints towards green human capital creation and the stimulation of innovative capacity. From the start, business park De Mars and the inner city are put forward as future locations for a new economy with the focus on circular industry and a new energy network. These will be leading in the trademark that Zutphen pursues: the innovative city of care and of circular industry. Investments are made by Zutphen and via the Regio Deal to provide employment in De Mars, directly increasing the size of the circular industry. But, this industry will not become circular on its own. This is why investments are also made in hydrogen projects which contribute to future innovations in circularity.

“The inner city and ‘The Mars’ are our economical engines. This offers chances for an economy with a new circular industry” (Gemeente Zutphen, 2021a)

In the budget report, the one time subsidy flows are provided in a transparent overview. Most important in these single financial boosts is that a number of entrepreneurial funds enjoy a 868.500 euro subsidy. The foundations that receive this money are ‘Binnenstadmanagement’, ‘Ondernemersfonds Binnenstad’, ‘Parkmanagement’ and ‘De Zutphense Uitdaging’. The first two are mostly overlapping foundations and have the goal of connecting the inner city entrepreneurs with the government and local residents (Bezoek Zutphen, 2022). Parkmanagement is a foundation focused on multiple business parks, like ‘De Mars’ and ‘De Stoven’ (Bedrijvenkring Zutphen, n.d.). The foundation connects the

businesses with the government and aims to stimulate sustainable developments. Lastly, De Zutphense Uitdaging connects businesses with non-profit organizations to make the quality of everyday life in Zutphen better (De Zutphense Uitdaging, n.d.). So, the first two foundations help with the triple helix collaboration in the region, while the third helps in the development of the most important sustainable business park of the future of Zutphen, while the last foundation does not seem to have that much to do with human capital creation.

"We combine the interests of entrepreneurs and the municipality and stimulate sustainable developments. Collaboration between entrepreneurs and the municipality of Zutphen is the keyword in this project." (Bedrijvenkring Zutphen, n.d.)

In the economic vision and ambition of the municipality, once again Zutphen takes on the image of a circular industrial city and innovative city of care (Gemeente Zutphen, 2021b). Zutphen makes its economy future proof by focussing on the circular industry, which is prone to become progressively more important in the future. What especially enhances the green human capital in the city, is that the municipality aims to facilitate a further growth in the circular industry. This should form a favorable innovation climate for businesses.

"We facilitate the growth of the circular industry … We will research possible locations for creative makers, who attract innovative entrepreneurship" (Gemeente Zutphen, 2021b)

So, Zutphen invests in the Cleantech Regio and furthermore has a few green human capital enhancing programmes themselves. Pursuing a brand of innovative city, businesspark 'De Mars' is of great value and this cluster should produce green technological developments. Also, certain funds are supported as a more bottom-up approach of enhancing innovative capacity. By investing in these funds, the government indirectly provides the means for a strong triple helix collaboration on a low level. Furthermore, different sustainability projects receive investments, embedding the governments' regulating role in these projects.

4.4 SWOT-analysis

STRENGTHS	WEAKNESSES
• Available tertiary educational programs in cleantech touch upon 'the real world'. • Circles offers many ways for businesses to learn about sustainability and circularity. • The Regio Deal and renewable energy systems as big projects to underline the importance of sustainability. • Apeldoorn uses external links to gain knowledge and strengthens internal business - knowledge institution links to enhance green human capital creation. • Zutphen invests directly into funds which are enhancing green human capital.	• Stagnation in regional cleantech patent applications. • Almost no tertiary cleantech education. • Cleantech Regio has a relatively small budget compared to municipalities' budgets.
OPPORTUNITIES	**THREATS**
• Many municipalities with rising percentages of middle- or highly educated people. • VNO-NCW Midden strengthens the triple helix, but could invest more in cleantech. • All big municipalities want to reach an innovative climate by upgrading business parks.	• Little focus on directly raising innovative capacity in Cleantech Regio policy. • Apeldoorn also focuses on the IT-sector, which could threaten the prosperity of the cleantech ambitions.

Figure 7: SWOT-analysis

5. Conclusion

The Cleantech Regio has strong ambitions to become an innovative region in the field of cleantech (Strategische Board Stedendriehoek, 2016). This research has been conducted because the region acknowledged that the skills, knowledge and experience are not sufficient to fulfill these ambitions (N. Kraehe, personal communication, January 1, 2022). This region is just an example, as all regions that want to innovate in cleantech need the proper green human capital to do so (Ali et al., 2021; Wan & Juo, 2021). The aim of the research was to provide an overall framework for regions willing to improve their cleantech innovativeness by using green human capital. To find out how the regional green human capital could be improved to reach an increase in cleantech innovations, the following research question had been set up to guide the research:

How can a green human capital analysis help to map opportunities and challenges for regional development towards cleantech innovation?

To answer this research question, the answers to the sub questions should be explored briefly first. The first subquestion '*What is human capital and in what way does it affect innovative output?'* aimed to form a definition for human capital and its relevance to innovation and is answered by the literature review. Human capital is the sum of many individual factors, but most importantly the skills, knowledge and experience of individuals. In this regional research, the regional human capital is the sum of all skills, knowledge and experience of the individuals in the region. This introduces the next sub question '*Which human capital components are relevant to cleantech and how do they affect cleantech innovation?'*. The three dimensions correlate positively with innovativeness overall and especially in cleantech they seem to have a strong positive effect. The so-called green human capital that is needed affects the total intellectual capital positively, which is human capital and the structural- and organizational capital. The personal skills, knowledge and experience of workers, combined with relationships and firms' resources raise the firms' chances for innovations. So, raising the human capital sets a process in motion which ends in innovativeness. Furthermore, a triple helix collaboration seemed to positively affect the process, which is why the governments, firms and knowledge institutions were included in the research.

After the literature review elaborated on how the process of human capital to cleantech innovativeness works, the third subquestion '*How can the human capital components be measured?'* moved the research towards the methods section. Different data sources have been utilized to serve as the human capital analysis. Demographic data, patenting data and policy documents have all been utilized to form an answer to the fourth sub question and eventually the research question. The fourth sub question was *'What are the strengths, weaknesses, opportunities and threats for the cleantech innovation in the Cleantech Regio?'*. A SWOT-analysis is often used to determine the competitive position of a firm or region, which is what this research aims to do. The SWOT-figure can be found in figure 7.

The answer to how a region can improve human capital in favor of cleantech innovativeness is not unequivocal. It lies in the nature of such research that some aspects are productive towards cleantech innovativeness, and some aspects are counterproductive. This is why the choice has been made to categorize the strengths, weaknesses, opportunities and threats that are present in the region, regarding the demographics, firm performance and policy. The

framework of this research helps to map the opportunities and challenges by presenting a SWOT-table, which is to be discussed further. By further discussion, policy flaws arise and recommendations can be made. Also, weaknesses come to light which should be taken into account and strengths which can be exploited are touched upon. To conclude, the research question is answered by the methods applied in this research. A framework is offered to help comparable research, fulfilling the scientific relevance. The discussion chapter will provide further understanding and implementation of the methods, to fulfill the societal relevance of improving human capital to raise cleantech innovativeness.

6. Discussion

6.1 Interpretation and recommendations

Figure 7 provides the SWOT-analysis based on the results. In this section, the analysis will be explored point by point with regards to scientific research and recommendations.

Strengths

From the exploration of the available tertiary educational programs, it became clear that the few which offered cleantech educational programs should be, according to scientific findings, very productive in increasing innovative capacity. Firms are involved in the educational programs to a great extent, for example by required internships in the *Klimaat en Management* course. Following the triple helix approach of Etzkowitz & Zhou (2017), it is expected that the implementation of the triple helix will produce more human capital as compared to educational programs which don't include internships. The firm side is also implemented by the MBA with a specialization in clean technology management, but this course is more promising in regards to cleantech innovation because of another reason: the initiative of the programme comes from an international cooperation of governments (Hogeschool Wittenborg, n.d.). A strong governmental governance in projects should lead to better innovative results, especially in cleantech (Shen, Li, Wang & Liao, 2020). Furthermore, the government takes on a role in the triple helix which Etzkowitz & Zhou (2017) concluded to be important: the delegation of tasks to a university. Lastly, the many courses in cleantech associated subjects provide a boost for the education dimension of human capital. It is recommended that this strength is expanded upon. By initiating more of these initiatives, the government can continue to regulate education strongly and influence it so that favorable knowledge is being produced. This is the first step in the process of increasing intellectual capital, leading to innovative capacity (Kalkan, Bozkurt & Arman, 2014; Popescu, 2021).

Circles gives off all signs to be a strong intermediary organization in the region regarding green human capital production. Workshops and services are offered which result in bringing firms and knowledge institutions together. Bringing these actors together enhances openness and cooperation between them and that should positively affect environmental innovation (Galia et al., 2015). Circles takes on the governing role, which completes the triple helix, raising human capital and innovative capacity in the region (Etzkowitz & Zhou, 2017), with for example 'spending on training' and 'soft skills training', both very important in raising human capital according to Mubarik et al. (2018). Especially in the green sector this is important (Kiryushin et al., 2013). The strong influence that Circles asserts should help lead to higher green innovativeness (Shen et al., 2020; Yi et al., 2020). A recommendation to the governments is that Circles should receive more money and attention, as they help entrepreneurs and

students directly. These training events could be of high value and could very well repay themselves in the form of innovations. Circles' actions theoretically raise the green innovative power of the region substantially, which is why its presence is a strength.

The Regio Deal is a very promising policy initiative. A sizable budget of 100 million euros has been made available purely for sustainability projects by the *Strategische Board*, also known as the Cleantech Regio. The projects will function by connecting the triple helix, producing a stronger collaboration, which enhances human capital (Etzkowitz, 2008; Mubarik et al., 2018) and is especially beneficial for green innovation (Kiryushin et al., 2013). The strong governmental funding will, according to scientific literature, be very beneficial for innovative capacity (Shen et al., 2020; Yi et al., 2020) and green innovation specifically (Yang et al., 2021). The creation of jobs that comes forth from the plans tackles societal issues, solidifying the government's interests and strengthening the triple helix (Etzkowitz & Zhou, 2017). So, the strong triple helix and funding from governments are two separate processes which both should enhance the green innovative capacity. Furthermore, this deal can also be seen as symbolic: the Cleantech Regio has spoken out on their sustainability goals, branding their entire name around it. This is the biggest project to date, money-wise. With this project, the regions' brand is bound to become more renowned and to attract more external investments. But, there is still a recommendation to be made. Owen at al. (2018) concluded that a strong governmental funding role could be productive in initial innovation stages, but somewhere along the innovative process private funding takes over in productivity. The Regio Deal is a great stepping stone, but eventually the governments should not shy away from private investors to maximize their green innovative potential, as from R&D onwards, private investors seem to become increasingly more effective in helping the innovative progress (Yi et al., 2020).

Apeldoorn has proven to already possess some strong policy towards green innovation. As the biggest city within the region, their policy is also the most aimed at external sources. The municipality is involved in European-wide projects with other European cities (Gemeente Apeldoorn, 2022a). External links have proven to positively influence innovativeness (Laursen & Salter, 2006) and influx of external knowledge and finances help especially in later stages of innovation (Owen et al., 2018). Although local cooperation, which Apeldoorn also promotes, has a positive effect on innovativeness (Galia et al., 2015), an openness towards the external actors, which firms can reach through the municipalities' projects, will benefit them as well (Laursen & Salter, 2006). Furthermore, Apeldoorn implements three zones as innovative milieus and will govern these areas strongly, which should have a positive effect on human capital creation according to Etzkowitz & Zhou (2017). Also, the clustering that happens will positively influence the green innovative potential (Diez-Vial et al., 2022). Lastly, the municipality aims for closer business - knowledge institution relations. An increased closeness and openness towards each other is very beneficial for potential innovative achievements (Bektaş & Tayauova, 2014), but how this will take place is still vague. It is recommended that the municipality keeps participating in international projects to expand its network as much as possible, but to also keep the local entrepreneurs involved as they are eventually the actors that should benefit from the network. Furthermore, although the innovative milieus are productive for green innovativeness and can serve as hubs, the improvement of business - knowledge institutions is still vague. This is why the recommendation is to focus on making this collaboration come to life in these innovative milieus. There is already a hogeschool in or near each of these terrains, but the educational programs offered are not cleantech-oriented.

To make this terrain successful innovation-wise, the government should bring together cleantech firms and knowledge institutions to create a synergy on the terrain, essentially applying a triple helix.

The municipality of Zutphen also possesses some strong policies regarding enhancing green human capital. The funds in which the municipality invests seem to implement policy in a green human capital enhancing manner. Firstly, the funds strengthen the link between firms and the government. The government can govern the firms more closely, creating a strong triple helix, where human capital creation happens (Etzkowitz & Zhou, 2017). Also, firms become more innovative because of potential environmental restrictions following this strong governing (Shen et al., 2020; Yi, Wang, Yan, Fu & Zhang, 2020). Secondly, investment is made in business parks for sustainable development. Like Apeldoorn, the implementation of such parks should have a positive effect on human capital creation according to Etzkowitz & Zhou (2017) and the clustering will raise green innovative capacity (Díez-Vial et al., 2022). The funds have plans which should be able to enhance green human capital and innovative capacity. It is recommended that the municipality governs these funds and their results strongly and to possibly increase funding in the future. So, Zutphen exert their influence in the local business operations and multiple points in their policy point towards an increase in green innovativeness.

Weaknesses

The patenting in the cleantech regio has proven to be very weak. The absolute numbers of green patents have been relatively stable between the years before the region has spoken out on its ambition and the most recent data, while the relative numbers were under national averages almost every year. There seems to be little improvement in the regional cleantech patenting, which could make the region less attractive for external investors. The amount of cleantech patents is an indicator for their innovativeness of the previous years, so no single recommendation can be made: this entire chapter offers recommendations for enhancing green human capital and raising innovativeness.

There is a substantial amount of tertiary education in the region. Many *hogescholen* and *MBO's* are present, which all offer a broad variety of educational programs. But, only two of the 427 educational programs are deemed green human capital enhancing. Sustainability studies are barely available, and of the ones that are available, almost none engage in innovation. Education is one of the most important dimensions in enhancing human capital (Mubarik et al., 2018) and in green innovation, human capital is even more important to possess (Consoli, Marin, Marzucchi & Vona, 2016; Hsu et al., 2021; Jensen et al., 2020). It is urged that local and regional governments focus on improving the amount of sustainability studies focused on innovativeness. Without the proper education in the region, it is likely that the cleantech ambitions will never be fully fulfilled.

The Cleantech Regio, as an ambitious organization, appeared to have a relatively small budget. While other discussed projects could count on multiple million euros, even 100 million euros in the case of the Regio Deal, the Cleantech Regio has to divide about 1.3 million euros over several projects. The plans of the Cleantech Regio seem to have the potential to enhance green human capital, by providing workshops to raise the training dimension, which is important (Mubarik et al., 2018). Furthermore, the strengthening of the triple helix is also important for the organization, which also enhances human capital (Etzkowitz, 2008; Mubarik

et al., 2018), and is especially beneficial for green innovation (Kiryushin et al., 2013). A strong governmental influence in the form of sizeable subsidies could embed the government's role in the triple helix, raising green innovativeness in the region (Shen et al., 2020). The organization is on the right track with their projects, but the lack of funding seems to keep the scale of their effect down, so it is recommended to the regions' municipalities to increase their funding of the Cleantech Regio. For now, the funding is partly found externally, essentially shifting the grip on this project from the government to external actors. When the project is already reaping benefits from prior R&D, this external financing is beneficial to green innovativeness (Owen et al., 2018). If the project is not that mature yet, the government would be better off by providing funding itself (Yi et al., 2020). The Regio Deal is the leading cleantech project of the region, but still can only count on just over 5 million euros from the municipalities, which shows that the municipalities are hesitant to support the cleantech ambitions. Without proper funding, the ambitions have a smaller chance to be fulfilled. With increased public funding from the start of the projects onwards, the chance of increasing innovativeness will rise.

Opportunities

Although the quantity of tertiary cleantech education in the region lacks and is a weakness, this can not be said about the overall education levels of the residents. It can not be concluded exactly why the relative amount of middle- and highly educated is rising, but it is clear that in a number of municipalities this is the trend. It has already been stated many times before: human capital is enhanced by education (Mubarik et al., 2018) and especially in green innovation, education is important (Consoli, Marin, Marzucchi & Vona, 2016; Hsu et al., 2021; Jensen et al., 2020). It is recommended that the region puts effort to continue this growing trend, by working together closely with local tertiary knowledge institutions and to help them expand. Furthermore, businesses can be increasingly implemented in the schooling, to on one hand further develop the experience dimension of students and on the other hand take some of the education out of the schools' hands, resulting in more broadly educated students and space for more students registered at the schools. This upward trend, when continued, can result in the region becoming a top region within the Netherlands, education-wise.

The VNO-NCW Midden has been explored. It is an entrepreneurs' association helping regional small firms with the likes of workshops and subsidies. They offer for example subsidies for businesses making their operations more sustainable, which should lead to an increase in green innovativeness when this top-down investment is done on a larger scale (Shen et al., 2020; Yi et al., 2020). This also should have a positive long term effect on green innovation, as it stabilizes the green innovation system (Yang et al., 2021). Unfortunately, the projects of VNO-NCW Midden seem to have very little to do with directly enhancing green human capital, as it does not directly involve an increase in education, training or experience. But, with the network the organization has, there are possibilities for green human capital creation. If only part of their budget is used to start up a new programme with regards to innovating in sustainability, the organization could bring together many actors and act as the governing party. Such synergy is beneficial for human capital creation (Etzkowitz & Zhou, 2017). So, the investments promise future innovations, but in the short term they are unlikely to seriously impact innovativeness.

The last observed opportunity is regarding the business parks. All of the three big municipalities have plans to reach innovative business climates by upgrading their business

parks. This is included in a programme of the Cleantech Regio (Rijksoverheid, 2020), but also expanded upon in the policy documents of municipalities. First of all, this enhances innovativeness, as clustering causes knowledge spillovers, which enhance the green human capital overall (Díez-Vial et al., 2022). Also, as stated before, knowledge institutions are present in and around these parks, bringing the triple helix together on a small scale, which is also very beneficial for human capital creation (Etzkowitz & Zhou, 2017). The municipalities' vision on the circularity and sustainability of these parks concludes a plan that should enhance the regional green human capital. Most of these business parks are still to be developed, which makes it an opportunity rather than a strength. When the plans are brought to completion, it is probable that green human capital will be created in these parks and innovation will take place. The municipalities take on a coordinating and funding role in the creation of these parks, increasing the innovative capacity (Shen et al., 2020; Yi et al., 2020). These business parks increase openness and closeness between firms and knowledge institutions localized here, which also has a positive effect on the innovativeness (Etzkowitz & Zhou, 2017; Owen et al., 2018). Seeing how public funding is especially important early in the innovative process (Owen et al., 2018), the municipalities seem to be seizing the opportunity to raise the green innovativeness with these business parks.

Threats

The Cleantech Regio has described a lot of policies regarding human capital creation and the move towards circularity, but the threat in the policy documents is that the policy is not specific enough. Organizations like the funds of Zutphen are explored, which clearly describe how and where they spend their money in order to improve the local triple helix. Also, VNO-NCW Midden announced for example that entrepreneurs can get up to 25.000 euros of subsidy. However, the Cleantech Regio stays shallow in their descriptions, like 'investing in alternative energy sources' or the fact that a few hundred thousand euros go towards projects that are described with terms like 'we facilitate meetings' or 'we will create lobby plans'. The programmes that have less to do with human capital creation are described in more detail, but it seems like the Cleantech Regio is struggling with how to exactly invest the money in favor of green innovation. This also has to do with the reason this research started: the Cleantech Regio struggles with creating green human capital. It is recommended that they follow the main, recurring points within this research, by for example taking on a strong governing role in sustainability projects and bringing businesses and knowledge institutions closer together to create a synergy between the two actors.

Apeldoorn is the biggest municipality of the region and contributes the most to the Cleantech Regio (Cleantech Regio, 2021a). This suggests that they are focused on cleantech innovations and circularity. This also comes forward in their budget report, with the theme 'sustainable Apeldoorn' (Gemeente Apeldoorn, 2022a). However, in their vision for 2040, the municipality states that their education should focus on IT (Gemeente Apeldoorn, 2020). Although the municipality has many plans about sustainability, they do not seem to want to focus their education on this aspect. Education is very important in creating human capital (Mubarik et al., 2018) and without the proper green human capital, green innovation would be hard to reach (Kiryushin et al., 2013). It is recommended that, if the region wants to succeed in green innovation, that their biggest municipality also focuses on education in the green sector. Otherwise, the investments made by the municipality and region in creating a green, innovative milieu could be wasted money, as they run the risk of lacking the needed green human capital in the future.

6.2 Reflection

During this research, many options were available and choices were made to answer the research question. In this paragraph, a critical reflection is given on these choices.

Firstly, a choice was made to not conduct any interviews or surveys. Although it is quite common to conduct at least one of these methods, the patenting data and demographic data, in combination with policy reports, represents a clear view of where the region stands with regards to their cleantech innovations and what they are working towards. Surveys would not be interesting, seeing the nature of the research. Interviews could however very well bring new insights in the research, but potential interviewees, like policy makers or entrepreneurial organizations, would have a conflict of interest or a subjective view on the matter. This, in combination with the time constraints around this research, resulted in that I deemed it most effective to exclude interviews.

Secondly, the use of patenting data had some flaws. Because this is a Master's Thesis, no budget was available to purchase a patenting database. The research started with the assumption that detailed patenting data was freely available, but the place of residence proved to be a variable which was unknown or too expensive to include. I could receive part of the OECD Regpat Database, but in the results section it has been stated multiple times that there are suspicions of missing data in this database. These suspicions can not be confirmed by consulting just the received data. Because the data only contained patent registrations and not the pending requests, it can not be said to what extent data was missing, so the choice was made, based on a logical trend, that 2017 was probably the final complete year. So, the choice for the OECD Regpat database resulted in being able to compare regions with each other, but the quantity of the patent registrations is questionable.

Thirdly, the allocation of budgets within organizations was unfortunately very vague. Many projects, especially those with private involvement, barely had indications about what budget is spent on them. Furthermore, municipalities often group multiple projects under one programme and do not justify what projects get which proportions of the budget. Because of this, the results section could not get a clear view about which projects get priority over others, which was the intention in this research. The choice was made to keep the discussion of budget reports as they are now, but with more detailed budget reports, more insights could have been discovered.

The last choice that needs further explanation is that of the SWOT-analysis and working towards the conclusion. In this research, the choice has been made to summarize the important points in a SWOT-analysis, because the results section became quite extensive. This SWOT-analysis seemed the most fitting way to give a simple overview of the competitiveness of the region in green human capital creation and cleantech innovation. But, this analysis does not take into account which points are more important than others, which makes it oversimplified. To get a better view of the competitiveness and which points make a difference, a weight system could be implemented in a way like Mubarik et al. (2018) developed. In this research, investing in networks seems to be on the same level as investing in big infrastructural business park projects for example, while in reality one of the two has a greater effect on green human capital creation. Because of time constraints, this was not possible to include in this research and although the SWOT contains more strengths than weaknesses, it should be kept in mind that the weaknesses may actually outweigh the strengths.

6.3 Future research

This research provides stepping stones for future research to expand upon. It acts as a guide to analyze the innovative competitiveness of a region in the cleantech sector, which has not been done before in this form. Few points of improvement have already been brought up, but will be discussed again briefly.

Firstly, interviews could help with exploring different points of view in human capital creation and background information. Policy documents show the intentions of governments and patent data shows facts about the innovative performance of the region. This research has exposed some strengths and weaknesses in policy and performance, but does not go into why certain policy has been made. Conducting interviews with policy makers after exploration of the policy documents could clear up questions about why certain choices are made, what effects they expected and how policy could be altered in favor of cleantech innovation. So, the chosen methods provide an overview of the situation and the effects of government policy. Interviews could bring a deeper understanding about the policy choices.

Secondly, the triple helix in this research is dubbed as a very efficient, human capital creating concept. However, this triple helix theory is not unchallenged. Collaborations that fall outside of this traditional public-private partnership are said to be underestimated (Diercks & Avelino, 2022). Although the triple helix has proven to be very strong in human capital creation, future research could look beyond this model and also focus on for example ‘hybrid organisations and translocal networks’.

Thirdly, this research mainly focuses on the influence of public and semi-public organizations on green human capital creation. The bulk of the research goes into the policy effects on how firms and knowledge institutions can increase their green human capital production and on how firms are performing in recent years. Private institutions can be of great value for innovation processes (Owen et al., 2018), which is why future research should also include more information on the actions and decisions that private institutions take internally. Interviews with big firms could for example clarify these actors’ internal intentions of experience creation and training.

Lastly, follow up research in the Cleantech Regio is needed to learn what policies had the most effect. This research predicted effects on other scientific research in the same sector but a different setting. Follow up research in a few years could be of great value in determining what cleantech sectors should do to approach optimal green human capital creation.

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Appendix

Appendix 1

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Netherlands	66	65.6	66.2	67.4	68	68.5	68.7	69.7	70.2	70.6
Zuidwest-Overijssel (CR)	68.1	67.3	69.9	69.9	69	70.8	69.3	69.6	69.8	70.1
Veluwe (CR)	64.8	63.4	64.5	66.6	67.8	68	66.9	68.1	68.8	69.1
Achterhoek (CR)	64.9	63.2	63.6	65.1	66.2	66.9	66.3	67.6	67.2	67

Middle- or highly educated 15-75 year olds per NUTS-3 region in %.

Appendix 2

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Netherlands	66	65.6	66.2	67.4	68	68.5	68.7	69.7	70.2	70.6
Apeldoorn	67	64.3	66.1	68.1	69.3	71.8	67	68.1	70	71.1
Brummen	62.5	62.5	56.3	62.6	62.5	62.5	62.5	68.8	62.5	66.7
Deventer	69.9	69.9	72.6	72.6	72.6	72.6	71.2	70.2	70.6	70.6
Epe	62.5	58.4	62.5	66.7	66.7	66.6	70.9	66.6	66.7	70.8
Heerde	57.1	53.9	61.6	57.1	64.3	64.3	71.5	71.5	64.3	64.3
Lochem	66.7	66.7	70.9	70.8	75	70.8	66.7	70.8	75	70.8
Voorst	64.7	64.7	64.7	70.6	70.6	70.6	61.1	72.2	66.7	66.7
Zutphen	65.7	65.7	68.6	68.5	71.4	71.4	71.4	74.3	74.3	72.2

Middle- or highly educated 15-75 year olds per municipality in %.